PROCEEDINGS OF THE THIRTEENTH ASIAN PACIFIC WEED SCIENCE SOCIETY CONFERENCE 1991

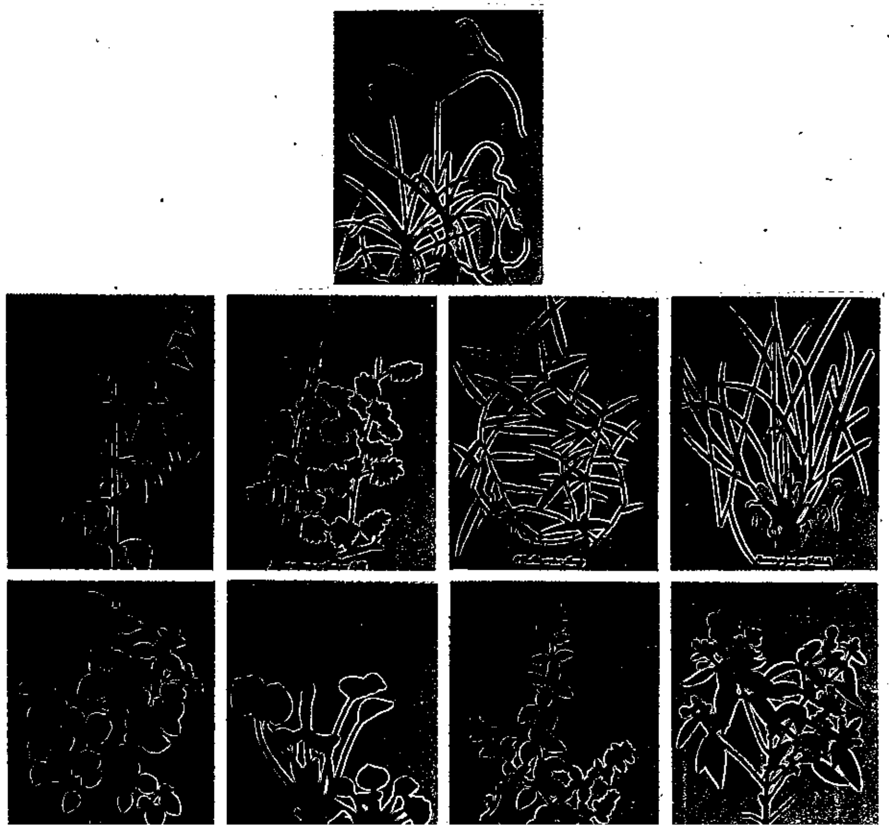
13 TH CONFERENCE
JAKARTA - INDONESIA

PROCEEDINGS OF

THE THIRTEENTH
ASIAN PACIFIC WEED SCIENCE SOCIETY CONFERENCE

JAKARTA, INDONESIA
15 - 18 OCTOBER, 1991

VOLUME II



THEME : VEGETATION MANAGEMENT STRATEGY FOR SUSTAINABLE DEVELOPMENT

PROCEEDINGS OF

THE THIRTEENTH ASIAN PACIFIC WEED SCIENCE SOCIETY CONFERENCE

Jakarta, Indonesia
October 15 - 18, 1991

Volume II

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PREFACE

Due to some circumstances it has taken a longer time than previously planned to print the remaining papers submitted to the Thirteenth Asian Pacific Weed Science Society Conference, conducted in Jakarta, October 15 - 18, 1991.

This second volume contains 42 papers including the one which was submitted to the last APWSS Conference by Dr. Joe De Frank of the Department of Horticulture, University of Hawaii at Manoa, Hawaii, USA.

I am most grateful to all those who have devoted much of their efforts and valuable time in ensuring the publication of the second volume of the proceedings.

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1989-1991

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WEED MANAGEMENT

WEED CONTROL AS A COMPONENT OF THE INTEGRATED PEST MANAGEMENT (IPM) PROGRAMME

P.J. VAN RIJN[1]

ABSTRACT

The control of pests, diseases and weeds by minimal (or ideally zero) use of pesticides, and by implementing a package consisting of crop varieties resistant to certain pests and diseases, and able to compete well with weeds, use of biological agents and cultural practices, is called Integrated Pest Management (IPM). So far, generally, weed control does not form the 3rd component of the IPM programme, the other 2 being: the reduction of the incidence of (1) pests and (2) diseases by rationalised (reduced) use of pesticides.

In this paper a brief description is given of the IPM approach, the use of ground covers, cultural practices, and the necessity of studies to establish the relationship between the presence or absence of weeds and incidence of pests and diseases.

INTRODUCTION

In Indonesia, weeds in rice and other food (palawija) crops such as soybean, mungbean and groundnut are generally controlled by hand-weeding and **not** by the use of herbicides. This implies that weed control in the Integrated Pest Management (IPM) programme in Indonesia is classified as one of the cultural/agronomic treatments, and that it does not form the 3rd component of the IPM programme, the other 2 being: the reduction of the incidence of (1) pests and (2) diseases by rationalised (reduced) use of pesticides.

Weed control is obviously aimed at increasing the production of crops by reducing the competition for space, light, water and nutrients. However, yields of crops are also negatively affected if weeds are hosts of harmful insects, fungi, viruses and other micro-organisms. On the other hand, weeds can be the host of useful insects, etc., viz. natural enemies of pests and diseases, such as predators. The above implies that the required degree of weed control is not only part of the agronomic programme, but also of the IPM programme.

THE INTEGRATED PEST MANAGEMENT/IPM APPROACH

The control of pests, diseases and weeds by minimal (or ideally zero) use of pesticides, and by implementing a package consisting of crop varieties

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resistant to certain pests and diseases, and able to compete well with weeds, use of biological agents, and cultural practices (proper time of planting, rotation and mixed cropping system, use of mulch and trap plants) is called Integrated Pest Management (IPM), and is a response on control of pests, diseases and weeds by mainly pesticide applications. The practice of mainly chemical control results to pests becoming resistant to certain pesticide applications, and to residue/ toxicity problems in the crops and the environment, especially if high dosages of potent chemicals are regularly applied.

In 1980 a FAO-supported IPM programme in rice became operational in various S.E. Asian countries, including Indonesia, and presently, MARIF/ATA-272 project at Malang, East Java, is involved in the development of IPM in grain legumes (Oka, 1990 and Nasir Saleh *et al.*, 1991).

USE OF WEEDS

The use of ground covers is a well-known, established practice in tree crops in many tropical countries for preventing soil erosion, preserving soil structure, regulating soil fertility, and preventing, suppressing or controlling weeds through competition for light, water and nutrients. Intercropping weed controls in the cover crop is important, and the tree crops receive maximum benefit from this practice if additional weed control measures are also conducted in the rows of tree crops.

Ground covers can be used for control of weeds both in perennial and annual crops. Akobundu (1980) found that maize planted in fields with the legumes centro (*Centrosema pubescens*) and wild winged bean (*Psophocarpus palustris*) gave very good weed control without affecting the yield of the crop.

In the humid tropics, weeds are often not destroyed by handweeding or hoeing, but the above-soil parts of the weeds are removed by cutting, and this weed vegetation is used as fodder for cattle. The economics of using this weed control system, which only solves partly the competition problem, should be examined as part of the farming systems research.

MANUAL, MECHANICAL AND CULTURAL WEED CONTROL

In the rainfed crops grown in areas where distinct dry periods are experienced, weeds are a special problem during land preparation: handweeding and digging by hand of the dry, hard soils are very difficult operations, and in those areas the agronomic and economic aspects of cultivation by animal or mechanical traction could be essential part of farming systems research.

Time of land preparation is also an important factor in obtaining a proper seedbed: tests could be conducted to examine the efficiency of cultivating the land as soon as possible after harvesting when the soil is still moist. If rice is

preceding the growth of grain legumes, it deserves consideration to thresh the rice mechanically, so that the land can indeed be cultivated soon after harvesting this crop.

Spacing of crop plants is also important from a weed control point of view. The notorious weed *Cyperus rotundus* (teki) cannot stand full shade, and the spacing should thus be such that the crop can form a closed canopy.

Dead mulches are used for preventing germination of light-sensitive weeds, such as *Portulaca oleracea*, *Euphorbia hirta* and *Ageratum conyzoides* (Van Rooden *et al.*, 1970), and for suppressing weeds by light interception and by allelopathy, viz. release of toxic materials. Toxins can also be exuded by roots and other parts of the living plant, an example being the inhibitory effect of alang-alang on growth of maize (Eussen *et al.*, 1976). However, it must be mentioned that the damage caused by allelopathy from living plants is insignificant compared to the suppression of plants due to competition. In contrast with this, the role of allelopathy is clearly apparent when dead mulches are used for weed control.

THE WEED CONTROL COMPONENT IN INTEGRATED PEST MANAGEMENT

Referring to the IPM programme, studies have to be conducted to examine the relationship between presence of weeds and incidence/ levels of pests and diseases. The method of mulching the soil with rice straw at the time of planting the grain legumes is a good example of research on integrated pest management conducted at MARIF, Malang: mulching suppresses weed growth, conserves soil moisture, maintains soil fertility, and there is evidence that it reduces the bean fly (*Ophiomyia phaseoli*) pests attacking seedlings of soybean and mungbean (Marwoto, 1983). Control of leguminous plants that are hosts of main viruses attacking grain legumes, may be necessary to prevent the spread of these viruses, which are transmitted by aphids and other vectors. In this connection it has to be mentioned that on farms a closed season for the growing of grain legumes has to be included in the cropping system, while during fallow periods sanitation activities have to be conducted, consisting of removal of spontaneous growing grain legumes and certain leguminous weeds.

The above implies that studies/experiments are needed to establish the relationship between the presence or absence of weeds and occurrence and distribution of virus diseases as well as other pests and diseases. Experiments to determine the effects of weeds used as trap plants or trap crops (intercropping) on the development of pest populations deserve special consideration.

The preparation of a small booklet illustrating and describing the weeds competing most severely with crops, as well as the weeds acting as main hosts of pest or natural enemies, could be conducted within the framework of the also 1995 paper (Biol control in Asia)

Farming Systems Research (FSR)/Integrated Pest Management (IPM) activities in the area under study.

CONCLUDING REMARKS

For achieving successful introduction of integrated pest management (IPM) in a certain area, this approach of controlling pests, diseases and weeds has to be included as a component of farming systems research and extension, because it embraces a package consisting of varieties with resistance characteristics, cultural practices reducing the infestations of pests, diseases and weeds, and judicious/reduced use of pesticides, decreasing the incidence of toxicity problems. The ultimate goal of IPM is the adoption of this approach by the farmers, which will only occur if it is economically more attractive than the "chemical methods", and if the farmers are actively involved in the process of implementing IPM.

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WEED MANAGEMENT IN WET AND DRY SEEDED RICE IN JAPAN

HIDEJIRO SHIBAYAMA[1]

ABSTRACT

Areas of wet and dry seeded rice fields are not extensive in Japan, they are only about 2,400 and 5,600 hectares, respectively, among 2.06 million hectares of total rice fields in 1990. However, the Japanese Government intends to increase the direct seeded rice by technical improvement to decrease the cost of rice production by farmers.

One of the serious problems of the direct seeded rice in Japan is weed control. For the wet seeded rice, farmers usually apply herbicides two times as pre- and early post-emergence treatments. For the dry seeded rice, farmers are recommended to use herbicides three times, as it is necessary to apply pre- and post-emergence herbicides at dry seeded fields and pre- or early post-emergence one after flooding fields at 20 to 30 days after dry seeding.

Pyrazolate, pyrazoxyfen, bensulfuronmethyl mixed with dimepiperate and some others are applied to the wet seeded rice, and thiobencarb mixed with prometryn, propanil and bentazon are mainly applied to the dry seeded rice before flooding. But, for these treatments, proper water management by farmers and/or good soil condition are requested, although many Japanese farmers are busy with their city jobs, taking only a little care of their rice fields, and the season is rainy in Japan. Therefore, these herbicide treatments are often not so successful in efficacy or in economy, and farmers unwillingly are forced to eradicate weeds by hands at direct seeded rice fields.

INTRODUCTION

Direct seeding in rice cultivation is common in many countries, but the method is not popular in Japan or in some other countries where small-scale farmers are the majority. In Japan, each farmer has only 0.9 ha paddy fields in the average, so they usually find that transplanting method by machine is better than direct seeding one, because transplanted seedlings are bigger and more tolerant to pests and herbicide treatments than the germinated ones, although the more labor and money will be necessary for cultivating seedlings by nursery boxes and transplanting them into paddy fields. Especially, costs of labors, machineries and some materials are very expensive at the transplanted rice cultivation.

The areas of wet and dry seeded rice fields in Japan are not extensive, and they are about 2,400 ha and 5,600 ha, respectively, among 2.06 million ha

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of rice fields in 1990, which had been decreasing gradually every year since 1974 when the total of wet and dry seeded areas was 55,280 ha at the maximum (mainly dry seeded one) (Figure 1). However, the Japanese Government has recently intended to increase the direct seeded cultivation again, as the production cost of transplanted rice cultivation by Japanese small scale farmers has become very expensive compared to the price of rice in the world market.

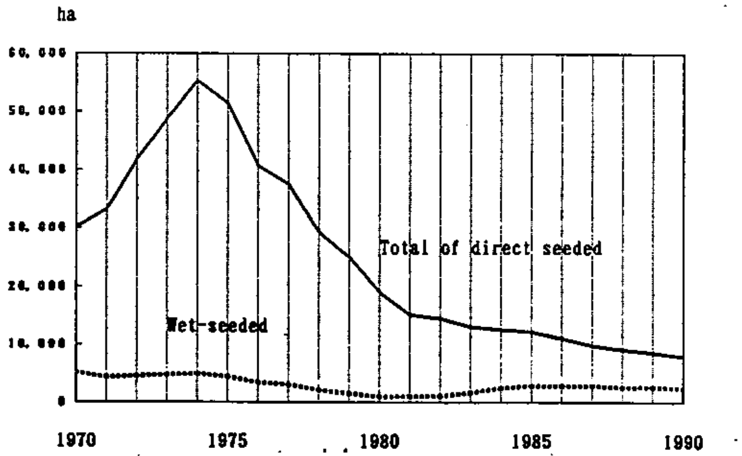

Figure 1. Areas of total direct seeded and wet-direct seeded rice fields in Japan.

One of the serious problems of the direct seeded rice in Japan is weed control. Japanese farmers usually apply "one-shot herbicides" to their transplanted paddy fields within 12 weeks after transplanting, which can control well both the annual and perennial weeds without chemical injuries to young rice seedlings. On the other hand, germinated seedlings by direct seeding are more sensitive to herbicide treatments than transplanted ones, so farmers can use only a few chemicals as pre- or post-emergence herbicides to the direct seeded rice. Really, many farmers are forced to eradicate uncontrolled weeds by hands or another herbicide application. More useful herbicides are expected to develop for the direct seeded rice in Japan.

WEED MANAGEMENT IN WET SEEDED RICE AND ITS PROBLEMS

In the wet seeded rice fields of Japan, paddy fields are puddled, and rice seeds coated with the oxygen supplier, of which the active material is calcium peroxide, are broadcasted or seeded at about 0-1 cm depth into the puddled soil

by broadcaster or by seeding machine. Weed species in wet seeded fields ar almost the same as those in machine transplanted ones, which emerge b irrigating and puddling paddy fields. The main weed species which infest we seeded rice fields are listed in Table 1. The growth of these weeds is more tha that of weeds in transplanted fields, because they have more advantage in we

Table 1. Weed species infesting wet-seeded rice fields in Japan

English name	Species	Family	Seriousnes
Annual grasses			
Barnyardgrass	*Echinochloa oryzicola* Vasing.	Gramineae	○
Barnyardgrass	*E. crus-galli* (L.) Beauv. var. *crus-galli*	Gramineae	
Sprangletop	*Leptochloa chinensis* (L.) Nees	Gramineae	
Annual sedges			
Small flower umbrella sedge	*Cyperus difformis* L.	Cyperaceae	○
Rice flat sedge	*C. iria* L.	Cyperaceae	
Fringerush	*Fimbristylis miliacea* (L.) Vahl	Cyperaceae	
Annual broadleaves			
Monochoria	*Monochoria vaginalis* (Burm. F.) Presl. var. *plantaginea* (Roxb.)Solms-Laub.	Pontederiaceae	○
Toothcup	*Rotala indica* (Willd.) Koehne var. *uliginosa* (Miq.) Koehne	Lythraceae	○
Falsepimpernel	*Lindernia procumbens* (Krock.) Borbas	Scrophulariaceae	○
Dopatrium	*Dopatrium junceum* (Roxb.) Hamilt.	Scrophulariaceae	
Eclipta	*Eclipta prostata* (L.) L.	Compositae	○
Bidens	*Bidens frondosa* L.	Compositae	
Ludwigia	*Ludwigia epilobioides* Maxim.	Onagraceae	○
Perennial grasses			
Knotgrass	*Paspalum distichum* L.	Gramineae	
Cutgrass	*Leersia oryzoides* (L.) Sw.	Gramineae	
Perennial sedges			
Mizugayatsuri	*Cyperus serotinus* Rottb. et Schult.	Cyperaceae	
Spikerush	*Eleocharis acicularis* (L.) Roem. var. *longiseta* Sven.	Cyperaceae	
Kuroguwai	*E. kurogawai* Ohwi	Cyperaceae	
Bulrush	*Scirpus juncoides* Roxb. var. *ohwianus* T. Koyama	Cyperaceae	○
Koukiyagara	*S. planiculmis* Fr. Schm	Cyperaceae	
Perennial broad leaves			
Waterplantain	*Alisma canaliculata* A. Br. et Bouche	Alismataceae	
Urikawa	*Sagittaria pygmaea* Miq.	Alismataceae	○
Arrowhead	*S. trifolia* L.	Alismataceae	
Giant duckweed	*Spirodella polyrhiza* (L.) Schleid.	Lemnaceae	
Duckweed	*Lemna paucicostata* Hegelm.	Lemnaceae	
Algae			
Spirogyra	*Spirogyra arcla* Kutz.	Zygnemataceae	○

seeded fields under less competition with the germinated rice plants. Duckweeds and algae are important species, too, there, as rice sprouting are sometimes damaged by them.

Weeds in wet seeded fields include both annual and perennial species, so herbicides applied sequentially there should be active to control both of them. Among the recommended herbicides (Table 2), pyrazolate and pyrazoxyfen, the similar chemicals, are the most popular for pre-emergence treatment, because they are quite safe for rice germination even at the application on seeding day. However, their herbicidal activity is frequently reduced by the inadequate water management or by the forced drainage to increase rice sprouting after wet seeding. In some case, many weeds appear after their treatments, so another herbicide is often necessary as the second treatment.

Table 2. Some herbicides which are applied to wet-seeded rice fields in Japan .

Herbicides (formulation)	Time of application	Target weeds
Pyrazolate (G)	Pre-emergence	Annual weeds
Pyrazoxyfen (G)	Pre-emergence	Annual weeds
Chlornitrofen (G) (2nd applic.)	pre-emergence	Annual weeds
Chlomethoxynil (G) (2nd applic.)	pre-emergence	Annual weeds
Bensulfuronmethyl + dimepiperate (G)	Early post-emergence	Annuals and perennials
Bensulfuronmethyl + thiobencarb (G)	Early post-emergence	Annuals and perennials
Molinate + pyrazolate (G)	Early post-emergence	Annuals and perennials
Thiobencarb + chlornitrofen (G) (2nd. applic.)	Early post-emergence	Annual weeds
Thiobencarb + simetryn (G) (2nd. applic.)	Early post-emergence	Annual weeds
Thiobencarb + simetryn MCPB (G) (2nd. applic.)	Early post-emergence	Annuals and some perennials
Molinate + simetryn MCPB (G) (2nd. applic.)	Early post-emergence	Annuals and some perennials
Bentazon (WP) (G)	Post-emergence	Broadleaves
2,4-D, MCP and their mixtures	Post-emergence	Broadleaves

Formulation: G = Granule; WP = Wettable powder

As the early post-emergence herbicides, the mixture of bensulfuron methyl and dimepiperate or thiobencarb can be applied after 1 leaf stage of rice until 2 leaf stage of barnyardgrass among "one-shot herbicides" for the transplanted rice. In several areas, molinate and its combinations are restricted to be applied to paddy fields because of fish toxicity. Other early post- or post- emergence herbicides are applied there when weeds are not controlled well by pre-emergence treatment (Table 2).

Main problems by these weed control system in wet seeded rice are as follows:

1) Cost of herbicides: Popular herbicides for wet seeded rice are pyrazolate, pyrazoxyfen and combination products of bensulfuron methyl as they are safe for seed germination and establishment of rice, but they are expensive to apply for the sequential application.

2) Re-emergence of weeds after controlling them by pre-emergence herbicides: Their herbicidal activity is reduced by draining off the flooded water of fields after treatment.

3) Limited number of herbicides which can be applied to wet seeded rice: Many "one-shot" and other herbicides for the transplanted rice can not be applied there, because they may cause injuries to germinating rice seeds.

WEED MANAGEMENT IN DRY SEEDED RICE AND ITS PROBLEMS

In the dry seeded rice cultivation, rice seeds are drilled into the fields at dry condition. So, weed species there are almost similar to those in upland crop fields as in Table 3. At 20 to 30 days after dry seeding, fields are flooded by water, and hygrophytic and aquatic weeds emerge there as in the transplanted or wet seeded paddy fields. Most of the problem weeds are the same as those in upland fields, although two species of barnyardgrass, *Echinochloa oryzicola* and *E. crus-galli* var. *crus-galli*, are the most serious ones. Perennial weeds are not so important there, probably because they are almost paddy weeds which will appear after flooding and they can be controlled well by chemicals applied at flooded condition. Recommended herbicides at dry condition are oxadiazon, thiobencarb and the mixed product of thiobencarb and prometryn for pre-emergence treatment, propanil and the tank mixture of thiobencarb and propanil for early post-emergence one and bentazon for post-emergence one (Table 4). Although fine weather condition is necessary for dry seeding, the herbicidal efficacy of these pre-emergence treatments is often reduced in dried condition, when there is little rainfall within a few days after herbicide application, and many farmers are forced to eradicate weeds, especially, barnyardgrass, by hand, before flooding water to their fields. After flooding, several early post-emergence herbicides are recommended to be applied to control paddy weeds which appear at the wet condition.

Main problems by these weed control system at dry seeded rice are as follows:

1) Low efficacy of pre-emergence herbicides at dry soil condition: Their efficacy is frequently reduced by unfavorable weather condition, so farmers should control the remained weeds by post-emergence herbicides or by hand weeding.

2) Farmers can not use propanil or its mixture freely for post- emergence treatment: These herbicides will cause severe damage to rice seedlings when insecticides are applied just before or after herbicide application. Some insects cause severe virus diseases to the direct seeded rice.

3) Dry seeded fields often become the over-percolating paddy ones: At 20 to 30 days after dry seeding, these fields are flooded. But, herbicides applied after flooding will be drained off at the over-percolating fields, and it causes the poor weed control.

Table 3. Weed species infesting dry-seeded rice fields in Japan

English name	Species	Family	Seriousness
Annual sedges			
Barnyardgrass	*Echinochloa oryzicola* Vasing	Gramineae	○
Barnyardgrass	*E. crus-galli* (L.) Beauv. var. *crus-galli*	Gramineae	○
Crabgrass	*Digitaria ciliaris* (Retz.) Koeler	Gramineae	○
Sprangletop	*Leptochloa chinensis* (L.) Nees	Gramineae	○
Annual sedges			
Rice flatsedge	*Cyperus iria* L.	Cyperaceae	○
Flatsedge	*C. microiria* Steud.	Cyperaceae	
Smallflower umbrella sedge	*C. difformis* L.	Cyperaceae	
Fringerush	*Fimbristylis miliacea* (L.) Vahl	Cyperaceae	
Annual broad leaves			
Eclipta	*Eclipta prostata* (L.) L.	Compositae	○
Bidens	*Bidens frondosa* L.	Compositae	○
Bittercress	*Cardamine flexuosa* With.	Cruciferae	
Marsh yellowcress	*Rorippa islandica* (Oeder) Borb.	Cruciferae	○
Chicweed	*Stellaria media* (L.) Villars	Caryophyllaceae	
Nominofusuma	*S. alsine* Grimm. var. *undulata* (Thunb.) Ohwi	Caryophyllaceae	
Purslane	*Portulaca oleracea* L.	Portulacaceae	○
Smartweed	*Persicaria longiseta* (De Bruyn) Kitag. [*Polygonum longisetum* De Bruyn]	Polygonaceae	
Monochoria[x])	*Monochoria vaginalis* (Burm f.) Presl. var. *plantaginea* (Roxb.) Solms-Laub.	Pontederiaceae	○
Toothcup[x])	*Rotala indica* (Willd.) Koehne var. *uliginosa* (Miq.) Koehne.	Lythraceae	
Falsepimpernel	*Lindernia procumbens* (Kroc) Borbs	Scrophulariaceae	○
Perennial sedge			
Mizugayatsuri	*Cyperus serotinus* Rottb.	Cyperaceae	
Bulrush	Scirpus juncoides Roxb. var. *ohwianus* T. Koyama	Cyperaceae	
Perennial broad leaves			
Uriawa	*Sagittaria pygmaea* Miq.	Alismataceae	

[x]) These species appear after flooding water to dry seeded fields.

Table 4. Some herbicides which are applied to dry-seeded rice fields in Japan

Herbicide (formulation)	Time of application	Target weeds
At dry condition after sowing seeds		
Thiobencarb + prometryn (EC)(G)	Pre-emergence	Annual weeds
Oxadiazon (WP)	Pre-emergence	Annual weeds
Thiobencarb (EC)	Early post-emergence	Annual weeds
Propanil (EC)	Post-emergence	Annual weeds
Thiobencarb + propanil (EC)	Post-emergence	Annual weeds
Bentazon (WP)	Post-emergence	Broadleaves
After flooding water to dry-seeded fields		
Chlomethoxynil (G)	Pre-emergence	Annual weeds
Thiobencarb + simetryn (G)	Early post-emergence	Annual weeds
Thiobencarb + chlornitrofen (G)	Early post-emergence	Annual weeds
Molinate + simetryn + MCPB (G)	Early post-emergence	Annual weeds
Piperophos + dimethametryn (G)	Early post-emergence	Annual weeds
Bensulfuronmethyl + dimepiperate (G)	Early post-emergence	Annuals and perennials
Bensulfuronmethyl + thiobencarb (G)	Early post-emergence	Annuals and perennials
Bentazon (WP)(G)	Post-emergence	Broadleaves
2,4-D, MCP and their mixtures	Post-emergence	Broadleaves

Formulation: EC = Emulsifiable concentrate; G = Granule; W = Wettable powder

FUTURE IMPROVEMENT IN WEED CONTROL OF WET AND DRY SEEDED RICE IN JAPAN

1) In wet and dry seeded rice fields by small-scale farmers in Japan, weeds should hopefully be controlled well by new herbicides which would be safer to rice than the current chemicals. Especially, grass killers which can control barnyardgrass and crabgrass at 3 to 4 leaf stage without damages to rice are expected.
2) Deep flooding at 12 to 15 cm or more will be necessary to Japanese direct seeded rice fields, in the future, to control barnyardgrass and some other species in combination with herbicide treatments, although the height of leaves of Japanese paddy fields are too low to keep deep paddy water.
3) More labor saving methods to spray chemicals should be developed for direct seeded fields, because small-scale farmers in Japan are almost all weekend farmers, and most of them are not young. Usually, they do not like heavy work in their rice fields.
4) The cost of herbicides and labors can be reduced by using more effective chemicals, because the number of herbicide applications will be reduced.

WEED CONTROL STRATEGIES AND PROFIT IN RICE-SOYBEAN CROPPING SYSTEMS

P. VONGSAROJ[1] AND C.E. PRICE[2]

ABSTRACT

The use of herbicides will generally increase crop yield by reducing weed compet tion, but the major aim of the farmer is to increase his profit, even if this is achieve from a lower yield. Herbicides are a significant cost component of crop production so is reasonable that the farmer should require assurance that this additional cost will b repaid by higher profits. A series of trials were carried out during the period 1986 t 1989, to study the use of herbicides and other weed control methods in a rice-soybea crop rotation in Central Thailand. The increased yield obtained with both crops, whe weed control measures were taken, have been translated into financial terms for th two seasons 1986-87 and 1987-88, when there were big changes in the prices tha farmers were paid for rice and soybeans. The contrast between the two years sugges that adequate prices are essential for the development of a healthy, integrated wee control strategy, in which herbicides can be selected to optimise profit with maximu yield.

INTRODUCTION

There is abundant evidence that herbicides can increase the yield arable crops by reducing competition from weeds. Work carried out in Thailan during the period 1986 to 1988, showed that the yield of rice was increased b herbicides application and that there was a residual effect, which gave som measure of weed control in a succeeding soybean crop (Vongsaroj and Pric 1987; 1991). The increased yield, however, required increased investment, s it is important to find out if the additional costs of the herbicides can give a equivalent increase in crop value.

MATERIALS AND METHODS

Rice-soybean rotation trials commenced after the herbicides we screened separately on both crop species under greenhouse conditions

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Imperial College, in the UK and in the field at the Chai Nat Experiment Station, Rice Research Institute, Department of Agriculture, Thailand. The rice herbicides, 2,4-D, oxadiazon and oxyfluorfen were selected and used on the rice crop at rates of 0.75, 0.75 and 0.2 kg ai per hectar respectively. The herbicides were mixed with sand and broadcast over the paddy, ten days after sowing pregerminated rice seeds. Soybean seeds were planted directly into the rice stubble immediately after harvest, at a spacing of 25 cm x 25 cm, five seeds per hill, thinned to three plants per hill. Rice was given a basal treatment of 18.75 kg/ha nitrogen plus 25 kg/ha phosphorus followed by 25 kg/ha nitrogen at initiation of panicle primordia. One kilogram of *Rhizobium* was mixed with every 20 kg of soybean seed, before planting, and 37.4 kg nitrogen + 37.5 kg phosphorus + 18.75 kg potassium were added per hectare 30 days after seeding. The trial was designed as a 4 x 5 factorial, plot size 3 m x 8 m with four replications.

The total revenue was determined by the multiple of yield by value. The value of rice and soybean was 3000 and 7000 Baht/ton respectively in 1986-87, increasing to 3500 and 12000 Baht/ton in 1987-88. Treatment costs consist of the cost of herbicides and labour for their application, while other variable costs consist of seed, land preparation, fertilizers, pesticides, harvesting and threshing (Figure 1 and 2). The cost values used were those operating at the time of the trials. No account has been taken of land costs.

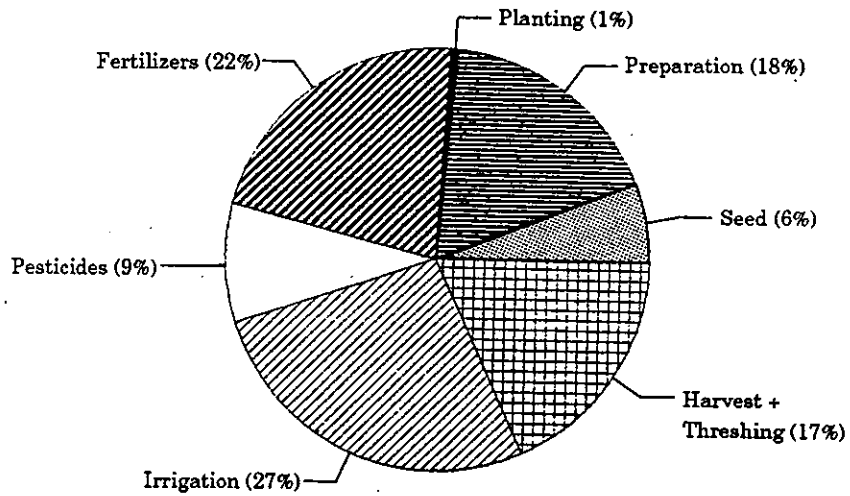

Figure 1. Rice variable costs.

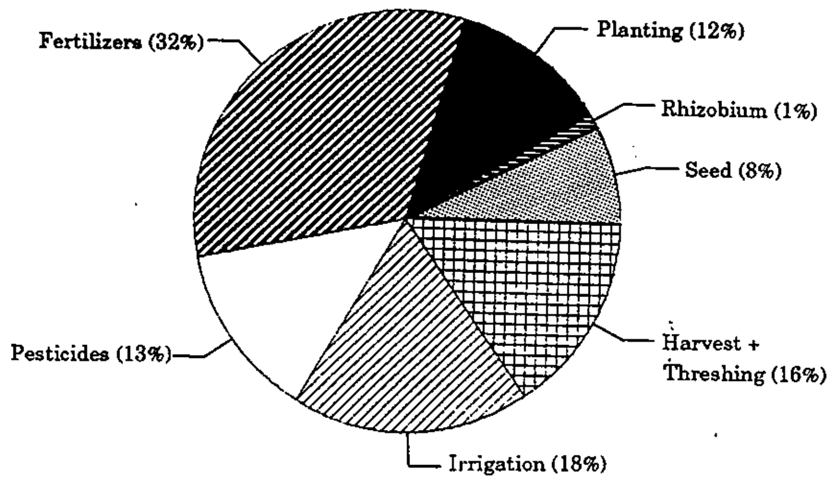

Figure 2. Soybean variable costs.

RESULTS

The yields of rice for the two years are given in Figure 3. There were fev differences between the two years with the herbicide treatments yieldin significantly higher than the untreated control. The corresponding profit (Figure 4) show the influence of the increased price for rice in the second year and it is noticeable that the profits of the herbicide treated plots compared wit the untreated plot, were greater than would be expected from the yiel differences. The explanation for this effect is given in Figure 5 and 6 where th crop values are plotted along side the total variable costs. Profit is calculate as the difference between crop value and production costs, and in both year the total variable costs were large compared with the value of the crop fron untreated plots. The additional costs of herbicides were small compared wit the yield they produced (Figure 7 and 8).

The soybean yield was more variable between the two years and betwee the herbicide treatments, than was the case for rice, and only oxadiazon an oxyfluorfen showed a significant increase in yield for both years, compare with the untreated control (Figure 9). In the first year the 2,4-D and untreate soybean gave a loss, while oxyfluorfen gave only a small profit, but in the secon year, all the soybean treatments gave a profit (Figure 10). The difference i profit between the two years was the result of the higher price obtained fo soybean by the farmer in the second year, but the difference in profit betwee

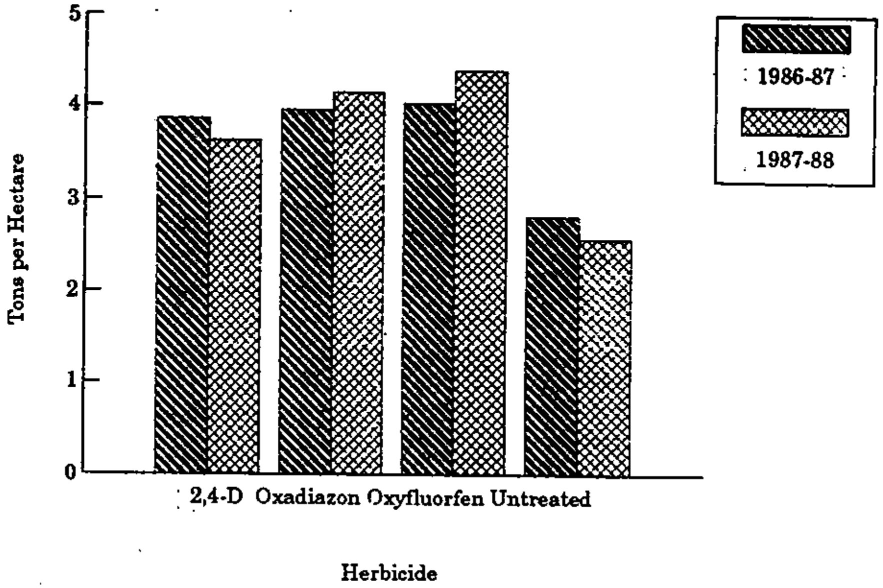

Figure 3. Rice yield 1986-87 and 1987-88.

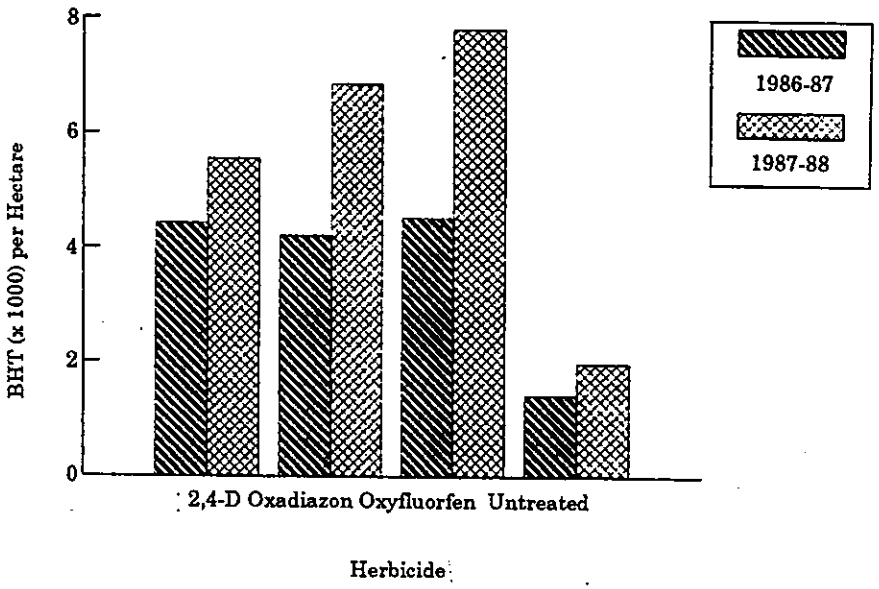

Figure 4. Rice profits 1986-87 and 1987-88.

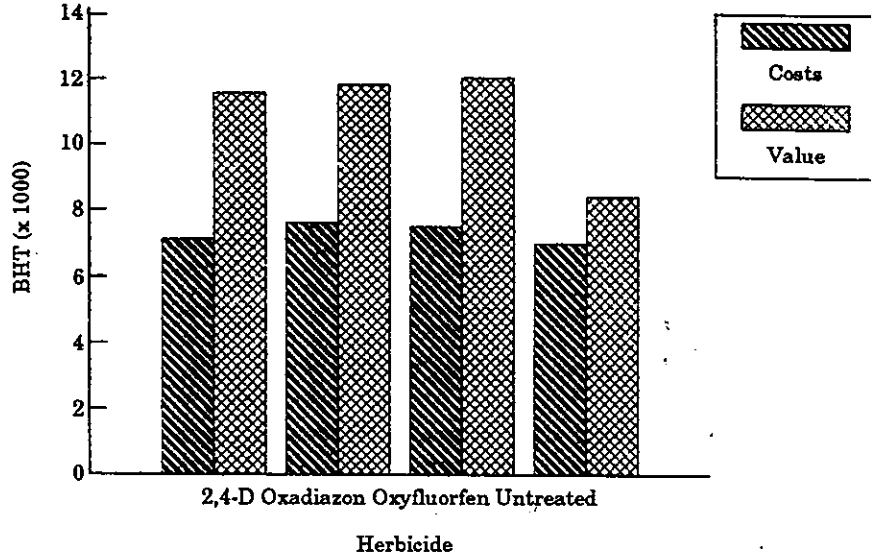

Figure 5. Rice costs and value 1986-87.

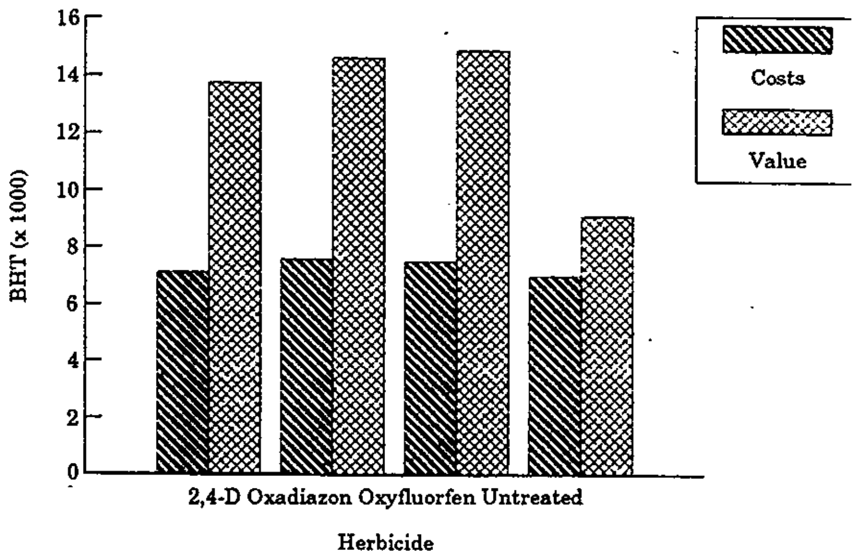

Figure 6. Rice costs and value 1987-88.

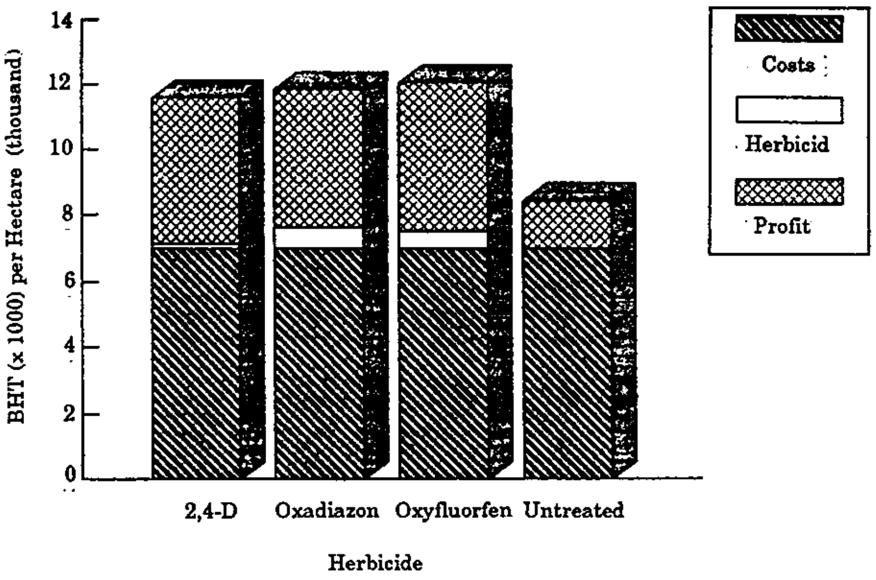

Figure 7. Rice costs and profits 1986-87.

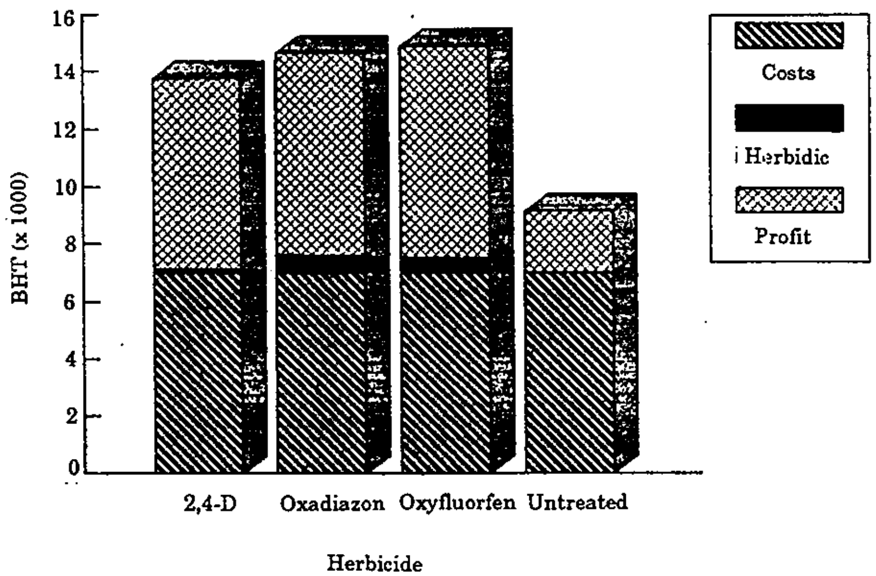

Figure 8. Rice costs and profits 1987-88.

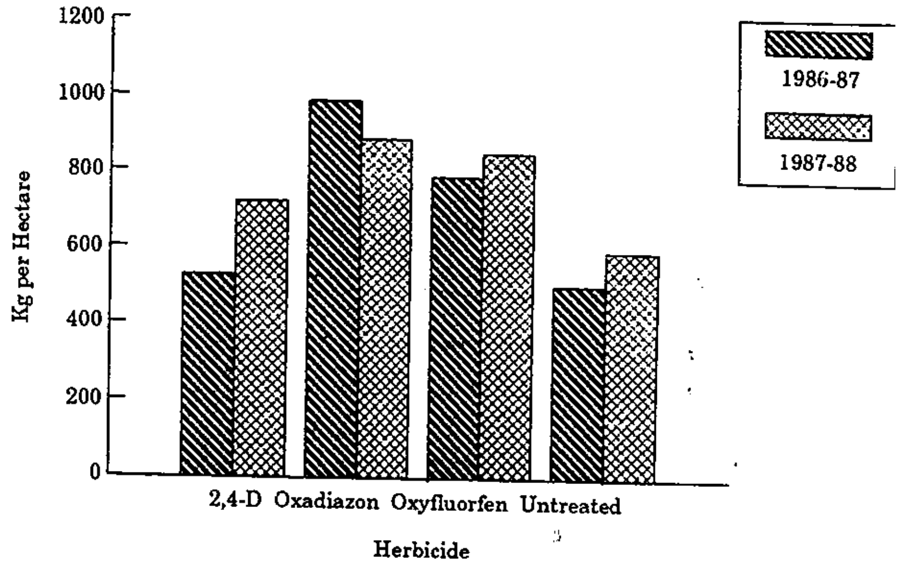

Figure 9. Soybean yield 1986-87 and 1987-88.

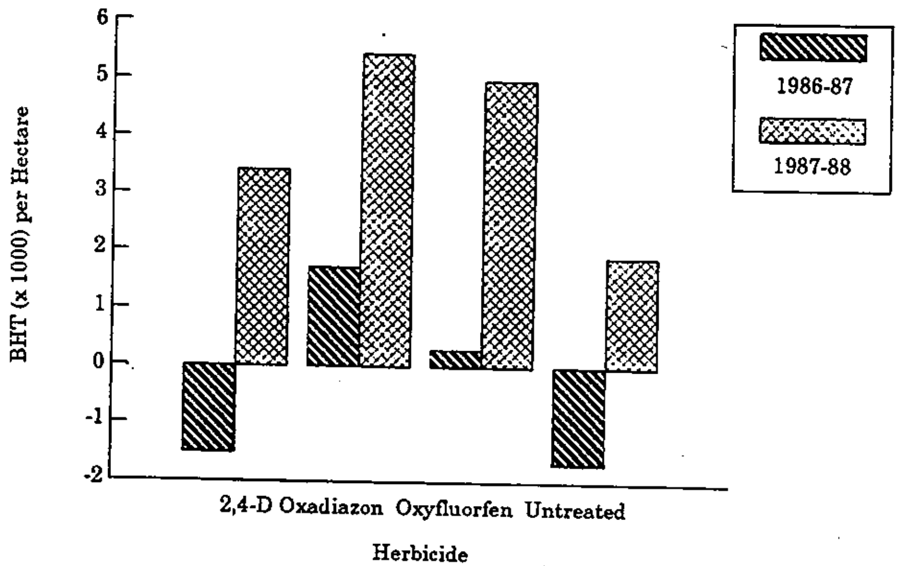

Figure 10. Soybean profits 1986-87 and 1987-88.

the treatments was caused by the difference between the variable costs and the value of the crop (Figure 11 and 12). The variable costs for the 2,4-D and untreated plots were higher than the value of the crop in the first year resulting in a loss (Figure 10), but in the second year the higher prices for the soybean gave a profit for all the treatments, though oxadiazon and oxyfluorfen still gave the best profits (Figure 11 and 12).

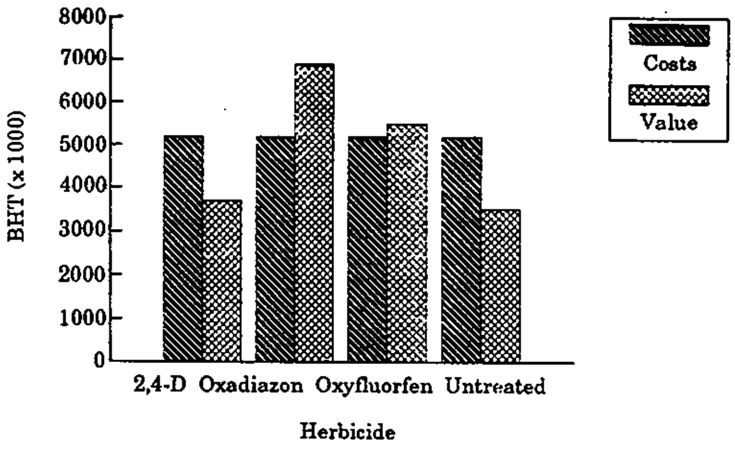

Figure 11. Soybean coast and values.

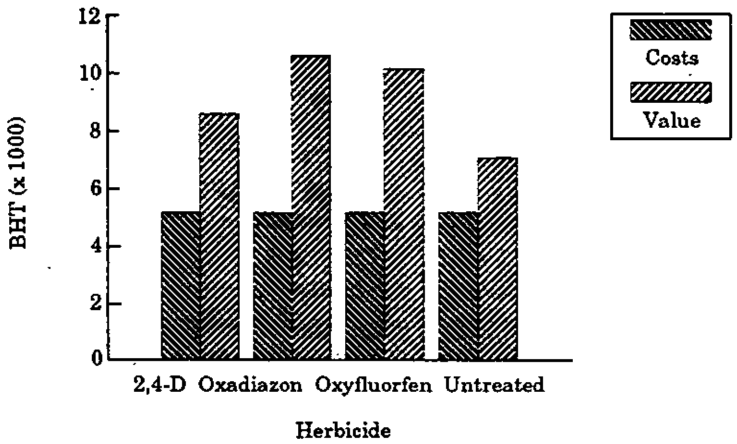

Figure 12. Soybean costs and values 1987-88.

The combined profits from the two crops for the two years are shown in Figure 13 and 14. The losses resulting from the 2,4-D treated and untreated soybean in the first year, reduced the total profits to below the profits from rice alone, giving an overall loss for the untreated plots, but in the second year all treatments resulted in profit. Oxadiazon and oxyfluorfen gave the best overall results, and all the herbicides were considerably better than the untreated controls.

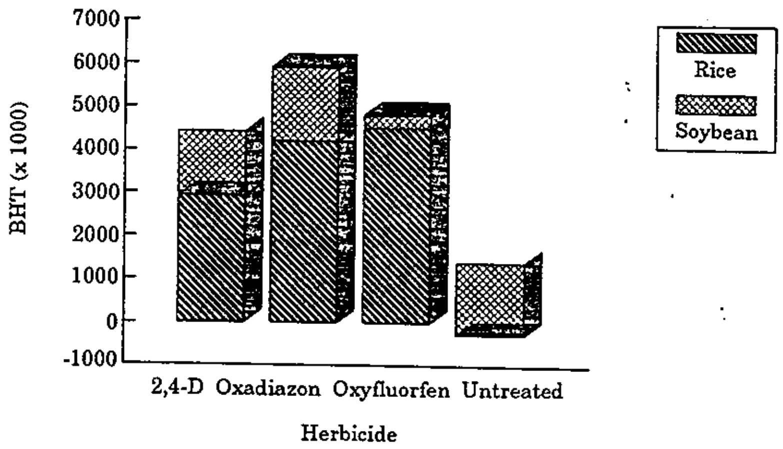

Figure 13. Total profit 1986-87.

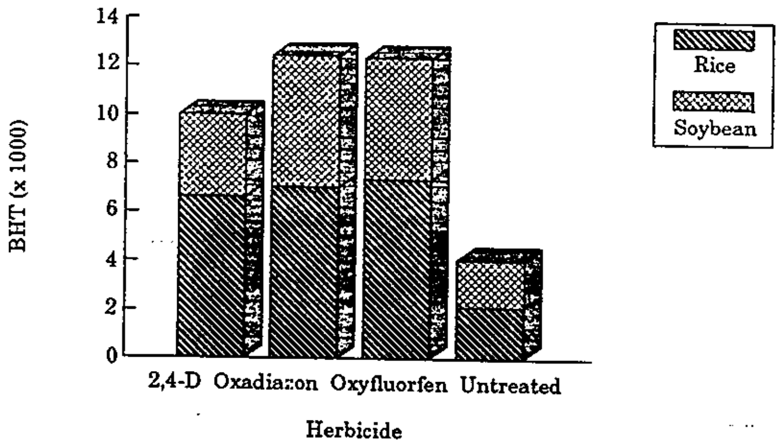

Figure 14. Total profit 1987-88.

DISCUSSION

It is clear that herbicides can improve the yield and profitability of rice, and in some cases will increase the yield and profit of a subsequent soybean crop. This was especially notable for oxadiazon and oxyfluorfen and justified the extra expense of using them. The farmer price for the crop was especially important in the overall economy of the two crops, but even when the prices were low, profits were maximised by using high cost, highly effective herbicides. The costs of the herbicides and their application were small, compared with the other variable costs, which explains why the herbicide costs had little effect on the overall profitability of the different treatments.

Small differences in yield gave relatively big differences in profit, because the variable production costs were so high relative to the profit. It is clear that treatments that give relatively small increase in yield may still be capable of giving a profit and means that herbicides should be selected primarily on based on effectiveness rather than cost alone. The farmer may also increase his profit by reducing the variable costs, for instance by doing his own land preparation and planting, but there is a limit in the area of land that can be managed by a single family.

The economic factors included in this report are incomplete; land costs are not included, and many of the variable costs, such as land preparation, pesticide application and harvesting could be done by the farmer and so would become part of the profit. There would also be income supplements inthe form of vegetables, livestock and possibly fish, available to the farmer, but it is also evident that in the same way that profit is what is left over after subtracting all the costs, so wealth is the income remaining after the essentials for living have been paid for. Small increases in yield can lead to relatively large increases in profit, and small increases in profit can mean the difference between hunger and wealth.

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CINOSULFURON: APPROPRIATE FOR WEED MANAGEMENT OF TRANSPLANTED RICE IN INDONESIA

PRIYATNA, DARWANTO, H. BURHAN AND D. NEVILL[1]

ABSTRACT

Cinosulfuron (Setoff^R), a new rice herbicide from the sulfonylurea chemical clas was tested in 12 field trials in West and East Java, Indonesia. Cinosulfuron at the ra of 19 g a.i./ha was applied to transplanted rice under different water managemer conditions, i.e. onto saturated soil and into various water depths. The product was als applied by different methods, i.e. knapsack sprayer (with or without spray nozzle pouring into the irrigation inlet and also broadcasting by mixing the compound wit sand. In general, crop safety and activity were excellent and were independent of te location, water management and application method.

INTRODUCTION

An effective control of weeds during early period of rice growth is ver important (Zimdahl, 1979). Good irrigation in transplanted rice will offer a indirect method of control for some weed species. Maintaining the water leve depth in paddy fields at 3 to 10 cm during the first 28 to 30 days afte transplanting can reduce the germination of annual grass species (Mercado 1979), but broadleaved weeds such as *Monochoria vaginalis* dominate unde these conditions.

Hand weeding is an important method for weed control in Indonesia an the labor costs required for weeding are approximately 17 % of the total inpu costs for rice production (Sayogya, 1982) and comprise 30-40 man-days pe hectare. Labor costs are increasing and in some areas there is a shortage o labor. These factors have led to an increasing use of chemical weed control. Since grasses can usually be controlled by water management, activity against broad leaved weeds and sedges is particularly important. For successful use in Indonesia, the herbicide must not only have an appropriate spectrum of activity, but it must also give excellent weed control under many different application conditions as well as being very cost-effective.

Cinosulfuron, a sulfonylurea herbicide, is being developed by Ciba-Geigy Ltd. in Indonesia especially for use in transplanted rice. It acts as an inhibitor of cell division and growth in susceptible plants (Quadranti *et al.*, 1987). Initial results have shown that it gives excellent control of broadleaves and sedges under a wide range of conditions (Burhan *et al.*, 1989). In this paper, further

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results are presented to demonstrate the consistently good activity of cinosulfuron at the very low rate of 10 g a.i./ha. The effect of different water management regimes and different application methods will also be described.

MATERIALS AND METHODS

Performance of 10 g Cinosulfuron per Hectare

A total of twelve trials to compare cinosulfuron with metsulfuron (Ally 20 WG) as a standard product were carried out in Cikampek (West Java), Subang (West Java) and Mojokerto (East Java). Both products, cinosulfuron and metsulfuron, were applied at 3, 6 and 9 days after transplanting. A special sprayboom equipped with four fan jet nozzles was used for herbicide application at a water volume of 500 l/ha. Plots of the rice varieties IR-36 or IR-64 were laid out in a randomized block design with three replication and plot size was 10-20 sq.m.

Crop injury and weed control were assessed at 10-15 and 50-55 days after application respectively. Rice grain yield was assessed at a standardized 14% moisture content.

In six trials, cinosulfuron was applied to saturated soil which was then flooded approximately 50 days after application (early booting stage of rice development). The rate of cinosulfuron was 10 g a.i./ha and application timing was 3 and 9 days after transplanting the variety IR-36. The standard compound was pretilachlor (Rifit 500 EC) applied at 600 g a.i./ha. Plots were laid out in a randomized complete block design with three replications.

Application and assessment methods were the same as in the trials under normal water management.

Effect of Water Depth

The trial was conducted during the dry season of 1990/1991 in Cikampek on alluvial soil (3.9% organic matter, 60% sand, 40% silt, 54% clay; pH 5.4). The trial was designed in randomized complete block with three replications and 10 sq.m plots. Soil was applied at 6 days after transplanting. Rates of 5, 7.5, and 10 g a.i./ha were applied to rice of the variety IR-36 under the following conditions :

1. Application onto saturated soil which was kept saturated until harvest.
2. Application onto 1-2 cm water depth which was maintained until rice development reached the booting stage.
3. Application onto 2-5 cm water depth which was maintained until booting stage.
4. Application at 5-10 cm depth which was maintained until booting stage.

At 17 and 56 days after herbicide application, crop tolerance and weed control were assessed based on the estimation of biomass reduction in percent. Rice grain yield was measured from whole plots and standardized to 14% moisture content.

Effect of Application Method

A trial was conducted in transplanted rice at Cikampek and plots were laid out in a randomized block design with three replications and plot size was 20 sq.m. The rice variety was IR-36.

Application methods were :

1. Sprayboom with four fan jet nozzles and a water volume of 500 l/ha.
2. Broadcast by mixing cinosulfuron with 20 kg sand per hectare.
3. Cinosulfuron was diluted into 1 liter water, then poured into the irrigation water at the inlet.
4. Knapsack sprayer without nozzle and a water volume of 50 l/ha.

Cinosulfuron at rates 5 and 10 g a.i./ha was applied by all methods at 6 days after transplanting. For comparison, 10 g a.i./ha was applied at 1 day after transplanting by using a standard sprayboom. Crop safety and weed control were assessed at 17 and 56 days after application respectively.

RESULTS AND DISCUSSION

Performance of 10 g Cinosulfuron per Hectare

Cinosulfuron was well tolerated at a rate of 10 g a.i./ha when applied under both normal water management and saturated soil conditions. Evaluations at 10-25 days after application showed that phytotoxicity was comparable to standard products and never exceeded 2-5%. Cinosulfuron applied at 3, 6 and 9 days after transplanting gave excellent control of predominant weeds such as *Monochoria vaginalis*, *Fimbristylis miliacea*, *Cyperus* spp. and *Scirpus juncoides* (Table 1 and 2). The level of control was similar under normal water management and saturated soil conditions.

Yield obtained with cinosulfuron were comparable to metsulfuron, however they were lower than in hand weeded plots (Table 3).

Effect of Water Depth

Under all water management regimes, cinosulfuron was well tolerated by rice at rates of 5-10 g a.i./ha. Evaluation at 17 days after application showed excellent activity against *Monochoria vaginalis* and *Scirpus juncoides*. All treatments with cinosulfuron attained 90% weed control (Table 4).

Table 1. Weed control by cinosulfuron and metsulfuron applied at their recommended rates in transplanted rice under normal water management conditions

Treatment	Rate g a.i./ha	Timing (DAT)	% weed control at 50 DAA			
			MON	CYP	FIM	SCI
Cinosulfuron	10	3	98	96	97	96
		6	97	94	95	96
		9	94	87	87	90
Metsulfuron	5	3	99	98	98	99
		6	99	97	97	99
		9	98	94	93	98

Average of 12 trials
DAA = days after application
DAT = days after transplanting
MON = *Monochoria vaginalis*
CYP = *Cyperus* spp.
FIM = *Fimbristylis miliacea*
SCI = *Scirpus juncoides*

Table 2. Weed control by cinosulfuron and pretilachlor applied at recommended rates in transplanted rice under saturated soil conditions

Treatment	Rate g a.i./ha	Timing (DAT)	% weed control at 50 DAA			
			MON	CYP	FIM	SCI
Cinosulfuron	10	3	95	86	87	93
		6	99	80	92	98
Pretilachlor	600	3	96	97	96	73
		6	71	85	88	42

Average of 2 trials (timing 3 DAT)
Average of 4 trials (timing 6 DAT)

Table 3. The effect of cinosulfuron and metsulfuron on yield when applied at recommended rates under normal water management conditions

Treatment	Rate g a.i./ha	Timing (DAT)	Yield t/ha	Yield % of untreated check
Untreated	-	-	3.7	100
Hand weeded	-	21 & 42	5.4	144
Cinosulfuron	10	3	5.1	137
		6	5.3	142
		9	5.2	140
Metsulfuron	5	3	5.1	138
		6	5.3	142
		9	5.2	140

Average of 12 trials

(Figure 6). The safe limit for flooding was from 6 to 9 days after sowing where farmers need only to control the weeds at the critical period in order to obtain optimum yields.

Table 5. Comparative survival of *E. crus-galli* and rice under different water levels in experimental pots (Anon., 1985)

Water* level (cm)	% survival of			
	Non treated seeds of		Pregerminated seeds of	
	Echinochloa crus-galli	*Leptochloa chinensis*	*Echniochloa crus-galli*	*Oryza sativa#*
0	95	57	100	100
1	89	0	100	100
2	68	0	100	100
3	51	0	96	98
4	41	0	80	100
5	24	0	87	98
10	21	N	65	90
15	4	N	32	83

* Raised to respective levels 3 days after seeding
\# Variety makmur
N = Not tested

Table 6. Weed infestation in unweeded plots at 25 days after sowing, MARDI Station, off season 1990, Seberang Perai

Group	Weed species	Time of flooding (DAS)						
		3	6	9	12	15	18	21
Grass	*Echinochloa crus-galli*	*	*	**	***	***	****	****
Sedges	*Cyperus iria*	*	*	**	***	****	****	****
	Scirpus lateriflorus	*	*	*	*	*	*	*
	S. juncoides	*	*	*	*	*	*	*
	Fimbristylis miliacea	-	-	-	-	-	*	*
Broad-leaves	*Monochoria vaginalis*	*	**	**	**	**	***	***
	Sagittaria guyanensis	**	**	**	**	**	*	*
	Ludwigia hyssopifolia	-	*	*	*	*	*	*
	Bacopa rotundifolia	*	*	*	*	*	*	*

- = not present, * = rare (1-5%), ** = occasional (5-25%), *** = frequent (25-50%), *** = abundant (75-95) and ***** = very abundant (>95%).

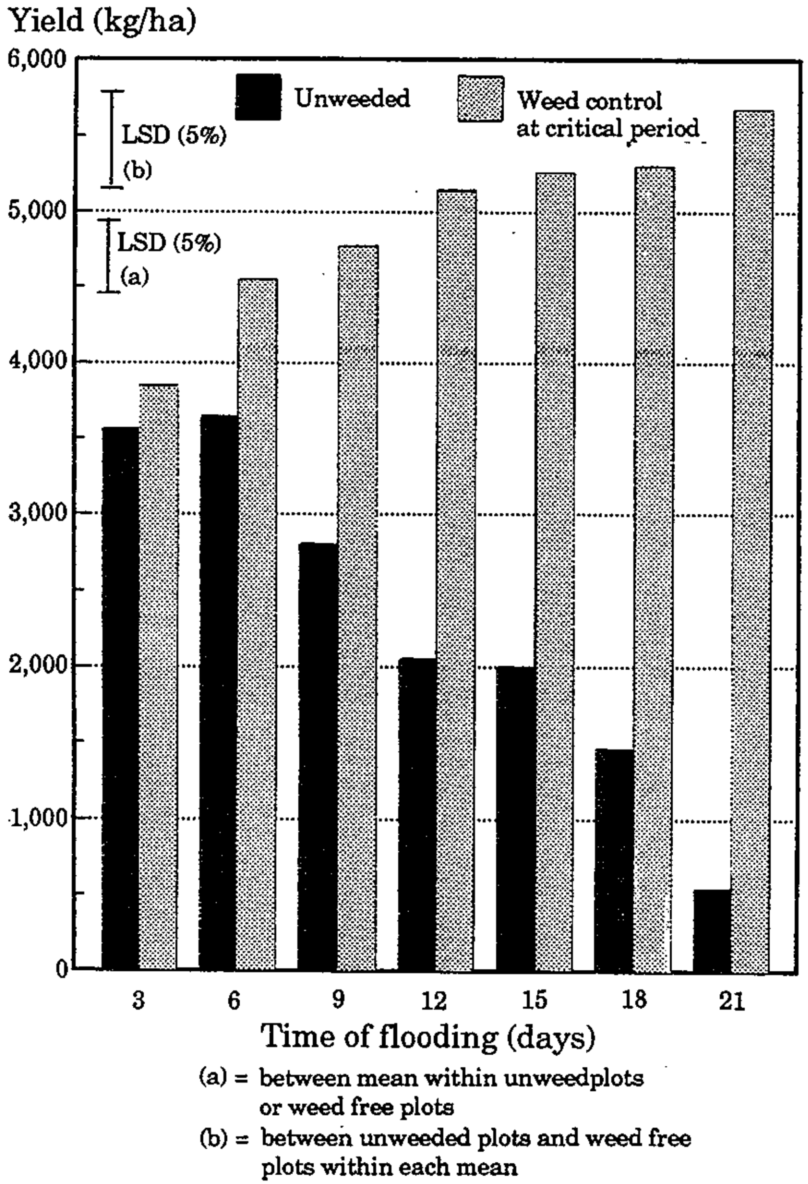


Figure 5. Effect of time of flooding of direct seeded rice under two weed control regimes, off season 1990, Seberang Perai.

Usual practices are that during the first four to five days after seeding the field should be moist but not flooded. Following that, 2-3 cm of water should be introduced to keep the emerged rice seedling ahead of the water. About 10 days after seeding, the water level should be increased to 5 cm and maintained at that depth until crop maturity or about seven days before harvest (Cheong *et al.*, 1982).

Manual Weeding

Weed competition is greater in wet-seeded rice than in transplanted because of similarities in age and morphological characteristics of grass weeds and rice seedlings. Effective methods of weed control are hand pulling/weeding. Although manual weeding is most reliable in terms of weed control, it is impractical in wet broadcast seeded rice because it is difficult to distinguish between young grassy weeds and young rice plants; both are of similar morphological characteristics and some rice plants are destroyed in the process. Furthermore, handweeding could do more harm to the crop through physical damage than the benefits through weed control, particularly at later crop stages. However, cutting of grassy weeds panicles at later crop stages could reduce the source of viable seeds in the following season. This method is useful for a long term strategy for weed control.

Chemical Control

Herbicides are used extensively in the U.S.A., Australia, Europe and Asian countries such as Taiwan, Republic of Korea, Japan and Malaysia. Being labour saving and efficient, it is now commonly accepted that herbicides are most useful particularly in D.S. in addition to the proper agronomic practices and good water management.

During the early days of D.S., trifluralin was the only grass herbicide available beside phenoxy compounds like MCPA, amines, sodium salts and esters of 2,4-D which were meant for broadleaf weeds and sedges. As barnyard grass was not as widespread then, the limited range of these herbicides was able to cope with any weed problem. It became timely when suitable herbicides like molinate, propanil, oxadiazon, pretilachlor, benthiocarb, quinclorac and fenoxaprop-ethyl were introduced when barnyard grass became widespread (Lim and Azmi, 1985; Ooi, 1988; Lo, 1988; Ooi and Chong, 1988; Chang, 1988; Hidajat, 1988 and Sallehhuddin, 1990). In addition, propanil and fenoxaprop-ethyl were also affective against *L. chinensis* and *I. rugosum*. On the other hand, pretilachlor was effective against many weed species if applied at pre-emergence stage. The effectiveness of herbicides being used were dependent on rates and time of application. Herbicides were used either alone or in combination with manual weeding.

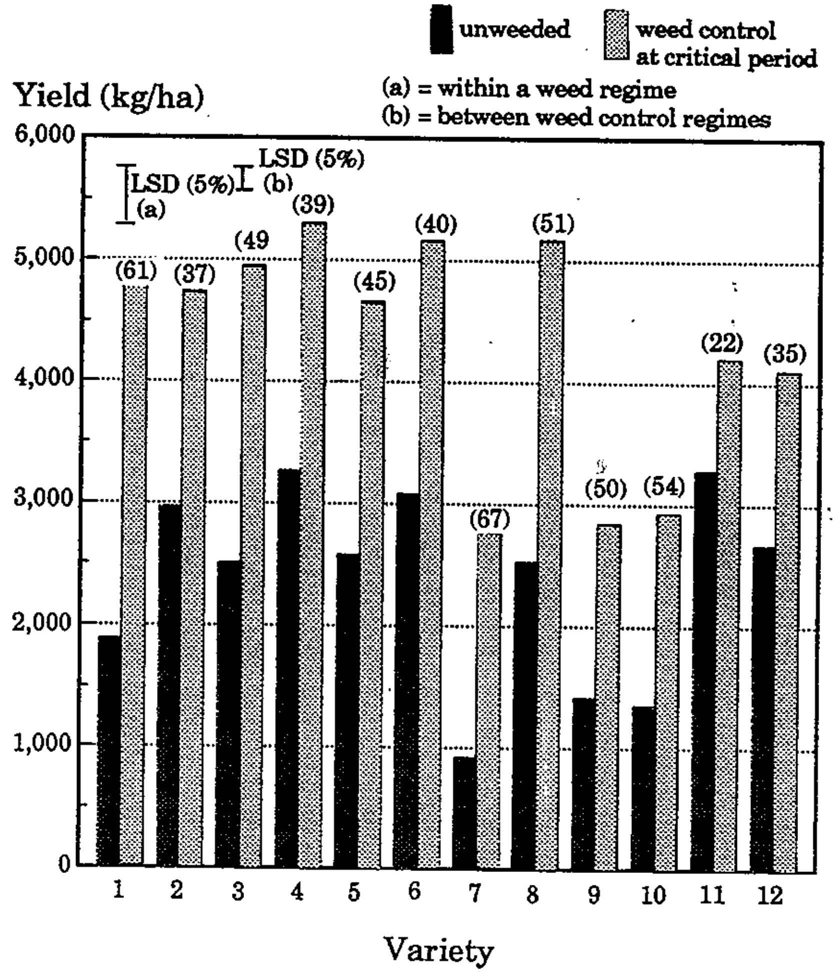
Generally, a single application of a herbicide has not given sustainable weed control in D.S. rice. Combinations of herbicide in a mixture or in sequential application were more effective than treatment with only one herbicide. Azmi and Supaad (1990) suggested the following herbicide combinations for use in D.S. rice for a broader weed control spectrum, i.e.

* quinclorac + bensulfuron (0.25 + 0.03 kg a.i./h at 10-14 DAS)
* molinate + 2,4-D IBE (2.5 + 0.75 kg a.i./ha t 10-14 DAS)
* molinate + bensulfuron (2.5. + 0.03 kg a.i./ha at 8-12 DAS)
* benthiocarb + bensulfuron (2.0 + 0.01 kg a.i./ha at 10 DAS)

In the event that manual weeding is impossible, chemical control will be of great help. Herbicide use is limited to areas where labour is not plentiful and the wage rates are high. There is usually the need for the field to be flooded for the efficacy of most herbicides on rice weeds to be expressed fully. Table 8 showed that the efficacy of molinate + 2,4-D IBE was good at 5 cm standing flood water, beyond which the efficacy of this herbicide would beaffected. In addition, timely irrigation is important, for even when a particular herbicide like propanil is best applied on to drained or dry soil, the treated fields, has to be flooded promptly, within a day or two after application so as to realize the expected efficacy of such chemical.

Variety Grown

The adoption of modern rice varieties had led to changes in weed control practices. Modern varieties need more crop care than traditional ones because the selection of short-statured, erect leaved and nitrogen responsive cultivars had reduced the ability to compete with weeds (Moody 1983). Azmi (1990) reported the improvement in yields among the varieties studied when weeds were controlled during the critical period; they were different among the varieties studied (Figure 6). Reduction in weed populations after weeds were controlled could improve yield substantially. Yield increase in the range of 22.2-66.5% was recorded. Plant height, number of tillers and maturation period were the factors influencing grain yield production. For example, IR64 an introduced variety from IRRI for virus disease resistant, which is a short cultivar with upright leaves, had showed higher increase in yield production (61%). The short maturing cultivars like Basmati also recorded higher yield improvement (67%). Bahagia, a tall variety, had stood up well under the full season of weed competition, but showed lower improvement in yield productions (22%).



1 = IR 64, 2 = E 78, 3 = MR 112, 4 = MR 106,
5 = IR 42, 6 = MR 94, 7 = Basmati, 8 = MR 71,
9 = Padi siam, 10 = Kel. 23, 11 = Bahagia, 12 = Manik
Figures in paramenthesis indicate % increase in yield

Figure 6. Effect of weed control at critical period on yield production of several rice varieties in direct seeded rice, main season 1989/90, Seberang Perai.

Seed Rate

Generally, under normal circumstances, a seed rate of 40-60 kg/ha is adequate for sowing of D.S. rice (Anon., 1986). The rate of 60 kg/ha was found suitable when sown in competition with low infestation of grasses. Only when competition becomes more intense and fields are not level that the seed rate for D.S. rice needs to be raised to 90 kg/ha. However, although high seed rate could reduce weed infestations it also increases incidence of pest and disease attack. On the other hand, a low seed rate usually is associated with high infestation of weeds that needs good weed management.

Fertilizer Application

Weed growth is usually stimulated by the application of phosphate and nitrogen fertilizers to rice fields, but the ensuing weed competition with the crop can be reduced by selection of times of fertilizer application that are more advantageous to the rice than to the weeds. Therefore, weeds must be controlled early if the rice is to get maximum benefits from nitrogen (Aris *et al.*, 1990). Table 7 showed that a D.S. crop generally responds to nitrogen application after weeds were controlled. Therefore, it is essential that weed management be practised, be it through the use of herbicides or through manual weeding, in order to obtain maximum benefits from nitrogen application.

Table 7. Effect of nitrogen and weeding regimes on direct seeded rice (MR 84), off season 1988, Seberang Perai (Aris *et al.*, 1989)

Rate of nitrogen (kg/ha)	Weeding regime	Yield (kg/ha)	Per cent increase over Unweeded
50	Unweeded	1442	-
	Hand weeding*	5318	73
	Molinate+ bensulfuron	5879	75
	Unweeded	1248	-
100	Hand weeding	5391	77
	Molinate+ bensulfuron	5674	78
	Unweeded	1280	-
150	Hand weeding	5187	75
	Molinate+ bensulfuron	5083	75

*Twice hand weedings at 20 and 40 days after sowing

#Molinate (Ordram 10G) + bensulfuron (Londax 10WP): 3.0 + 0.05 kg a.i./ha

C.V. (nitrogen) = 11.3%

C.V. (weed control) = 13.1%

Seed rate: 40, 80 &120 kg/ha

General Practices

Chemical weed control combined with other cultural practices is now a practical way to reduce weed competition in D.S. rice. Currently, the most promising single approach to D.S. crop is the use of manual weedings in conjunction with herbicide application. However, the choice of weed control methods is dependent on crop establishment technique. The most popular crop establishment technique is wet seeding. It has become an increasingly important method of crop establishment in Malaysia. Table 8 summarised the recommended practices that should be followed in wet seeded areas.

Fortunately, farmers are becoming aware of the losses caused by weeds and the impressive advantages from effective weed control program. For example, the strategic extension campaign on IWM in the Muda area, the largest rice granary in Malaysia, has created substantial impacts after its launching in I/1989 season (Ho, 1990). Infestation of barnyard grass in the campaign area was reduced by 66%, while rice yield increased by 27% compared with the I/1989 season prior to the campaign.

In conclusion, the IWM is the best solution to control weeds in D.S. rice. IWM is not to control one particular weed species but all species affecting the crop. Adequate weed control could be achieved through proper land preparation, good water management practices, supplemented with herbicide application. Consequently, high yields of rice can be obtained with minimum cost.

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Table 8. Weed control package for weed control in direct seeded rice

Day	Operation	Remarks
Before sowing		
-	Cutting and burning of rice stubble	To reduce weed seeds on the soil surface
-21 DBS*	1st tillage (dry) i.e. after harvesting	Removal of perennial weeds
-14-10 DBS	2 nd tillage (wet)	To encourage germination of weed seeds after rotovation
-3-1 DBS	3 rd tillage (wet) followed by levelling	Adequate rotovation will eliminate weeds emergence
-1 DBS	Draining excessive water,	
0	Broadcasting of pregerminated rice seeds Seed rate 60-80 kg/ha	Sowing of rice seeds should be carried out immediately after land levelling
After sowing	Selection of herbicide,depending on time of application,water depth and weed species to be controlled	
3-5 DAS#	Pretilachlor @ 0.5 kg a.i./ha	Preemergence herbicide
8-10 DAS	Molinate + 2,4-D (3.0 + 0.5 kg/ha)	Water depth at the time of application should be maintained at 5-10 cm depth
	Molinate + bensulfuron @2.5 + 0.03 kg/ha	
	Propanil @ 2-4 kg/ha followed by 2,4-D (1.0 kg/ha) after 10 days	Do not apply carbamate pesticides 1-2 weeks before and after spraying propanil (effective under dry condition)
14-20 DAS	Molinate + 2,4-D @ 4.0 + 0.75 kg/ha	
21-25 DAS	Molinate + 2,4-D @ 3.0 + 0.75 kg/ha followed by Molinate @ 2.0 kg/ha (10 days after)	
26-30 DAS	Fenoxaprop-p-ethyl @ 0.06 kg/ha	Post-emergence herbicide. Highly toxic to rice plants if applied before 25 DAS
30-40 DAS	Selective weeding for grassy weeds	Remove grass panicles
110-120 DAS	Harvesting	Combined harvester from seriously infested grassy weeds area should be properly clean to avoid weed seed spreads

* DBS = days before sowing #DAS = days after sowing

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SAFENED BUTACHLOR IN WET SOWN RICE

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ABSTRACT

Three butachlor/MON 7400 formulations were tested in wet sown or direct seeded rice. They are MON 12355 (600:60 g ai/l EC), MON a 12350 (550:55 g ai/l EW) and solventless MON 12320 (800:80 g ai/l sc). All these three formulations mixed and sprayed very well and showed no differences in improving crop safety on rice seedlings.

More than 50 directly seeded rice varieties were tested in 1990 in the Philippines, Sri Lanka, Thailand and Malaysia for their interaction with safened butachlor. Different South East Asian (SEA) rice varieties varied in their susceptibility to butachlor. However, the safened formulations provided excellent crop safety across all varieties tested.

Twenty eight user reliability trials (URT's) were conducted in 1990 in South East Asia. Rates tested were from 0.60-0.75 kg ai MON 12355/ha and from 0.30-0.50 kg ai safened pretilachlor (Sofit(R) /ha). The window of application ranged from 1-5 days after seeding (DAS) with 3 DAS as the highest application frequency. Crop injury evaluations revealed that MON 12355 was as safe as Sofit. There were no essential differences in efficacy of the three safened butachlor formulations at 0.75 kg ai/ha. At 5% variation, MON 12355 and Sofit had the same degree of weed control against grasses, sedges and broadleaves in the URT's.

INTRODUCTION

Wet sown rice culture is gaining increasing importance in many irrigated and favorable rainfall lowland rice areas. The switch from transplanting to direct seeding is attributed mainly to the scarcity and the increasing cost of labor. With the advent of short duration rice varieties and cost-effective herbicides, this trend is likely to be accelerated.

Weed competition is a more serious problem in wet-seeded rice because the rice and weed seedlings grow simultaneously (Moorthy and Dubey, 1979). The proper use of herbicides offer the best approach for weed control under such situations.

To obtain maximum yields in wet sown rice, precise draining and introduction of irrigation water, good herbicide crop safety and weed control, and optimum fertilization are needed (DeDatta, 1981).

This study was conducted to : a) determine the performance of 3 safened butachlor formulations, b) the interaction of a safened butachlor formulation

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with commonly-grown rice varieties in South East Asia, and c) verify the performance under farmer field situations.

MATERIALS AND METHODS

Comparison of Safened Butachlor Formulations

Trials were conducted in various South East Asian countries in the 1990 wet and dry seasons. Pre-germinated rices were sown at 80-100 kg/ha in 20 m^2 plots replicated three times at each site in an RCB design. The three main KRS (Kawachi Research Station) butachlor/MON 7400 formulations tested at 0.75 kg ai/ha were MON 12355 (600:60 g ai/l EC), MON 12350 (550:55 g ai/l EW) and solventless MON 12320 (800:80 g ai/l SC) along with butachlor EW (0.75 kg ai/ha) and safened pretilachlor (0.50 kg ai/ha). The herbicide treatments were applied at 2-4 DAS (days after seeding) by knapsack sprayer at an application volume of 300-400 l/ha on properly prepared, leveled, seeded and water-saturated soil. At the time of application, temperatures were about 28-30°C, the sedges and broadleaves had 0.5-1 leaf while the rice grasses, sedges and broadleaves had 0.5-1 leaf while the rice seedlings had 0.5-2 leaves. Fertilization and insect control were done as in normal direct seeded rice cultivation practices.

The trials were visually assessed for crop safety at 10 and 20 DAS and for efficacy against grasses, sedges and broadleaves at 20 DAS.

Interaction of Safened Butachlor with Pre-Germinated Puddle-sown Rice Varieties

The following rice varieties in the Philippines, namely: IR-72, BPI Ri 10, IR-74, IR-66, IR-68, Malagkit and Sinantoyong were tested in 1990 for their interaction with safened butachlor. Those tested in Thailand were Supan 60, RD 1, RD 23 and RD 15 while those in Malaysia included MR 84, MR 103, MR 106 and MR 77. Varieties tested in Sri Lanka were BG series 350, 34-8, 34-6, 850, 301, 797, 1165-1, 300, 94-1 and 276-5. Procedures followed were similar to those stated above except that split plot design was used with the rice variety as the main plot while the herbicide treatments 0.75 kg ai Machete EC/ha, 0.75 kg ai MON 12355/ha, 0.50 kg ai Sofit/ha and the untreated as the sub-plots.

Criteria evaluated were % rice crop injury at 10 and 20 DAS as well as weed control efficacy against *Echinochloa, Cyperus* and *Sphenoclea* 40 DAS.

Evaluation or Safened Butachlor in user Reliability Trials

Fifteen user reliability trials were conducted in 1990 in the Philippines, 10 in Thailand, 2 in Sri Lanka and 1 in Malaysia. Application rates tested were

0.60 kg ai safened butachlor (MON 12355)/ha for 11 trials and 0.75 kg ai/ha for 17 trials. Side by side safened pretilachlor treatments were 0.3 kg ai/ha for 15 trials and 0.5 kg ai/ha for 11 trials applied at 2-4 DAS. Safened butachlor application timing were 1 DAS (2 trials), 2 DAS (4), 3 DAS (15), 4 DAS (6) and 5 DAS (1). The treated plot sizes varied from 500-2,000 m^2.

Parameters evaluated were crop injury at 10 and 20 DAS and weed control efficacy against *Echinochloa, Cyperus* and *Sphenoclea* species at 40 DAS.

RESULTS AND DISCUSSION

Comparison of Safened Butachlor Formulation

In the presence of an emulsifier, the three safened butachlor formulations MON 12355, 12350 and 12320 mixed easily with water and sprayed readily on wet sown rice seedlings. At the 10 and 20 DAS observations, the three safened along with water-based butachlor formulations (0.75 kg ai/ha) and the safened pretilachlor (0.50 kg ai/ha) showed no differences in improving crop safety (Figure 1) on pre-germinated puddle-sown rice (0.3-2.8% crop injury). In addition, at 20 DAS, all the tested herbicide dosages provided very good to excellent control (92- 97%) of *Echinochloa glabrescens, Echinochloa crus-galli, Cyperus difformis* and *C. iria*, but not that of *Sphenoclea zeylanica* (48-52 %).

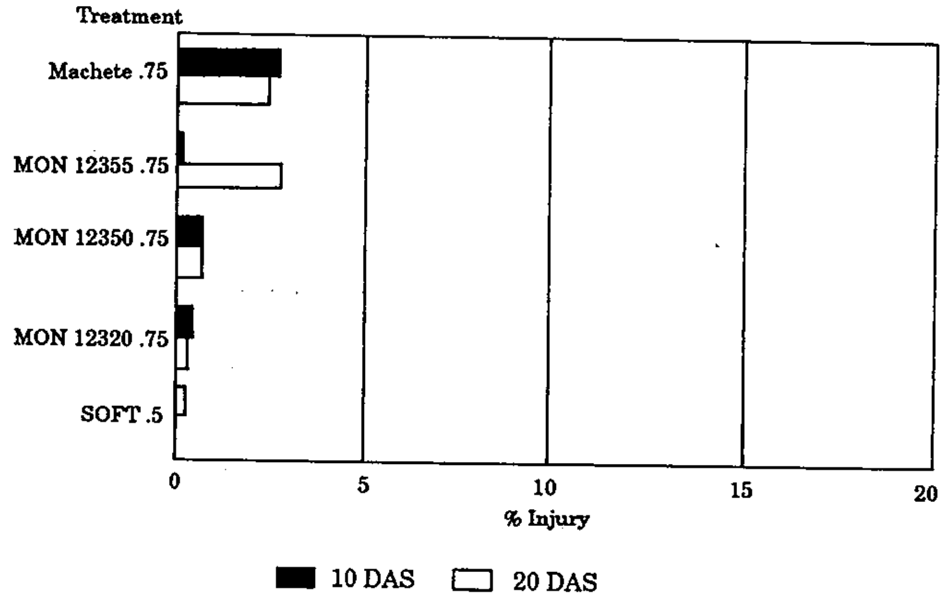

Figure 1. Crop injury of MON 7400/butachlor formulations.

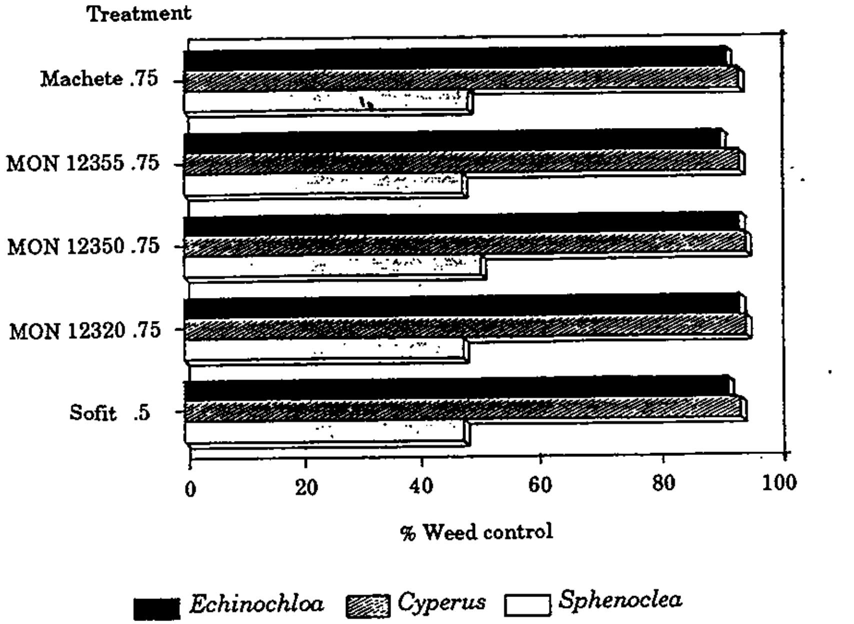

Figure 2. Weed control at 20 DAS of the MON 7400/butachlor formulations.

Interaction of Safened Butachlor with Pre-germinated Puddle-Sown Rice Varieties

Twenty representative rice varieties were analyzed for their interaction with the test herbicides. Results indicated that SEA puddle-sown rices vary in their susceptibility to butachlor, safened butachlor and safened pretilachlor at 10 (Fig. 3) and 20 DAS. At 10 DAS, the rice crop injury due to butachlor EC varied from 0-62%, that from safened butachlor (MO; 12355), from 0-15%, while that from safened pretilachlor (Sofit(R))ranged from 0-30%. The different rice varieties recovered slightly from crop injury at 20 DAS (Fig. 4). Irrespective of variety, the safener MON 7400 in MON 12355 reduced rice seedling injury at 10 DAS from 23.5% to the commercially acceptable level of 4% CI compared with 6% from safened pretilachlor. At 40 DAS, the weed control effi-cacy of the various herbicide treatments were practically similar against *Echinochloa* (97-98%), *Cyperus* spp. (98-99%) and *Sphenoclea zeylanica* (90-92%) (Fig. 5). The trials therefore confirmed that 0.75 kg ai/ha of the safened butachlor formulation provides excellent crop safety and control of the grass and sedge weeds.

Table 4. The efficacy of cinosulfuron under different water management regimes

Water management	Rate g a.i./ha	% Weed control at 56 DAA		Yield (t/ha)
		MON	SCI	
Saturated soil until harvest	0	58*	42*	4.3
	5	97	95	4.4
	7.5	99	97	4.3
	10	100	98	4.8
Saturated soil then normal water 15 days after transplanting	0	57*	43*	4.0
	5	99	99	5.0
	7.5	99	98	4.8
	10	100	100	5.1
1-2 cm water	0	67*	33*	4.2
	5	97	96	4.7
	7.5	99	98	4.6
	10	99	99	4.5
2-5 cm water	0	58*	42*	4.3
	5	99	99	4.5
	7.5	99	100	4.7
	10	100	100	4.8
5-10 cm water	0	65*	35*	4.4
	5	93	92	4.5
	7.5	94	92	4.7
	10	95	96	4.7

* : % weed cover

Effect of Application Method

Cinosulfuron gave excellent crop tolerance with all application methods. No phytotoxicity was observed at 17 days after application. The activity of cinosulfuron applied at 6 days after transplanting was also independent of application method (Table 5). Evaluation at 56 days after transplanting showed excellent efficacy against *Monochoria vaginalis* and *Scirpus juncoides* (> 90% weed control).

Yields from all application methods were similar, giving about a 24% increase over the untreated check. However they were 5-8% lower than in the handweeded check (Table 5).

CONCLUSIONS

Results presented in this paper show that cinosulfuron is an appropriate herbicide product for transplanted rice in Indonesia.

Table 5. The effect of different application methods on efficacy of cinosulfuron

Application methods	Applic. time (DAT)	Rate g a.i./ha	% Weed control at 56 DAA		Yield (t/ha)
			MON	SCI	
Untreated	-	-	60*	40*	4.7
Hand weeding	21 & 24	-	95	95	6.1
Spray 500 l/ha	1	10	96	96	5.8
Spray 500 l/ha	6	10	99	99	5.8
Spray 500 l/ha	6	5	99	93	5.7
Broadcast	6	10	98	93	5.9
Into water	6	10	99	99	5.7
Spray 50 l/ha	6	10	98	99	5.9

* % weed cover

Cinosulfuron applied at a rate of 10 g a.i./ha gave consistently good activity against broadleaved weeds and sedges. Crop safety has also proven to be excellent when the product was applied under a wide range of conditions. Cinosulfuron also allows a great flexibility of application. Efficacy and crop tolerance were excellent, not only when the product was applied by the special sprayboom, but also by knapsack sprayer or even when broadcast after mixing together with sand.

It can therefore be concluded that cinosulfuron, when applied at a rate of 10 g a.i./ha, gave excellent weed control with little phytotoxicity under a wide range of agronomic and application conditions.

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CROP WEED COMPLEXITY

WEED MANAGEMENT PRACTICES FOR WET SEEDED RICE-FIELDS IN MALAYSIA

M. AZMI[1], M.A. SUPAAD[2] AND K. ITOH[3]

ABSTRACT

In Peninsular Malaysia, manual transplanting has been the dominant method of crop establishment in irrigated rice in the past. Since 1980, the trend is to directly seed rice in the main fields. Various direct seeded (D.S.) methods are being practised, namely wet seeded, dry seeded and volunteer seedlings rice cultivation. Insufficient labour and high cost of production are the main reasons why farmers resort to direct seeding practice. The widespread and expanding practice of direct seeding technique had resulted in dramatic changes of the weed spectrum. Poor land preparation and lack of water at the early stage of crop growth leads to the emergence of a wide range of grasses, sedges and broadleaf weeds in the fields. The most competitive and difficult to control were grassy weeds such as *Echinochloa crus-galli* (L.) Beauv., *Leptochloa chinensis* (L.) Nees and *Ischaemum rugosum* Salisb. Losses in yield are high if these weeds are not properly controlled. The presence of *E. crus-galli* alone could reduce yield as high as 41%.

Current weed control practices include both direct and indirect measures depending on farmers resource base, profitability and degree of weed infestation. Effective weed control through integrated weed management (IWM) practices is essential for the success of direct seeded rice production. In IWM, all methods of weed control at least cost are aimed to minimise the weeds at critical period (15-30 days after sowing) in order to obtain optimum yields. Therefore, establishment of alternatives in weed control strategy for D.S. is very important. These strategies include proper land preparation, effective weed control practices, good crop establishment, suitable rice varieties and optimum seeding rate. This is followed by good agronomic practices and proper usage of suitable herbicides. The success of effective weed management practices is dependent upon the adoption by farmers of the systematic weed control strategy and their ability to adapt this technology in accordance with their local field conditions.

INTRODUCTION

The area planted with rice in Peninsular Malaysia is 402,800 ha, producing about 1.7 million tons of rice with self sufficiency in the range of 60-70% (Anon., 1989). Direct seeding (D.S.) had been adopted by farmers in major rice

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growing areas (Muda area, Barat Laut Selangor, Seberang Perai, Seberang Perak and Besut area) embracing at present 35-45% of the total rice area (Figure 1). In Muda area, for example, the area cultivated by direct seeding had increased from 9 ha in the first season of 1977 to 59,407 ha by the first season 1986 (Ho 1988). From 1986 onwards D.S. culture has become the predominant crop establishment in the Muda area.

The main reason of a widespread adoption of D.S. technique is due to high cost of transplanting and seasonal labour shortage during transplanting time. Various direct seeded (D.S.) methods are being practised in this country. Among them are wet seeded, dry seeded and volunteer seedlings rice crop. Direct seeding is mainly by hand broadcasting, and to some extent by drill sowing. In recent years the practice of volunteer growth with minimum tillage to incorporate the shattered seeds of the previous crop was practised by farmers in Muda area. Direct seeding field may produce reasonable yields in the first two seasons after its introduction, but after that yields will be unacceptably low due to severe infestation of weeds and other pests.

Changes in Weed Flora in Rice

The widespread adoption of D.S. had brought a change in weed flora, i.e. from the predominance of broadleaf weeds and sedges in transplanted crop to the more competitive grasses in D.S. crop (Azmi & Supaad, 1986; Ho and Zuki, 1988; Itoh *et al.*, 1990). The grassy weeds found associated with direct seeding were *Echinochloa crus-galli, Leptochloa chinensis, E. colon* and *Ischaemum rugosum*. They usually became conspicuous after several seasons of D.S. In certain in Muda area, *E. stagnina* infestation was also found in D.S. fields (Ho and Itoh, 1990). Therefore, a much wider range and intensity of weed problems can be expected in direct seeded rice than in transplanted rice because of differences in land preparation, the lack of water at the early stage of crop growth, and because weeds germinate at the same time as direct seeded rice.

Weed surveys carried out in all rice granary areas showed that grassy weeds especially *E. crus-galli* was the competitive weed in D.S. areas. For example, the degree of dominance for Muda area was in order of *E. crus-galli* > *L. chinensis* > *Fimbristylis miliacea* > *Scirpus grosus* > *Monochoria vaginalis*. The five most important weeds in most of rice granary areas from results of recent surveys are shown in Table 1.

Two definite varieties or biotypes of barnyard grass exist in rice granary areas in Peninsular Malaysia. The significant difference between the two types are short awned and long awned spikelets. The former has separated type recemes and the latter has closed or compact racemes. A mixture of both biotypes of barnyard grass are usually found in the same plots of D.S. fields.

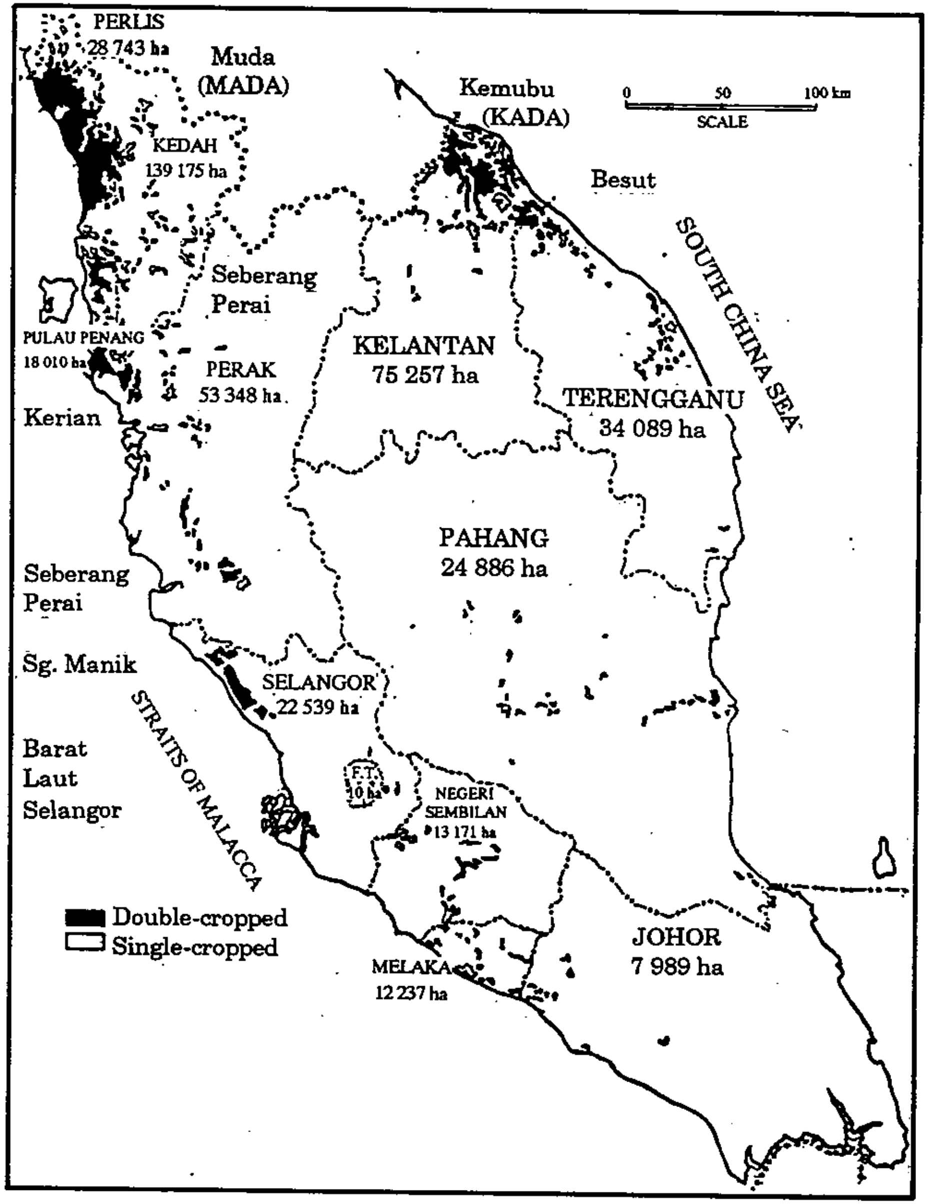

Figure 1. Major rice growing areas in Peninsular Malaysia. (Underlined are direct seeded areas).

Table 1. Major weeds in several rice granary areas in Peninsular Malaysia

Species	Area						
	Muda	Seberang Perai	Kerian/ S. Manik	Seberang Perak	PBLS	Kemubu	Besut
Grass							
Echinochloa crus-galli (L.) Beauv	*	*	*	*	*		*
Echinochloa colona (L.) Link.					*		
Hymenachne pseudointerrupta C. Muell	*					*	*
Ischaemum rugosum Salisb.				*			
Leptochloa chinensis (L.) Nees	*						
Broadleaf weed							
Bacopa rotundifolia (Michx.) Wettst.		*					
Limnocharis flava Buch		*				*	
Lindernia pedunculata Benth.		*				*	
Limnophila aromatica (Lamk.) Merr						*	*
Ludwigia hyssopifolia (G. Don) Exell	*				*		
Monochoria vaginalis (Burm. f) Presl		*	*			*	
Sagitaria guyanensis H.B.K.							*
Salvinia molesta D.S. Mitchell			*				
Sedge							
Cyperus babakan Steud.				*			
Cyperus compactus Retz.				*			
Cyperus iria L.				*			
Fimbristylis miliacea (L.) Vahl			*		*	*	*
Scirpus grossus L.	*		*				
Submerged weed							
Najas graminea (non Del.) Redl.					*		

PBLS = Projek Barat Laut Selangor, * - major weed, Kemubu, Besut & PBLS - 1989 season, Seberang Perak, Seberang Perai & Muda - 1990 season, Kerian & Sg. Manik - 1990/91 season, Sources: Anon. (1989); Azmi and Supaad (1986); Azmi and Anwar (1988); Azmi (1991).

Competitive Ability of *Echinochloa crus-galli*

Itoh *et al*. (1990) have conducted a study on dormancy and germination of the two biotypes of barnyard grass seeds. Both biotypes showed different percentage of germination when their seeds were buried in inundated soil for one to three months (Figure 2). Biotypes with awned/close panicle showed a reduction in the percentage of seeds germinated when the period of burying in inundated soils was extended to three months. On the other hand, untreated seeds of biotype with short awned/open panicle indicated low percentage of germination. When buried in inundated soils, the similar trend of germination was observed. This depicted that the former biotype has no dormancy period and the latter has some degree of dormancy.

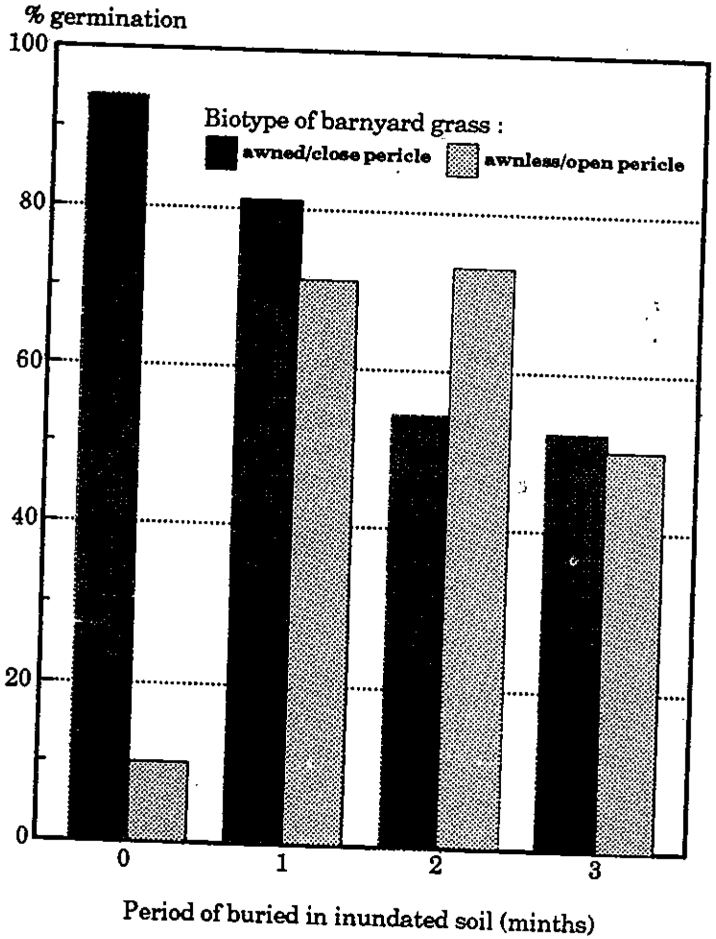

Figure 2. Percentage of germination of barnyard grass seeds after buried in inundated soils

In directseeded rice, the weed germinates in about the same period of time (5 to 6 days). It establishes before the rice is flooded and persists through out the crop season. The first tillers in the field are formed 10 days after emergence. It reproduces and spreads by seeds. Barnyard grass takes 80-95 days to mature and can produce as high as 10,000 seeds per plant (Azmi and Supaad, 1986). Usually, under field conditions, barnyard grass could grow till 1.5-2.0 m in height compared with the popular/modern rice varieties (semi dwarf type) which grows only up to 0.9-1.2 m. In addition, comparisons of various growth stages of this weed and rice plant under field conditions is shown in Table 2.

Table 2. Comparisons of growth stages between barnyard grass and direct seeded rice (Azmi and Mashhor, 1990)

Days after sowing	Stages of growth	
	Rice (MR 71)	Barnyard grass
0 - 3	germinated	germinated
15	3-4 leaves	4-5 leaves
30	tillering	active tillering
45	tillering	booting
60	maximum tillering	heading
75	booting	ripening
90	heading	maturity
120	maturity	

The importance of barnyard grass in reducing rice yields is startling. For example, grassy weeds, mainly barnyard grass, caused severe yield reductions as high as 41% in direct seeded rice. In addition, broadleaf weeds and sedges reduced yields by 28% and 10% respectively (Azmi, 1988).

Crop agronomy packages are commonly developed under weed-free conditions and it is usually assumed that management practices can eliminate all weeds. However, very often residual barnyard grass in the order of 10 plants/m^2 remain. Azmi and Mashhor (1989) reported only 10 barnyard grass/m^2 were required to cause significant yield reduction of about 18.9% (1 ton/ha) equivalent to M$665.94/ha that could justify the usage of proper weed control methods. The data presented in Table 3 and 4 confirm that such populations can depress yields substantially.

Critical Period for Weed Control

A knowledge of weed communities, types, or species growing in association and competition with rice is extremely important in developing an appropriate weed control technology (De Data, 1988). Relevant studies provide information on the potential damage of a weed, like the critical period of weed competition and weed competitive ability against rice and vice versa (Mercado, 1979).

Table 3. The effect of increasing density of *Echinochloa crus-galli* on yield of direct seeded rice (MR 71), main season 1988/1989, Bumbong Lima, Seberang Perai

Weed density (plants/m^2)	Rice yield (kg/ha)	Yield loss per hectare		
		kg/ha	%	Ringgit (M$) value
0	5412	-	None	None
1	5017	395	7.3	260.70
5	4883	529	9.8	349.14
10	4403	1009	18.7	665.94
15	4271	1141	21.1	753.06
25	3893	1519	28.1	1002.54
LSD ($p<0.05$)	498		-	-

Rough rice valued at M$o.66/kg,
Rice density = 16 plants/m^2.
US$1.00 = M$2.70

Table 4. The effect of increasing density of *Echinochloa crus-galli* on yield of direct seeded rice (MR 71), off season 1989, Bumbong Lima, Seberang Perai

Weed density (Plants/m^2)	Rice yield (kg/ha)	Yield loss per hectare		
		kg/ha	%	Ringgit (M$) value
0	5617	-	None	None
5	5128	489	8.7	322.74
10	4500	1117	19.9	737.22
20	4079	1538	27.4	1015.08
40	2809	2808	50.0	1853.28
80	2412	3205	57.1	2115.30
LSD ($p<0.05$)	598	-		-

Rough rice valued at M$0.66/kg,
Rice density = 16 plants/m^2
US$1.00 = M$2.70

Most farmers realise the importance of weeding early in the crop's life cycle without the insight of the critical period and why this is so. According to Woolley *et al*. (1988), the establishment of the critical period of weed interference is an important step in the development of an integrated weed management system. Hence, it is recommended to keep fields free of weeds during the critical period (Moody, 1976; Moenandir, 1985).

The critical period of compettition between *E. crus-galli* and direct seeded rice was found to be from 15 to 30 DAS (Azmi and Mashhor, 1990; Figure 3). The same duration of critical period was observed in direct seeded rice where *E. crus-galli, M. vaginallis, Scirpus juncoides* and *F. miliacea* were the major weeds (Azmi, 1990; Figure 4).

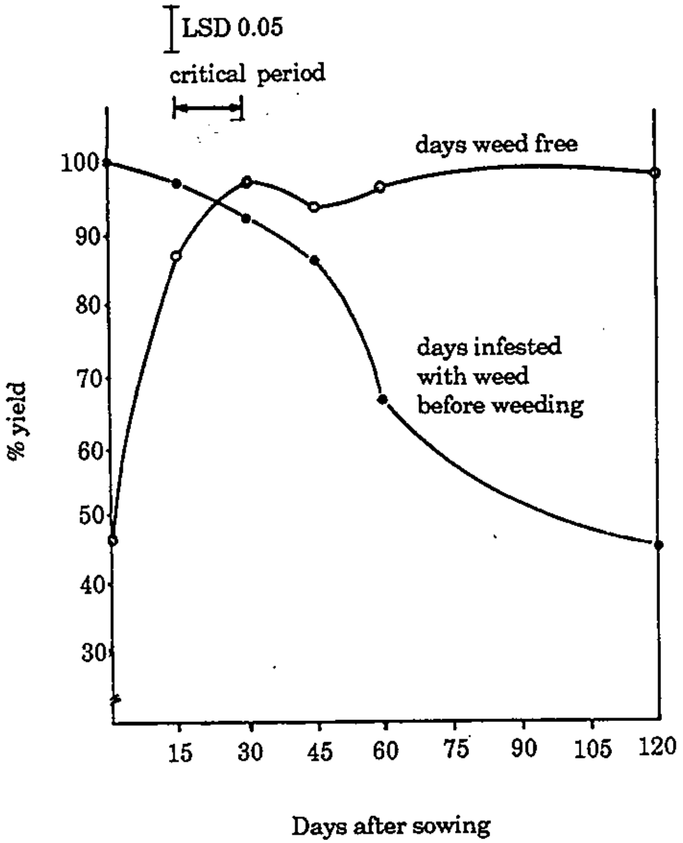

Figure 3. Critical period of competition for barnyard grass in direct seeded rice in main season 1988/89, Seberang Perai

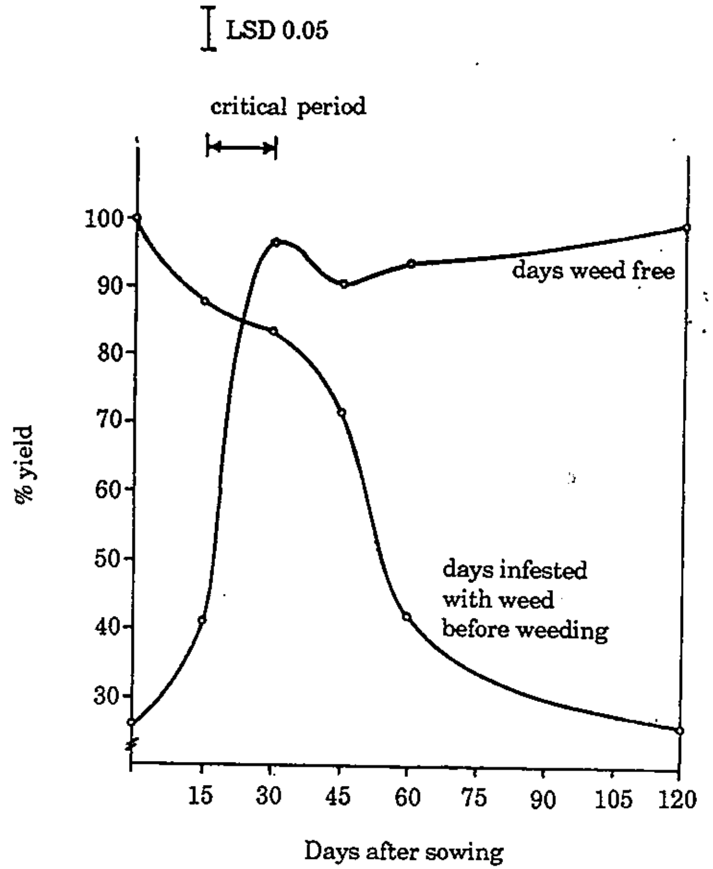

Figure 4. Critical period of weed competition in direct seeded rice in off season 1989, Seberang Perai.

After the critical period is established, the next logical step is to develop an effective and economical weed control program during this period (Wholley *et al.*, 1988).

Integrated Weed Management (IWM)

The most dependable results in weed control in rice are currently achieved by using as many of the various methods of weed control as are feasible in any given situation. For weeds of tropical Asia, developing integrated weed control methods, using limited quantities of low-cost herbicides in combination with direct and indirect weed control techniques, may be a more attractive alternative from agronomic, economic and ecological points of view. However, effective adoption of the IWM is dependent on the farmers' understanding of weeds, familiarity with the technique, experience, and resources (De Datta, 1988). Furthermore, extension effort to educate farmers on the importance of IWM aspects should be carried out.

The main concern in IWM is to use the most appropriate method of control for the conditions. There are several aspects to consider before a control measure can be justified: cost and energy requirements of the methods, potential crop damage by the weeds, possible adverse environmental effects, expected effectiveness and timing of application (Wholley *et al.*, 1988). Among the important aspects in IWM the following could be discussed :

Water Management

The weed suppressing ability of standing water has long been recognized. Therefore, the best weed control is obtained when rice is transplanted in well prepared fields. Flooding prevents growth of most of grassy weeds, but manual weeding or application of herbicides is necessary to control sedges and broadleaf weeds (De Datta *et al.*, 1977).

Water management and levelled field have a considerable effect on the germination and survival of weeds in rice. The deep water of irrigated rice considerably reduces the germination of grasses and sedges but does not limit regrowth of perennial sedges and broadleaf weeds (De Datta *et al.*, 1974; Swarbrick and Mercado, 1987). The survival of grassy weeds is greatly influenced by water depth in the rice field (Table 5). In addition, water maintained at a depth of at least 8 to 10 cm will provide partial control of most barnyard grass biotypes and many other weeds if conditions are favourable for vigorous rice growth (Anon., 1983). Once the weeds are established, they are much more difficult to control with water.

Unavailability of irrigation water and poor water management increase problems with weeds (Smith and Moody, 1979). If manual weeding methods are used, more time is spent on weeding when water control is poor than when controlled water management is available. Uniform and continuous water depth could reduce the severity of weed competition and improve the effectiveness of herbicide.

Severity of weed infestation was also dependent on time of flooding. Anon. (1990) reported early flooding after sowing of rice was found to reduce infestation of some weed species, especially barnyard grass in direct seeded rice (Table 6). However, early flooding to a depth of 5 to 8 cm could suppress the formation of productive tillers and weaken the rice resulting in low rice yields

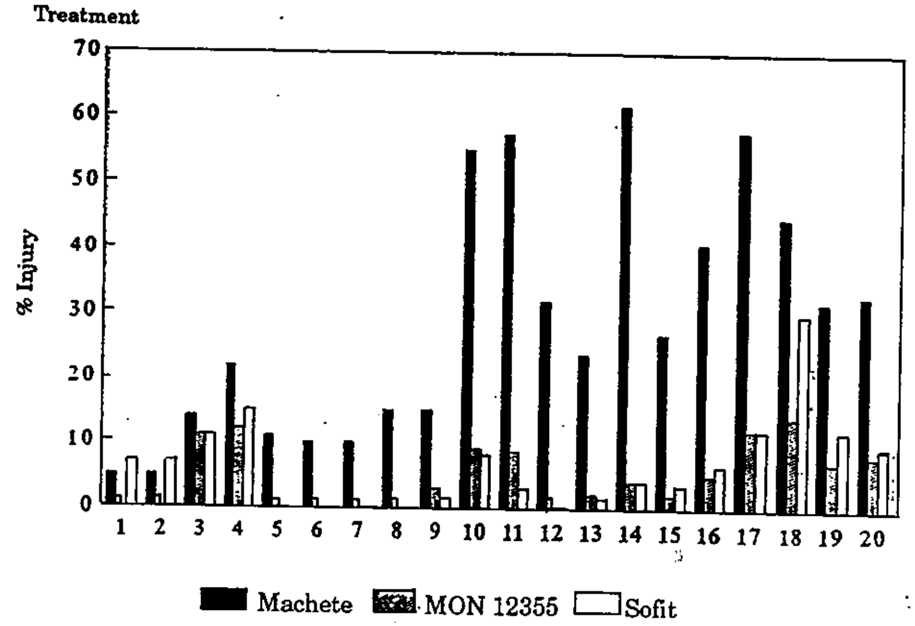

Figure 3. Crop injury on different rice varieties due Machete EC, MON 12355 and Sofit at 10 days after sowing.

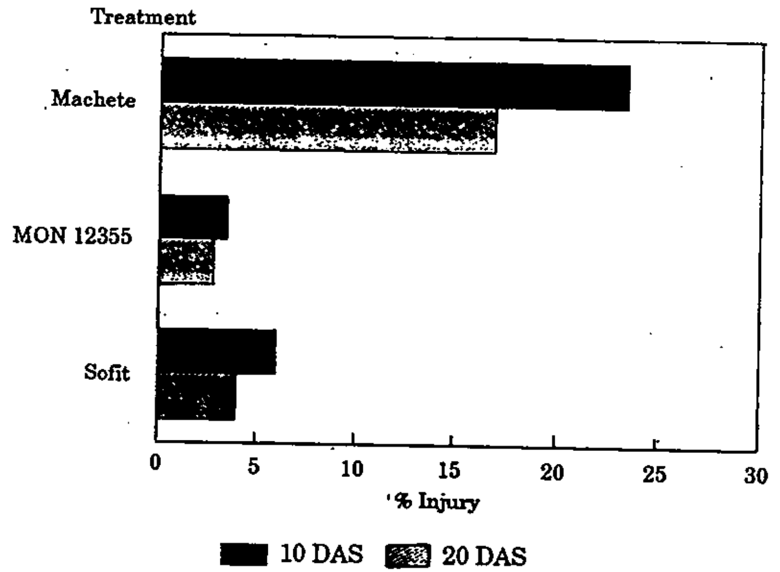

Figure 4. Summarized crop injury due to MON 12355, Machete EC and Sofit on all rice varieties.

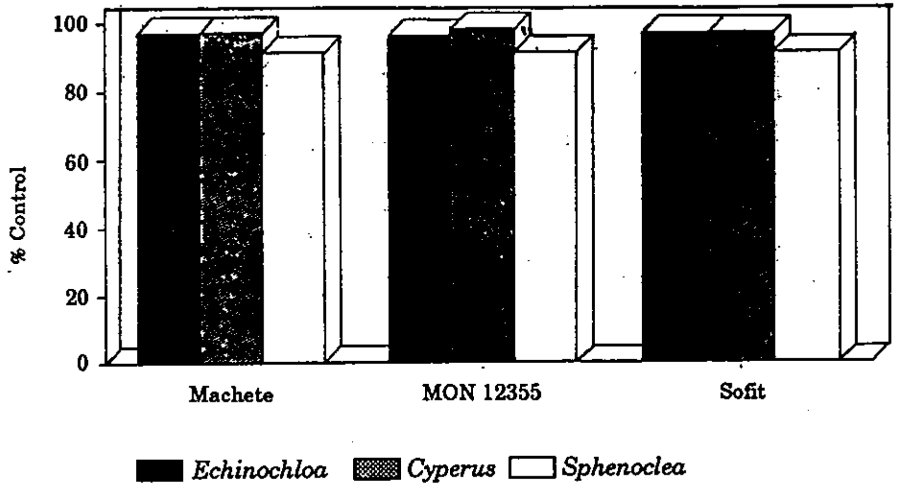

Figure 5. Weed control efficacy of MON 12355, Machete EC and Sofit on all rice varieties at 40 days after seeding.

Performance of Safened Butachlor in User Reliability Trials

Extensive SEA user reliability trials revealed that at + 5% variation, the 0.60-0.75 kg ai MON 12355/ha was almost as safe (0-20% CI) as the 0.30-0.50 kg ai Sofit/ha when applied at the same window of application. On the frequency of occurrence of more than 5% CI, there were 6 times for Sofit and 7 for MON 12355. At > 10% CI, there were 4 incidences for MON 12355 and 1 for Sofit. For efficacy evaluation with ± 5% variation, at 40 DAS, MON 12355 was again just as effective as Sofit in controlling grasses (25 x), sedges (25 x) and broadleaves (22 x). MON 12355 and Sofit were likewise similar in the frequency of grasses, sedges and broadleaf weed control at < 80% and 90%. Moreover, the safety and efficacy performance of MON 12355 were similar to Other safened butachlor formulations at 0.75 kg ai/ha. When queried about grower purchase response for safened butachlor at competitive pricing as Sofit, 21 farmers answered in the affirmative, nobody answered no, while 7 were undecided.

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ABSORPTION, TRANSLOCATION, AND SELECTIVITY OF DITHIOPYR IN RICE AND BARNYARDGRASS

J.Y PYON[1], K.S. KANG[1] AND H.S. RYANG[2]

ABSTRACT

Nutrient culture study was initiated to examine the selectivity of dithiopyr (S,S-dimethyl 2-difluoromethyl)-4-(2-methylpropyl)- 6-(trifluoromethyl)-3,5-pyridine dicarbothiate) in rice (*Oryza sativa* L.) and barnyardgrass (*Echinochloa crus-galli* Beauv.). Absorption and translocation of ^{14}C- dithiopyr in rice and barnyardgrass were also investigated to determine their selective mode of action.

Rice was very tolerant but barnyardgrass was susceptible to dithiopyr. The absorption of dithiopyr was greater in barnyardgrass than in rice and most of them remained in the roots of both species. Dithiopyr was absorbed by roots and basal shoots of both species. Translocation of dithiopyr was very slow and there was no significant difference between the two species.

Therefore, this study suggest that the selectivity of dithiopyr between rice and barnyardgrass may be mainly attributed to the absorption of dithiopyr in plants.

INTRODUCTION

Many annual weeds such as *Echinochloa crus-galli* Beauv. (barnyardgrass), *Monochoria vaginalis* Presl. and *Cyperus difformis* L. are serious weeds in transplanted rice fields in Korea.

Dithiopyr developed by the Monsanto Company is active to most annual weeds, especially barnyardgrass and *M. vaginalis* with very low dosage. Control of barnyardgrass was obtained at 0.06 kg ai./ha with preemergence application and dithiopyr showed long persistence with longevity of 70 days (Fijayama *et al.* 1987; Ryang *et al.*, 1989). This herbicide was safe on transplanted rice and acceptable rice safety was obtained at recommended rate. Ryang *et al.*, (1989) reported that transplanted rice was safe to dithiopyr at rate of 0.48 kg/ha. Rice treated had good safety at shallow transplanting if the basal stem of rice was in the soil (Fijuyama *et al.*, 1987).

Dithiopyr showed insufficient control efficacy to paddy perennial weeds and hence mixture treatments with sulfonylurea herbicides were developed. The mixture application of dithiopyr with bensulfuron-methyl or pyrazosulfuron-ethyl showed good control of major annual and perennial weeds (Fujiyama *et al.*, 1987).

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The mode of mechanism of dithiopyr has not been understood yet, but Molin *et al.* (1988) reported that dithiopyr inhibited cell division in prometaphase and reduced spindle microtubules in dividing cells and thus altered regulation of tubulin polymerization.

The objectives of this study were to examine the differential selectivity of dithiopyr in rice and barnyardgrass and to determine the selective mode of action of dithiopyr by absorption and translocation of ^{14}C-dithiopyr in both species.

MATERIALS AND METHODS

Plants. To evaluate the selectivity of dithiopyr between rice and weed, rice cultivar Chuchung (*Oryza sativa* L. cv. Chuchung) and barnyardgrass were used. To compare growth respone of plants to dithiopyr, seedlings of the two species were grown in Kasugai nutrient solution until 2 and 4 leaf stage in the growth chamber (25/20°C, day/night). Roots of rice and barnyardgrass seedlings were treated to dithiopyr at the rate of 10^{-8}, 5×10^{-7}, 10^{-7}, 5×10^{-7}, 10^{-6} M for 10 days and than transferred to the Kasugai nutrient solution and grown for 4 days. Dry weight of roots and shoots was measured after plant harvest. Each treatment was replicated 3 times using 3 plants for each replication.

Absorption and translocation. For absorption and translocation study, ^{14}C-dithiopyr supplied by the Monsanto Company was used, which was pyridine ring-labelled with a specific activity of 72.5 μci/mg. Plants were cultured and treated as previously described. Roots or roots + 3 cm basal shoots of rice and barnyardgrass seedlings (2 leaf stage) were exposed to 500 ml of ^{14}C-dithiopyr at 5×10^{-7} M for 6, 12, 24, and 48 hours. Plants were removed, and roots were throughly washed with distilled water and acetone solution and were blotted dry. The plants were sectioned into shoots and roots; dried at 90°C oven for 24 hours; then weighed. Plants were combusted by the sample combustion system (Packard Tri-carb 306) and the radioactivity was quantified by the liquid scintillation spectrometer (Packard Tri-carb 2000) with correction for quenching. The translocation rate was calculated by the ratio of radioactivity in the shoots to that in the whole plants. Each treatment was replicated 3 times using 2 plants.

RESULTS AND DISCUSSION

Selectivity of dithiopyr. By nutrient culture test as shown in Tables 1 and 2, dry weight of rice and barnyardgrass was decreased as dithiopyr concentrations increased. However, this tendency was more remarkable in barnyardgrass than in rice. Dry weight of rice shoots at 4 leaf stage started to reduce at 10^{-7} M, whereas that of barnyardgrass at 5×10^{-8} M. In roots, dry weight of rice was reduced at 5×10^{-8} M or above and barnyardgrass at 10^{-8} M or above. Root growth of rice and barnyardgrass was more greatly inhibited by dithiopyr treatment compared to the shoots of both species. Growth of rice and barnyardgrass was more significantly inhibited at 2 leaf stage than at 4 leaf stage. Shoots of 4 leaf rice seedlings were slightly inhibited by dithiopyr, but roots of barnyardgrass were greatly inhibited at lower concentrations of dithiopyr. Therefore, these data indicated that rice was very tolerant to dithiopyr, whereas barnyardgrass was susceptible to dithiopyr.

Table 1. Dry weight of rice plants and barnyardgrass at 2-leaf stage as affected by dithiopyr treatment under nutrient solution culture

Dithiopyr conc. (M)	Dry weight (mg/plant)*			
	Rice		Barnyardgrass	
	Shoot	Root	Shoot	Root
Control	59.6 a	26.2 a	65.1 a	52.0 a
1×10^{-8}	56.0 a	18.1 b	59.6 a	31.9 a
5×10^{-8}	44.4 b	11.4 c	52.9 b	7.8 c
1×10^{-7}	33.1 c	10.3 c	45.5 c	4.9 c
5×10^{-7}	29.6 c	8.1 d	20.4 d	3.5 c
1×10^{-6}	27.8 c	7.4 d	19.6 d	3.6 c

* Means within a column followed by the same letter are not significantly different at the 5% level by the Duncan's multiple range test.

Table 2. Dry weight of rice plants and barnyardgrass at 4-leaf stage as affected by dithiopyr treatment under nutrient solution culture

Dithiopyr conc. (M)	Dry weight (mg/plant)*			
	Rice		Barnyardgrass	
	Shoot	Root	Shoot	Root
Control	102.8 a	50.1 a	98.4 a	115.6 a
1×10^{-8}	100.3 a	45.6 a	96.8 a	74.8 b
5×10^{-8}	96.2 ab	31.9 b	88.8 b	62.0 c
1×10^{-7}	92.5 b	28.8 b	85.4 b	51.9 cd
5×10^{-7}	83.0 c	27.0 b	84.0 b	47.1 d
1×10^{-6}	80.3 c	26.5 b	71.1 c	45.0 d

* Means within a column followed by the same letter are not significantly different at the 5% level by the Duncan's multiple range test.

Absorption and translocation of dithiopyr. As exposure time was extended from 6 to 48 hours, the amounts of ^{14}C-dithiopyr absorption was increased in rice and barnyardgrass (Table 3). Rice absorbed higher amounts of dithiopyr from 24 hours after treatment but barnyardgrass from 12 hours after treatment. The absorption amounts of ^{14}C-dithiopyr was greater in barnyardgrass than in rice and most of them remained in the roots of both species. Absorption of dithiopyr was also affected by sites of absorption in plants. Higher amounts of dithiopyr absorption was recognized in the root + 3 cm basal shoot treatment than in the root treatment alone and this trend was more remarkable in rice. Therefore, these results indicated that dithiopyr was absorbed by not only roots but also basal shoots in both species.

Table 3. Distribution of 14C activity in rice and barnyardgrass as affected by 14C-dithiopyr application time and sites of absorption

Site of Absorp.	Appli. time (hr)	^{14}C-distribution (dpm/mg)*			
		Rice		Barnyardgrass	
		Shoot	Root	Shoot	Root
Root	6	14.2 e	767.8 bc	18.3 f	995.8 c
	12	16.1 e	864.5 bc	18.6 cf	1020.4 c
	24	30.3 d	996.3 abc	27.3 e	1118.8 bc
	48	58.9 b	1113.8 ab	69.9 b	1198.5 ab
Root	6	31.1 d	855.2 bc	50.9 d	1029.2 c
+	12	34.8 d	876.4 bc	50.8 d	1097.7 bc
Shoot	24	46.6 c	1069.9 ab	58.8 c	1229.6 ab
(3 cm)	48	90.3 a	1314.5 a	116.0 a	1309.4 a

* Means within a column followed by the same letter are not significantly different at the 5% level by the Duncan's multiple range test.

Translocation rate of dithiopyr was extremely low in both species (Table 4). Translocation rate after 48 hours treatment was only 5.02% and 5.51% in rice and barnyardgrass, respectively. Since the difference of translocation between two species was also very negligible, these results suggested that translocation could not be attributed to species selectivity of dithiopyr.

Consequently, it may be concluded that difference in selectivity of dithiopyr between rice and barnyardgrass was mainly related to the absorption amounts of dithiopyr in plants.

Table 4. Translocation rate of ^{14}C-dithiopyr (5×10^{-7} M) from the roots to the shoots in rice and barnyardgrass

Species	Exposure time (hr)^z			
	6	12	24	48
	(%)			
Rice	1.82	1.83	2.95	5.02
Barnyardgrass	1.80	1.80	2.38	5.51

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EVALUATION OF NEW HERBICIDES FOR GENERAL WEED CONTROL IN OIL PALM

KHAIRUDIN HASHIM[1] AND TEOH CHENG HAI[1]

ABSTRACT

A general weed control trial established in collaboration with 16 agrochemical companies in a two-year-old oil palm planting compared the cost-effectiveness of 32 herbicide treatments and an estatate standard commercial treatment of a tank mix of paraquat (560 g a.i./ha) and diuron (560 g a.i./ha). Results from 36 months evaluation identified eight treatments which are more cost-effective than the standard estate treatment. These included combinations of glyphosate (504 g - 540 g a.i./ha) with dicamba (240 g a.i/ha) metsulfuron methyl 15 g and 20 g a.i./ha) and fluroxypyr (50 g a.i./ha; the most cost-effective was a pre-mixed formulation of dicamba and glyphosate (810 g a.i./ha). Three paraquat-based treatments were more cost-effective than the estate standard, of which a pre-mixed formulation of paraquat diuron (1000 g a.i./ha) was the second best treatment in the trial.

Under the conditions of the trial where herbicide spraying was closely supervised, no phytotoxicity symptoms were observed in any of the herbicides. Regular inspection of oil palm bunches during the initial 15 months showed no evidence of herbicide-induced development of parthenocarpic fruits.

The composition of the regenerating weed flora was influenced by the herbicide treatments. Application of glyphosate in combination with dicamba and fluroxypyr apparently encouraged emergence of broadleaf weeds such as *Borreria latifolia* Schum. and *Ageratum conyzoides* Linn. However, glyphosate in combination with metsulfuron encouraged *Axonopus compressus* (Sw.) P. Beauv. In contrast, the paraquat + diuron treatment had high proportion of *Paspalum conjugatum* Bergg. and legume covers. The succeeding vegetation from all treatment did not pose any problems in weed management and they could be controlled by the present range of herbicides.

INTRODUCTION

In order to verify the recommendations and claims by agrochemical companies on the performance on new products introduced into the Malaysia market, Golden Hope Plantations Berhad periodically organised collaborative trials with agrochemical companies to assess the new herbicides for their cost effectiveness and crop safety under common test sites and trial conditions. Selection of representative trial sites, herbicide spraying and assessment on weed control and effects on crop performance are undertaken by our R & D

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personnel while herbicide treatments considered most appropriate for the selected trial site would be nominated by the participating companies.

This paper summarises the results of a collaborative trail with 16 agrochemical companies to compare the cost-effectiveness of 32 herbicide treatments for general weed control in a 1985 oil palm planting in June 1987. Coded compounds which are promising and likely to be marketted have also been included in this trial. The treatments were also screened for any phytotoxic effects to oil palms, particularly in respect of possible development of parthenocarpy.

MATERIAL AND METHODS

Trial Site

The trial area was a 1985 oil palm planting which at the time of commencement had the following vegetation in descending order of dominance.

Leguminous cover crops (LCC), *Paspalum conjugatum, Ottochloa nodosa* (Kunth) Dandy, *Mikania micrantha* H.B.K. LCC comprising of *Pueraria phaseoloides* (Roxb.) Benth. (syn. *P. javanica* Benth.) Heinsl. and *Calopogonium caeruleum* Heinsl. which were planted as a routine agricultural practice was the dominant vegetation, amounting for 80-90% of the ground cover in plots in Replicates I and II and 50 to 60% in Replicate III.

The shade provided by the oil palm were between 0% to 30% in the first 15 months and exceeded 30% from 16 to 36 months.

Treatments

Thirty two herbicide treatments nominated by the participating companies i.e. two treatments per company were compared with the estate standard treatment, details of which are given in Table 1. The treatments were tested in three replicates in a randomised complete block design. Each plot had two rows of six palms each.

Before trials comencement, a detailed assessment of weed coverage and composition was undertaken and all plots were inspected jointly by representatives of participating companies. Plots considered atypical were discarded.

Herbicide Application

Herbicide treatments were applied by estate workers using the "Solo" knapsack sprayers. The lances were fitted with a 9508E fan nozzle to deliver a spray solution at a volume rate of 400 litres per blanket hectare. Herbicides were applied over 1.2 m wide swathe in harvesting paths and 1.8 m radius

Table 1. Cost-effectiveness ranking of 33 herbicide treatments over 36 months

Ranking	Treatment	Rate/ha	Active ingredients	No. rounds sprayed	Duration of contro (weeks)	Weed control/round (weeks/round)	Cost/ha/week (cents)#
1	Wallop	810 g a.e.	glyphosate + dicamba	11	132.7	12.1	135
2*	Paracol	1000 g a.i.	paraquat + diuron	12	123.2	10.3	142
3	Roundup + Ally 20DF	540 g a.e. + 15 ga.i.	glyphosate + metsulfuron-methyl	10	126.2	12.6	166
4	Roundup + Starane 200	504 g a.e. + 50 g a.e.	glyphosate fluroxypyr	13	102.1	7.9	170
5*	Checkthru + Banvel 400	1120 g a.i. + 200 g a.e.	paraquat + diruon dicamba	10	112.1	11.2	173
6	Roundup + Banvel 400	360 g a.e. + 240 g a.e.	glyphosate dicamba	10	107.7	10.8	176
7	Roundup + Ally 20DF	540 g a.e. + 20 g a.i.	glyphosate metsulfuron-methyl	10	116.7	11.7	180
8	Harquat + Gesapax 500 FW	280 g a.i. + 700 g a.i.	paraquat + ametryne	14	101.1	7.7	200
Estate Standard*	Harquat + Diuron 80WP	560 g a.i. + 560 kg a.i	paraquat + diuron	13	100.4	7.7	200
10*	Paracol + Banvel	1000 g a.i. + 200 g a.e.	(paraquat + diuron) + dicamba	12	105.8	8.8	202
11*	Anuron + Banvel	900 g a.i. + 200 g a.e.	(paraquat + diuron) + dicamba	12	99.6	8.3	203
12	Harquat + Dasaflo	700 g a.i. + 75 g a.i.	paraquat (DSMA + diuron + 2,4-D Na)	13	107.4	8.2	213
13	Roundup + Starane 200	504 g a.e. + 75 g a.e.	glyphosate + fluroxypyr	12	103.8	8.7	214
14	Anuron	1120 g a.i.	paraquat + diuron	13	92.7	7.1	216
15	Basta + Dasaflo	200 g a.i. + 1390 g a.i.	glufosinate-ammonium + (DSMA + diuron + 2,4-D Na)	11	88.2	8.0	224
16	Harquat + Duomix 700	280 g a.i. + 4340 g a.i	paraquat + (DSMA + diuron)	15	120.6	8.0	229
17	Weedaway + Diuron 80WP	633 g a.i. + 500 g a.i.	paraquat + diuron	15	94.6	6.4	240
18*	Paraxone	860 g a.i.	paraquat + sodium chlorate	17	79.4	4.7	243
19	Basta + Dasaflo	300 g a.i. + 1390 g a.i.	glufosinate-ammonium + (DSMA + diuron + 2,4-D Na)	11	87.7	8.0	253
20	Harquat + Despa 810	300 g a.i. + 4170 g a.i.	paraquat + (DSMA + diuron + 2,4-D Na)	12	90.6	7.6	269
21*	Strike + Free-flo	1444 g a.i. + 435 g a.i.	paraquat + MSMA diuron	13	85.9	6.6	290
22*	Harquat + Checkmate	340 g a.i. + 1499 g a.i.	paraquat + (MSMA + diuron)	13	103.3	7.9	316
23	Weedaway + Basta	253 g a.i. + 400 g a.i.	paraquat + glufosinate-ammonium	16	95.8	6.0	342
24	MON 8783	3.0 l	N.A.	11	122.1	11.1	N.A.
25	ACM 325, 327	4.0 l	N.A.	11	102.6	9.3	N.A.
26	GS 13529 + Roundup	2.0 l 360 g a.e.	N.A. + paraquat	10	89.8	9.0	N.A.
27	URN 456 + Paraquat Special	2.5 l 450 g a.i.	N.A. + paraquat	13	109.7	8.4	N.A.
28	SDZ 03 + Harquat	3.7 l 300 g a.i.	N.A. + paraquat	12	91.9	7.7	N.A.
29	FSAN 02 + Goldquat Extra	4.2 l 200 g a.i.	N.A. + paraquat	14	107.0	7.6	N.A.
30	ACM 315, 301	3.0 l	N.A.	12	87.2	7.3	N.A.
31	SDZ 07	5.2 l	N.A.	12	85.8	7.2	N.A.
32	TK 6200 + Harquat	4.0 l 300 kg a.i.	N.A. + paraquat	13	87.3	6.7	N.A.
33	SIR 1250 Paraquat Special	0.44 l 504 g a.i.	N.A. + paraquat	17	91.4	5.4	N.A.

@ commercial formulations applied as components and litres of herbicide formulations for coded compounds.
# including adjuvants and modification made to treatments.
* The same treatments used throughout the duration of evaluation, others involved some form of modifications.
Assumptions : Sprayed ha is equivalent to 25% Field ha. ---------- Labour for application at $6.00 per ha per round.

palm circles. The first application round was done in June 1987 and herbicide treatments were reapplied whenever weed regeneration and/or encroachment in the harvesting paths exceeded 70%, based on the average of the three replications. The palm circles were resprayed whenever the harvesting paths of a particular herbicide treatment was resprayed. This was to provide adequate herbicide dosage for crop safety assessment.

Although it was desirable to maintain the same herbicide throughout the duration of the trial, participants were permitted to modify their herbicide treatments and application rates to meet significant changes in weed flora.

The trial was terminated in May 1990, 36 months after commencement.

Assessment of Treatment Effects

Weed control and weed succession

Two quadrats measuring 1.2 x 2 m each were taken along the harvesting paths for assessment of weed control and weed succession. Assessments were made at between four to six weeks intervals throughout the trial period. Weed control was based on the visual assessment on the kill of the foliage and shoots while for weed succession, the percentage composition of weed regrowth whithin each quadrat was recorded.

Incidence of parthenocarpy

Four palms in the centre of every plot were marked for assessment on the incidence of parthenocarpy. Female inflorescence produced on these palms were assessed at three-monthly intervals for presence of fused or closed stigma which was an indication of parthenocarpic fruit developments. This assessment was discontinued after the 15th month from trial commencement when no parthenocarpy development was observed.

Computation of cost-effectiveness

The average cost per ha per week was calculated to facilitate the ranking of cost-effectiveness of the herbicide treatment. This was obtained by dividing the cumulative costs for herbicide applications by the cumulative duration (in weeks) of effective weed control. The effective weed control period refers to the interval between herbicide application or respraying and the time duration when 70% weed regeneration and/or encroachment was recorded. The cost of chemicals used are shown in Appendix 1. Comparison on cost-effectiveness was confined to 23 herbicide treatments as prices of coded compounds were not available.

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RESULTS

Efficacy of Herbicide Treatments

Results on the efficacy of herbicide treatments evaluated are shown in Table 1 which include the cost per ha per week for the 23 herbicide mixtures commercially marketted. For coded compounds only the bioefficacy data (weeks of weed control per round) are provided.

The 23 herbicide treatments can be classified into three groupings viz. glyphosate-based, paraquat-based and ammonium glufosinate-based. Their representations were six, fifteen and two respectively. Eight treatments were more cost-effective than the "estate standard" of tank-mixed paraquat + diuron. Five of these were glyphosate-based viz. glyphosate in combination with dicamba (ranked 1st and 6th), metsulfuron-methyl (3rd and 7th), fluroxypyr (4th). Another three were paraquat-based viz. pre- mixed formulation of paraquat + diuron (2nd), paraquat + diuron + dicamba (5th) and paraquat + ametryne (8th).

Among the eight most cost-effective treatments, six of them were modified during the course of the trial to cope with changes in shade regime and weed flora. Details on changes made are provided in Table 2.

Table 2. Changes made to the eight most cost-effective herbicide treatments

Ranking	Treatment	Particulars of Modifications
1	glyphosate + dicamb	The rate of this pre-mixed formulation was lowered from 810 g to 540 g a.e./ha from the 9th application.
3	glyphosate + metsulfuron-methyl	The rate of glyphosate was lowered from 540 g to 360 g a.e./ha and metsulfuron-methyl from 15 g to 10 g a.i./ha from the 10th application.
4	glyphosate + fluroxypyr	Only the fluroxypyr component at 100 g a.e./ha was applied at the 2nd, 3rd and 9th applications. The rate of glyphosate was reduced from 504 g to 360 g a.e./ha from the 12th application.
6	glyphosate + ducamba	The rate of glyphosate was decreased from 540 g to 216 g a.e./ha and dicamba increased from 240 g a.e. to 400 g a.e./ha on the 3 rd application. The rate of glyphosate was increased to 360 g a.e./ha from the 4th application. The rate of dicamba decreased to 200 g a.e./ha from the 8th application.
7	glyphosate + metsulfuron-methyl	The rate of metsulfuron- methyl was lowered from 20 g to 10 g a.i./ha from the 8th application and the rate of glyphosate was lowered from 540 g to 360 g a.e./ha from the 10th applicatio.
8	paraquat ++ ametryne	Only glyphosate was applied at 360 g a.e./ha as the 14th application.

Another 14 treatments evaluated were less cost-effective than the estate standard. They consisted of a glyphosate + fluroxypyr treatment (13th), DSMA + diuron + 2,4-D Na salt in combination with glufosinate ammonium at 200 g a.i./ha (15th) and at 300 g a.i./ha (19th) and 11 paraquat based mixtures. Being in the less cost-effective rankings, some were subjected to modifications to imrpove their efficacies.

Ten coded compounds were among the treatments evaluated. As costs and active ingredients were not available, comparison could be made in terms of bioefficacy only. ACM 325, 327, (3.0 l/ha), MON 8783 (4.0 l/ha) and GS 13529 (2.0 l/ha) + glyphosate (360 g a.e./ha) were outstanding in term of weeks of weed control per spraying round.

Safety of Herbicide Treatments

During the trial, observations on health of palms were made and no phytotoxicity on palm characters were recorded. Observations on parthenocarpy based on development for fused or close stigma were also made at three-monthly intervals and discontinued after between five to seven rounds of herbicide application when none were recorded.

Weed Succession in Relation to Herbicide Treatments

The weed composition in the 23 herbicide treatments based on the average of three replicates at termination (i.e. 36 months) are given in Table 3. There was a general shift in vegetation from a predominance of legume covers to a composition of broader spectrum of weeds. Three major factors contributing for these changes were the increasing shade as the palms grow, the types of herbicide mixtures employed and reservoir of weed seeds in the ground.

In general, glyphosate + dicamba treatments had encouraged growth of *P. conjugatum*, *Borreria latifolia* or *Ageratum conyzoides*; glyphosate + fluroxypyr treatments had encouraged growth of *P. conjugatum*, *B. latifolia* and legume covers; and glyphosate + metsulfuron-methyl had encouraged *Axonopus compressus* and legume covers. In comparison, the paraquat + diuron treatments had encouraged growth of *P. conjugatum* and legume covers. The paraquat + diuron + dicamba treatments were less consistent as the dominant vegetation could be *P. conjugatum*, in combination with either *A. compressus* or *B. latifolia* or legume covers. For the paraquat + ametryne treatment the succeeding population comprised *P. conjugatum* and to a lesser extent *M. micrantha* and legume covers.

As for the remaining five paraquat-based and two ammonium glyfosinate-based treatments, *P. conjugatum* emerged as the dominant succeeding vegetation. Further interpretation beyond this is avoided as these less cost-effective treatments and involved considerable modifications and may not be reflective of herbicides indicated.

Table 3. Weed species found in 23 herbicide treatments at termination of the trial

Treatment	Rate/ha (a.e. or a.i.)	Treatment # ranking	Weed composition (% coverage)							
			LCC	PC	ON	MM	BL	AgC	Ac	Others
glyphosate + dicamba	810 g a.e.	1	9	24	12	0	36	1	13	5
	360 g a.e. + 240 g a.e.	6	5	22	8	3	7	25	8	22
glyphosate + fluroxypyr	504 g a.e. + 50 g a.e.	4	20	4	0	5	71	0	0	0
	504 g a.e. + 75 g a.e.	13	25	18	0	0	23	0	13	21
glyphosate + metsullfuron-methyl	504 g a.e. + 15 g a.i.	3	17	25	3	0	7	0	33	15
	504 g a.e. + 20 g a.i.	7	27	25	5	1	0	0	10	32
paraquat + diuron	100 g a.i.	2	30	38	0	5	22	0	3	2
	560 g a.i. + 560 g a.i.	9	38	38	0	8	5	0	0	11
	120 g a.i.	14	51	31	0	1	14	0	0	3
	633 g a.i. + 500 g a.i.	17	12	32	0	5	5	5	0	41
(paraquat + diuron) + dicamba	1120 g a.i. + 200 g a.e.	5	10	28	15	2	2	0	22	21
	1000 g a.i. + 200 g a.e.	10	3	49	2	0	43	0	0	3
	900 g a.i. + 200 g a.e.	11	46	42	2	3	0	0	0	7
paraquat + ametryne	280 g a.i. + 700 g a.i.	8	17	47	0	15	8	0	5	8
paraquat + DSMA + diuron + 2,4-D Na	700 g a.i. + 1043 g a.i.	12	15	30	28	8	0	0	5	14
	300 g a.i. + 4170 g a.i.	20	7	43	8	15	0	22	0	5
paraquat + DSMA + diuron	280 g a.i. + 4340 g a.i.	16	0	45	15	7	25	0	2	6
paraquat + MSMA + diuron	1444 g a.i. + 435 g a.i.	21	12	38	27	3	5	0	0	15
	340 g a.i. + 1499 g a.i.	22	10	0	12	0	14	0	3	61
paraquat + sodium chlorate	860 g a.i.	18	12	32	0	5	5	5	0	41
paraquat + glufosinate _NH4	253 g a.i. + 400 g a.i.	23	2	57	0	2	2	3	0	34
glufosinate-NH + DSMA + diuron + 2,4-D Na	200 g a.i. + 1390 g a.i.	15	0	47	3	2	6	8	9	25
	300 g a.i. + 1390 g a.i.	19	0	39	0	19	0	3	2	37

* percentage weed composition based on average of three replicates.
LCC = Legume covers; PC = *Paspalum conjugatum*; ON = *Ottochloa nodosa*;
MM = *Mikania micrantha*; BL = *Borreria latifolia*; Ac = *Axonopus compressus*
AgC = *Ageratum conyzoides*;
\# Trade names of herbicide treatments as per Table 1

DISCUSSION

The results of the general weed control trial on oil palm over 36 months showed that there are several cost-effective herbicides as compared to the estate standard treatment of tank-mix paraquat + diuron. However, it should be borne in mind that these results apply to field conditions that are considered generally representative of Golden Hope estates. In this trial, the estate standard treatment of paraquat + diuron was employed because it was proven to be the most cost-effective treatment from previous trials (Teoh *et al.*, 1977 and Khairudin *et al.*, 1981) and since has been widely used on states (Teoh, 1985).

Although the estate standard treatment ranked 9th, the pre-mixed commercial formulation with the same active ingredients was placed 2nd. It was felt that the tendency of the diuron component to settle out from the tank-mixes of paraquat + diuron treatment had resulted in its inferior performance compared with the pre-mixed commercial formulation.

The 33 herbicide treatments evaluated were not phytotoxic to oil palm and they did not cause parthenocarpy. Although herbicides such as dicamba and fluroxypyr could induce parthenocarpic fruits when they come into direct contact with female inflorenscence (Khairudin and Teoh, 1987) there was no apparent root upake leading to parthenocarphy when herbicides were applied to palm circles at the recommended rates under supervised application.

The use of herbicides such as dicamba, fluroxypyr and metsulfuron methyl in combination with glyphosate had resulted in weed succession that was different from that of paraquat-based mixtures. The first two with glyphosate have encouraged emergence of broadleaf weeds such as *B. latifolia* and *A. conyzoides* while metsulfuron-methyl with glyphosate encouraged emergence of *A. compressus*. However, these weeds did not pose any problems as they could be easily control by either components of the above treatments.

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Appendix 1. Prices of herbicides (as in April 1990)

Herbicide	Active ingredients	Nett Price* (M$)	Packing	Company
ACM 315, 301	N.A.	N.A.	N.A.	N.A. ACM
ACM 325, 227	N.A.	N.A.	N.A.	ACM
Ally 20DF	metsulfuron-methyl (200 g a.i./kg)	230.00/kg	200 g	Du Pont
Anuron	paraquat (200 g a.i/l) + diuron (200 g a.i./l)	13.40	4 l	Ancom
Banvel 400	dicamba (400 g a.e./l)	26.25	4 l	F.E Zuellig
Basta	glufosinate-ammonium (200 g a.i./l)	22.50	4 l	Hoechst
Checkmate	MSMA (28%) + diruon (12.5%)	16.75	4 l	Harrisons & Crosfield
Checkthru	paraquat (200 g a.i./l) + diuron (200 g a.i./l)	14.50	4 l	Harrisons & Crosfield
Dasaflo	DSMA (53.2%) + diuron (4.5%) + 2,4-D Na (11.8%)	9.13	4 l	Ancom
Dasatox 325	DSMA (53.2% + diuron (4.5%) + 2,4-D Na (11.8%)	6.20/kg	25 kg	Ancom
Despa 810	DSMA (53.2%) + diuron (4.5%) + 2,4-D Na (11.8%)	6.20/kg	25 kg	Hif-Tech
Diuron 80WP	diuron (800 g a.i./kg)	20.00/kg	25 kg	F.E. Zuellig
Duomix 700	DSMA 6H20 (70%) + diuron (7.5%)	6.60/kg	25 kg	Hif-Tech
Freeflo	diuron (43.5%)	14.60	20 l	Kenso Corporation
FSAN 02	N.A.	N.A.	N.A.	F.E Zuellig
Gesapax 500 FW	ametryne (500 g a.i/l)	15.00	4 l	Ciba-Geigy
Goldquat Extra	paraquat (200 g a.i./l)	7.75	20 l	F.E Zuellig
GS 13529	N.A.	N.A.	N.A.	Ciba-Geigy
Harquat	paraquat (200 g a.i./l)	8.50	4 l	Harrisons & Crosfield
MON 8783	N.A.	N.A.	N.A.	Monsanto
Paracol	paraquat (200 g a.i./l) + diuron (200 a.i./l)	13.20	5 l	ICI Agrochemicals
Paraquat Special	paraquat (180 g a.i./l)	N.A.	N.A.	Bayer
Paraxone 910	paraquat (18.3%) + sodium chlorate (12.4%)	6.80	20 l	Kenso Corporation
Roundup	glyphosate (360 g a.e./l)	30.00	1 l	Monsanto
SIR 1250	N.A.	N.A.	N.A.	Bayer
Starane 200	fluroxypyr (200 g a.e./l)	42.00	1 l	Pacific Chemicals
Strike	MSMA (29.4%) + paraquat (6.7%)	9.00	20 l	Kenso Corporation
SDZ 03	N.A.	N.A.	N.A.	SDS Biotechnology
SDZ 07	N.A.	N.A.	N.A.	SDS Biotechnology
TK 6200	N.A.	N.A.	N.A.	Tiram Kimia
URN 456	N.A.	N.A.	N.A.	Bayer
Wallop	glyphosate (180 g a.e./l) dicamba (90 g a.e./l)	15.00	4 l	Monsanto
Weedaway 253	paraquat (25.3%)	8.25	4 l	Halex

N.A. = Not available
* Per l except where indicated

CINOSULFURON FOR WEED CONTROL IN PLANTATIONS IN SOUTH-EAST ASIA

J.L. ALLARD[1], A. ZOSCHKE[1] AND K.F. KON[2]

ABSTRACT

In a total of 40 trials carried out from 1988 to 1991, cinosulfuron was tested for its performance as a weed control agent in oil palm, rubber and cocoa in South-East Asia.

In practical estate trials, major grass weeds, legume cover crops and broadleaved weeds such as *Borreria alata, Mikania micrantha,* and *Asystasia intrusa* were well controlled by cinosulfuron applied in combination with glyphosate along the rows or for circle weeding (general weed control). Duration of activity against legume cover crops such as *Pueraria phaseoloides* was comparatively long. In addition, cinosulfuron controlled important fern species such as *Dicranopteris* and *Stenochlaena* when applied in mixture with an appropriate burn-down compound. The optimal use rate of cinosulfuron in tropical plantations varied between 15 and 30 g ai/ha depending on shade condition for general weed control and particular species in the case of fern control.

Repeated applications of cinosulfuron at two to four times the rate required for sufficient weed control did not injure newly planted oil palm, rubber and cocoa trees. Updated toxicological data indicate that cinosulfuron is safe to the applicator, the environment and wildlife.

INTRODUCTION

Weed control is an important management practice in tropical plantations in South-East Asia. Commonly in plantations, spraying of herbicides is carried out at regular intervals along the rubber rows or around oil palm trees.

The aim of such 'general weed control' is to suppress the competition of weeds for light, water and soil nutrients, to ensure optimal use of fertilizer, and to ease access to the trees for pruning and harvesting operations (Teoh *et al.*, 1978; Lubis & Hutauruk, 1982; Harahap, 1986; Hidzir, 1986; Chung, 1987). Benefits of herbicide use over excessive hand-weeding include reduced risk of creating depressions around the trees, reduced danger of soil erosion on slopes, avoidance of damage to the surface roots of crops, reduced requirements for manpower, and reduced costs (Pillai, 1978).

Requirements for modern herbicides have become increasingly stringent. New products not only should be safe to the crop and effective in managing

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weeds, but also should be easy to apply as well as safe to both applicators and the environment (Chung, 1987). In addition, the increasing scarcity of hired labour in some areas, prompted the need to reduce the application frequency (spray-rounds) for herbicides, especially in immature crops by using products that provide a longer duration of weed control (Chung & Chang, 1990).

Cinosulfuron [ISO-proposed common name], coded as CGA 142'464, is a herbicide discovered by Ciba-Geigy Ltd., Basel, and has been described by Quadranti *et al.* (1987). It is under development for weed control in rice worldwide and is already registered for use in several countries (Calderon *et al.*, 1987; Guerra *et al.*, 1989; Zoschke *et al.*, 1989). The purpose of this paper is to determine additional opportunities of cinosulfuron 20 WG for the management of weeds in estate crops in South-East Asia.

MATERIALS AND METHODS

1. Physical, Chemical and Toxicological Properties of Cinosulfuron

Cinosulfuron belongs to the chemical class of sulfonylureas. Its physical, chemical and toxicological properties have been described previously (Quadranti *et al.*, 1987). Updated information on its toxicology (Table 1) showed that cinosulfuron has low toxicity to mammals, the environment and wildlife.

Table 1. Updated results of toxicological studies and degradation studies in the soil with cinosulfuron

Acute toxicity of technical material

- LD_{50} (mammals)	oral (rat)	> 5000 mg/kg
	dermal (rat)	> 2000 mg/kg
	inhalation (rat)	> 5000 mg/m^3
- Skin irritation (rabbit): none		
- Eye irritation (rabbit): none		

Sub-chronic, chronic toxicity and oncogenicity studies

Cinosulfuron did not display any carcinogenic potential in chronic feeding studies in rats and mice. When tested in pro- and eukaryotic cells *in vivo* or *in vitro* cinosulfuron was devoid of any genotoxic effects. No teratogenic potential was evident in pregnant rats and rabbits, and no negative effects were observed on rat reproduction in a multi-generation study.

Environmental toxicity studies

Cinosulfuron is practically non-toxic to birds, fish, water flea and earthworm. It has shown no tendency for bio-accumulation in living organisms.

Degradation in the soil

Degradation studies carried out in the laboratory with standard upland soil (at 50% field capacity) indicate a half-life of cinosulfuron of 11-21 days at 35°C.

2. Crop Tolerance Studies on Cinosulfuron

In order to assess the tolerance of major tropical plantation crops to cinosulfuron, specific field trials were started in 1990 at Ciba-Geigy's Agricultural Experimental Station in Rembau, Malaysia, situated on a sandy loam of the Rengam Series (Ultisol).

These trials were carried out in oil palm (*Elaeis guinensis* Jacq.), rubber (*Hevea brasiliensis* Muell. Arg.) and cocoa (*Theobroma cacao* L.). Six-month-old trees were planted into 16 to 28 m^2 plots (two trees per plot). Treatments were replicated three times in randomised complete blocks. Fertilization followed local estate practice, but more frequently to ensure healthy plant growth.

One month (oil palm and rubber) and 6 months (cocoa) after planting, two to six consecutive applications of cinosulfuron at rates of 30 to 60 g ai/ha were made at 3-month intervals. The final rating was done 3 months after the last application of cinosulfuron. All plots were kept weed-free by regular handweeding. Reference treatment was metsulfuron at 30 g ai/ha (in Table 2).

Representative growth parameters for the trees were evaluated every 3 months after each application. Such evaluations included; for oil palm: the total number of fronds produced and the average length of second, third and fourth frond developed after each application; for rubber: height and girth at 60 cm from the ground; for cocoa: height and girth at 30 cm from the ground.

3. Weed Control Trials with Cinosulfuron

Between 1988 and 1991, a total of 31 trials (including eight on ferns) were carried out in Selangor and Negeri Sembilan (Peninsular Malaysia) and nine trials in West Java (Indonesia). Cinosulfuron was applied as 20 WG (200 g ai per kg formulated product) at a spray volume of 400 to 450 l/ha with a sprayer equipped with a two-metre boom, powered by compressed air at 150 kPa [1.5 bars]. Treatments were replicated three or four times and arranged in randomised complete blocks. Plot size was 8 to 12 m^2. Plots were located mainly in the interrows of rubber and oil palm.

For general weed control, cinosulfuron at 15 to 30 g ai/ha was applied in combination with glyphosate either at 540 g ai/ha (< 30% shade) or 360 g ai/ha (> 30% shade). For the control of ferns, cinosulfuron was applied in combination with a burn-down compound. Under open condition (< 30% shade) a non-ionic surfactant (0.2%) or ammonium sulfate (1 % of spray volume) were added as adjuvants. Weed growth stages and heights at the time of application were representative of practical conditions.

Herbicide efficacy (% control) was assessed at regular intervals following the application by estimating the percentage of biomass reduction in treated plots per weed species as compared with an adjacent, untreated check-strip. The percentage of soil covered by each weed species was also evaluated.

Reference treatments were the following standards: [1] glyphosate at 540 g ai/ha (Fig. 1), [2] glyphosate + metsulfuron at 540 + 15 g ai/ha (in Fig. 1), [3] paraquat at 300 g ai/ha (Fig. 2), [4] paraquat + metsulfuron at 300 + 15 g ai/ha (Fig. 2).

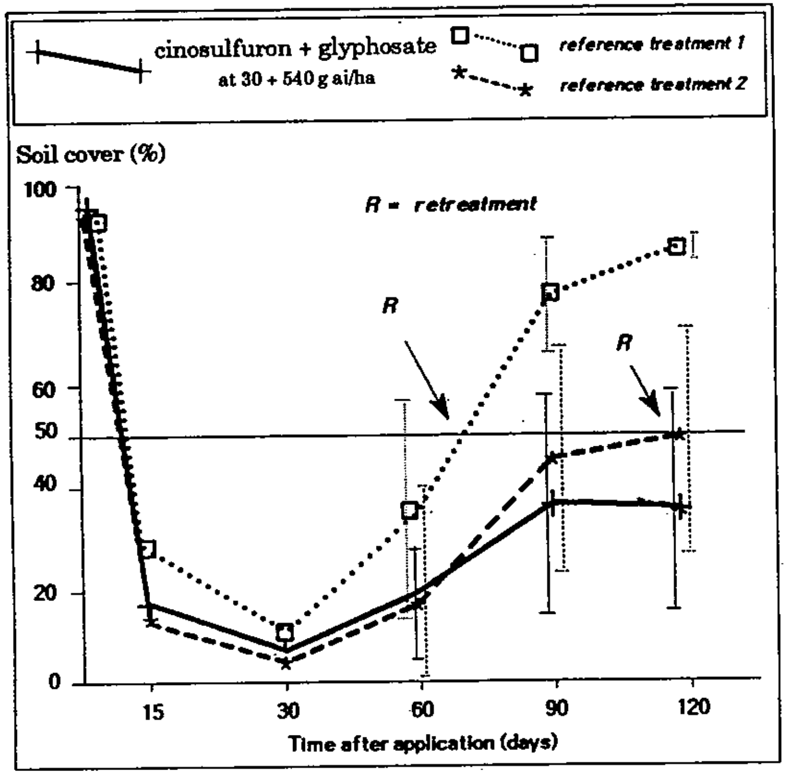

Figure 1. Duration of control (% soil cover) of *Pueraria phaseoloides* with cinosulfuron/glyphosate under open conditions (< 30% shade). (Result expressed as means across 4 trials and standard deviations).

RESULTS

1. Tolerance of Newly Planted Trees to Cinosulfuron

Applied at 3-months intervals, two to six applications of cinosulfuron at rates of 30 to 60 g ai/ha (equivalent to two- to four-times the rate needed to

control target weeds) did not affect the growth of newly planted rubber and oil palm trees; early evaluations on cocoa showed a similar trend (compare Table 2).

Further trials carried out in immature rubber in Indonesia with a single application of cinosulfuron at 30 to 40 g ai/ha along tree rows also confirmed the excellent crop tolerance of cinosulfuron (data not shown).

Table 2. Effect of repeated applications of cinosulfuron on growth parameters in rubber, oil palm, and cocoa

Estate crop/parameter	Untreated check [min-max values]	Cinosulfuron (g ai/ha) 30	60	Reference treatment
Rubber 1)				
- final height	524 cm [510-533]	102 %	106 %	101 %
- final girth	14.3 cm	96 %	101 %	103 %
Oil Palm 1)				
- final number of new fronds per tree	44 [41-46]	43	44	42
- mean relative length of newly produced fronds 4)	see 3)	104 % (57.203)	99 % (54.190)	98 % (52.187)
Cocoa 2)				
- final height	132 cm [131-133]	111 %	95 %	97 %
- final girth	6.7 cm [5.4-7.4]	118 %	104 %	93 %

1) six applications at 3-month intervals: 20-month evaluation period
2) two applications at 3-month intervals; 6-month evaluation period
3) mean frond length of untreated check of 51 ± 6, 76 ± 5, 98 ± 4, 128 ± 12, 157 ± 7, 194 ± 11 cm. resp. at each of the 6 applications
4) numbers in brackets refer to the mean frond length in cm after the 1st and 6th application, resp.

2. Spectrum and duration of weed control of cinosulfuron on oil palm and rubber

Results of trials carried out in rubber and oil palm plantations in Malaysia and Indonesia during the last 3 years showed that herbicide combinations with cinosulfuron provide good to excellent control of the most important legume cover crops, broadleaves weeds and ferns (Tables 3 and 4). Optimal application rate for cinosulfuron varied between 15 and 30 g ai/ha, depending on the degree of shade for general weed control and the particular species in the case of ferns.

Table 3. Spectrum of cinosulfuron (% control) for general weed control in oil palm and rubber in Indonesia and Malaysia. (Results are expressed as means and min-max values)

Degree of shade	< 30 %	30 - 60 %	> 60 %
Cinosulfuron rate[1] (g ai/ha)	30 - 40	15 - 30	15 - 20
No. of trials	18	7	7
Paspalum conjugatum	97 [93-99]	96 [94-98]	98 [95-100]
Ottochloa nodosa	91 [85-100]	98 [97-99]	99 [97-100]
Calopogonium caeruleum	87 [67-97]	79	97
Pueraria phaseoloides	93 [89-98]	91	NT
Asystasia intrusa	75 [70-80]	81	96 [95-97]
Borreria alata	82 [63-97]	95 [94-96]	NT
Mikania micrantha	88 [71-100]	85	NT

1) Applied post-emergence in mixture with recommended rate of glyphosate. Evaluation period: 60 days after application; NT = NOT tested.

Table 4. Fern control (%) with cinosulfuron in rubber in Malaysia. (Results are expressed as means across 5 trials and min-max values)

Cinosulfuron rate[1] (g ai/ha)	15 - 20	30
No. of trials	5	3
Dicranopteris linearis	91 [88-97]	95 [94-96]
Stenochlaena palustris	88 [85-91]	95

1) Applied post-emergence in mixture with burn-down compound. Evaluation period: 60 days after application.

2.1. *General weed control*

This mixture achieved high activity within 1 month after application on tropical kudzu (*Pueraria phaseloides* (Roxb.) Benth.) and extended control to 90 to 120 days under open conditions (Fig. 1). At 90 to 120 DAA, soil cover of weeds was below 50%. The duration of control of tropical kudzu with the mixture cinosulfuron/glyphosate was comparable to the performance of the standard mixture, metsulfuron/glyphosate, applied at recommended rates.

Under open conditions (< 30% shade) the mixture cinosulfuron/glyphosate performed well (average 88% biomass reduction) against caeruleum (*Calopogonium caeruleum* Desv.) and mile-a-minute (*Mikania micrantha* H.B.K.) and fair (average 79% biomass reduction) against common asystasia (*Asystasia intrusa* Bl.) and broadleaved button weed (*Borreria alata* (Aubl.) DC.); see Table 3. Both buffalo grass (*Paspalum conjugatum* Berg.) and slender panic grass (*Ottochloa nodosa* (Kunth) Dandy) were generally very well controlled by the mixture.

2.2. *Control of ferns with cinosulfuron*

Cinosulfuron applied in combination with a burn-down herbicide also demonstrated excellent herbicidal activity with regard to the level and duration of control against giant fern (*Stenochloa palustris* (Burm.) Bedd.) and tropical bracken (*Dicranopteris linearis* (Burm. f.) Und); see Fig. 2 and Table 4. An appropriate herbicide as combination partner to cinosulfuron was necessary to provide burn-down activity.

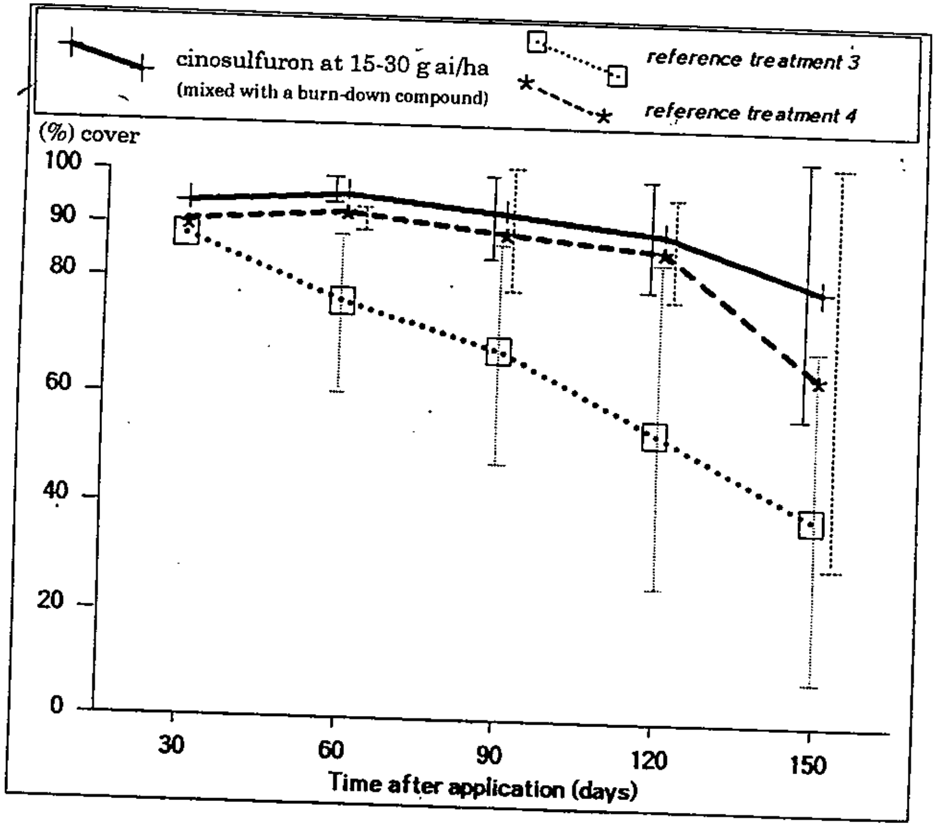

Figure 2. Control of ferns with cinosulfuron in mature rubber in Malaysia. (Results are expressed as means across 5 trials and standard deviations).

DISCUSSION

The trial results reported here demonstrated that cinosulfuron can be safely used in estate crops. Further monitoring of crop tolerance is being extended to oil palm, rubber and cocoa under practical conditions (repeated applications on weeding circles or strips) in different soil types and climatic conditions.

For general weed control, problems with broadleaved weeds, including legume cover crops such as tropical kudzu, become increasingly important along the rows or around both immature and mature rubber and oil palm (Hidzir, 1986; Chung, 1990). Glyphosate is well-known to effectively control grasses such as buffalo grass and slender panic grass (Sabudin *et al.*, 1984; Harahap, 1986). The addition of cinosulfuron to glyphosate provides a combined solution to grasses and broadleaved weeds: at the low rate of 30 plus 540 g ai/ha, respectively, under open conditions; and 15 plus 360 g ai/ha, respectively, under shaded conditions. Adjuvants, such as a non-ionic surfactant or ammonium sulfate (details reported by Kon *et al.* (1991)), have been proven to further enhance the level of activity of cinosulfuron under open conditions against broadleaved weeds and, therefore, are recommended to be added into the tank-mixture.

Based on our results, the duration of weed control and, consequently, the number of spray rounds per annum required when applying the cinosulfuron/glyphosate mixture can be expected to be equal to that of the best commercial standards under practical use conditions.

Owing to its very short cycle as well as mechanical seed propagation from interrows with constant germination (Khan, 1986), specific measures for the control of common asystasia may be required. For similar reasons, further investigations are needed for the control of fast growing creepers such as mile-a-minute. Studies on the control of weeds in cocoa are in progress.

Specific performance profiles and detailed use recommendations for general weed control of the mixture of cinosulfuron with glyphosate for Malaysia will be presented in a separate paper (Kon *et al.*, 1991).

For fern control, cinosulfuron has been shown to be very effective against giant fern and tropical bracken when applied in combination with an appropriate burn-down compound. These two ferns are found frequently in mature rubber and oil palm in Malaysia. Investigations on different mixing partners as well as the activity of cinosulfuron on other fern species are in progress.

The results presented in this paper illustrate the favourable properties of cinosulfuron with regard to different aspects of weed control in tropical plantations and can be summarized as follows:

1. Cinosulfuron has low toxicity to applicator, wildlife and the environment in general and can be used at comparatively low use rates (15 to 30 g ai/ha).
2. Cinosulfuron is well tolerated by oil palm, rubber and cocoa.
3. For general weed control, cinosulfuron offers a weed control spectrum complementary to glyphosate against broadleaved weeds including legume cover crops in immature and mature oil palm and rubber.
4. For the control of ferns, cinosulfuron provides excellent activity against major tropical fern species [in combination with appropriate burn-down compounds].
5. Results indicate that cinosulfuron combinations provide a duration of weed control probably resulting in a reduced number of spray rounds per annum comparable to the best commercial standards.

For the above reasons it is believed that cinosulfuron fulfills the requirements for new modern herbicides in plantation crops and can contribute to satisfy the major needs of South-East Asian planters with regard to the management of weeds in estate crops.

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The authors wish to express their gratitude to their Ciba-Geigy colleagues in both Malaysia and Indonesia for their engagement during the development of cinosulfuron in estate crops and for the quality of the data materials provided.

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CINOSULFURON FOR GENERAL WEED CONTROL IN RUBBER AND OIL PALM IN MALAYSIA

K.F. KON, F.W. LIM AND A.S. AZURI[1]

ABSTRACT

Between 1989 and 1990, seventeen trials were conducted with cinosulfuron in seven locations in Negri Sembilan and Selangor. In 13 trials, cinosulfuron was tested in tank-mixture with glyphosate for the control of common grasses and broad-leaved weeds in rubber and oil palm. In four other trial, young rubber and oil palm were investigated for tolerance to the herbicide.

Under 0 to 30% shade, cinosulfuron at 30 g ai/ha and glyphosate at 540 g ai/ha with 1% ammonium sulphate controlled 80% or more slender panic grass, buffalo grass, tropical kudzu, and mile-a-minute at 90 DAA. Under heavier shades of above 30%, however, cinosulfuron required only 20 g ai/ha in combination with 360 g ai/ha glyphosate; this mixture controlled more than 80% slender panic grass, buffalo grass, tropical kudzu, caeruleum, and common asystasia at 90 DAA. The control of mile-a-minute was about 70%. An adjuvant such as 1% ammonium sulphate or 0.2% DuPont Surfactant improved the control of all weeds except for grasses and common asystasia under immediate shades of 30 to 60%. Weed control was consistently superior to dicamba and glyphosate and similar to metsulfuron-methyl and glyphosate.

Cinosulfuron at 30 to 60 g ai/ha was not phytotoxic to young rubber and oil palm of 4 to 7 months old. Long-term field trials of over one year confirmed the excellent safety of cinosulfuron to both crops.

INTRODUCTION

Herbicides are an essential component of the technology of intensified plantation cropping of Malaysia. In the production of rubber, oil palm and coca, weed control accounts for between 10 to 40% of the total maintenance costs (Khairuddin and Teoh, 1989; Chee *et al.*, 1991). The vital reliance on herbicides to control weeds demands new compounds that are active at low rate, low in toxicity to non-target organisms, and acceptable environmentally. A relatively new chemistry that fits these requirements is the sulfonylurea.

Cinosulfuron (SETOFF® 20 WG, 20% a.i.), formally coded as CGA 142'464, is a sulfonylurea formulated as water dispersable granules. It was introduced in previous occasions as a rice herbicide for controlling annual and perennial broad-leaved weeds and sedges in South-East Asia (Quadranti *et al.*, 1987; Calderon *et al.*, 1987; Burhan *et al.*, 1989; Ooi and Chong, 1990). This

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paper demonstrates the broad-spectrum activity of cinosulfuron in combination with glyphosate on grasses and broad-leaved weeds in rubber and oil palm. The other paper in this series introduces the use of cinosulfuron in tropical plantations in South-east Asia (Allard *et al.*, 1991).

MATERIALS AND METHODS

Weed Control

Thirteen trials were conducted between 1989 and 1990 in the CIBA-GEIGY Agricultural Experiment Station (AES), plantation estates and a smallholding in Negri Sembilan and Selangor (Table 1). The major species of grasses and broad-leaved weeds including slender panic grass (*Ottochloa nodosa* (Kunth) Dandy), buffalo grass (*Paspalum conjugatum* Berg.), tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.), caeruleum (*Calopogonium caeruleum* Desv.), common asystasia (*Asystasia gangetica* (L) T. Anders (*Asystasia intrusa* BL. *sensu auctorum non* [Lee, S.A., personal communication])), and mile-a-minute (*Mikania micrantha* H.B.K.) were tested in rubber, oil palm and non-crop areas. The weeds distributed uniformly as single species or mixed

Table 1. Overview of trials on cinosulfuron tank-mixed with glyphosate in rubber and oil palm estates, a smallholding, and at AES from 1989 to 1990.

Trial/Year	Weed species[A]	Crop	Variety	Shade (%)	Estate
206/89	PASCO	Oil-palm	DxP	0-20	Teluk Merbau
208/89	OTTNO	Oil-palm	DxP	0-20	Connemara
209/89	MIKMI	Oil-pal	DxP	0-20	Teluk Merbau
210/89	PUEPH	Non-crop		0	AES, Rembau
105/90	CALCA	Non-crop		0	AES, Rembau
115/90	OTTNO	Non-crop		0	AES, Rembau
124/90	PASCO	Rubber	PB225	80-90	Kombok
125/90	OTTNO	Rubber	GT1	80-90	Kombok
126/90	ASYGA	Rubber	PB260	80-90	Pajam
127/90	CALCA	Rubber	BRIM600	50-60	Perhentian Tinggi
131/90	PASCO	Rubber	PB225	80-90	Kombok
208/90	ASYGA	Rubber		50-60	Smallholding
209/90	OTTNO/PUEPH/MIKMI	Rubber	BRIM605	30-40	Kombok
211/89	Crop tolerance	Oil-palm	DxP	0	AES, Rembau
216/89	Crop tolerance	Rubber	RRIM600	0	AES, Rembau
225/89	Crop tolerance	Oil-palm	DxP	0	AES, Rembau
226/89	Crop tolerance	Rubber	RRIM600	0	AES, Rembau

[A] Abbreviation follow WSSA-approved codes from *Composite List of Weeds* (Weed Science Society of America, 1989). Where codes of certain species are not in the list, we used the standard naming convention by retaining the first three letters of the genus and the corresponding first two letters of the eipthet.

species, with at least 25% of each component, in the trials. Shade conditions ranged from 0 to 90%, which were visual estimates of the total aerial cover by tree canopy.

The methods of testing were in line with the recent draft of *Efficacy Test Protocol: Weeds in Oil Palm and Rubber* (FAO, 1989). Plots of 4 by 3 m were arranged as randomised complete-blocks with three to four replicates in between rows of rubber or oil palm in all trials except for Trial 131/90; this trial was carried out within the rubber rows. Plots were separated by adjacent check-strips of 4 by 2 m to overcome temporal changes in weed cover. At application, weed species were about 0.4 to 0.6 m high.

Herbicides (Table 2) were applied with a two-metre or four-metre boom, powered by compressed air at 150 kPa (1.5 bar). Adjuvants were tank-mixed with the herbicides where required (Table 2). The flat-fan nozzles (Teejet® 11004, Spraying Systems Co.) delivered 450 l/ha (± 2%) of spray solution. The active ingredients (ai) of glyphosate, dicamba, and fluroxypyr are their acid equivalents, respectively.

Table 2. Trade names, formulations and use rates of the herbicides and adjuvants tested in the trials.

Product	Formulation	Active ingredient	Ai/product (g/l or g/kg)	Rates (g ai/ha)
SETOFF®	20WG	cinosulfuron	200	20-120 *
ALLY[R]	20DF	metsulfuron-methyl	200	10- 15
WALLOP®	SL	dicamba	90	180-270
		glyphosate	180	360-540
STARANE®	EC	fluroxypyr	200	88
ROUNDUP®	SL	glyphosate	360	360-540
DuPont Surfactant		non-ionic surfactant		0.2% v/v
Ammonium sulphate		fertilizer		1.0% w/v

* Rates above 30 g ai/ha only for crop tolerance trials.

Control of each weed species was assessed at application, 7, 15, 30, 60, 90, 120, 150, and 180 days after application (DAA). Each plot was visually for percent control by comparing with the adjacent check-strip. The assessment involved a general estimation of the total number, cover, height and vigour, that is, the total living weed volume in one figure (FAO, 1989).

Crop Tolerance

Young rubber (4.5-months-old) and oil palm (seven-months-old) were established in polybags for tests of tolerance to cinosulfuron (Table 1). The herbicide was dissolved in 20 cm3 of water and drenched into polybags at 0, 30, 60 and 120 g ai/ha. The polybags were replicated in four randomised complete-blocks and sprinkler-irrigated twice daily. Plant growth was assessed at application, 15, 30, 60, 90 and 120 DAA. Height of rubber was measured from the soil surface to the tip of the shoot. For oil palm, the final length of the first frond was measured from the lowest rudimentary leaflet to the tip of the rachis.

In two field trials, cinosulfuron was applied at 30 and 60 g ai/ha every 90 days to one-month-old field planting of rubber and oil palm (Table 1). Cinosulfuron was applied with a two-metre boom as before or a single flat-fan nozzle (Teejet® 11004) at 150 kPa (1.5 bar). The nozzle delivered 450 l/ha (± 5%) of spray solution. There were three replicates of 4.75 by 3.50 m plots for rubber and 7.50 by 3.75 m plots for oil palm; in both trials, each plot had two plants. The plants were assessed before each application; height of rubber and length of the third frond of oil palm were measured as for the polybag trials.

Statistical Analysis

Although weed control was expressed as persentages, the data were in the ordinal scale (O'Svanth *et al.*, 1979), and thus only treatment means were calculated. Quantitative data on measurements of crop tolerance were summarized as means and standard errors.

RESULTS

Weed Control

Open conditions of 0 to 30% shades. The activity of mixtures of cinosulfuron (30 g ai/ha) and glyphosate (540 g ai/ha) increased rapidly after applications; the activity peaked between 30 to 60 DAA. At 90 DAA, the mixture with 1% ammonium sulphate controlled 80% or more slender panic grass, buffalo grass, mile-a-minute, and tropical kudzu (Fig. 1 and 2). Control of caeruleum was about 65% (Figs. 1 and 2). In all comparisons, our mixture was superior to dicamba (270 g ai/ha) plus glyphosate (540 g ai/ha) and fluroxypyr (88 g ai/ha), but similar to metsulfuron-methyl (15 g ai/ha) and glyphosate (540 g ai/ha).

Intermediate shade of 30 to 60%. Under higher shades, we could reduce the rates in the mixtures of cinosulfuron and glyphosate to 20 and 360 g ai/ha, respectively. This mixture with either 1.0% ammonium sulphate or 0.2% DuPont Surfactant controlled 80 to 90% of slender panic grass, tropical kudzu and caeruleum (Fig. 3). The control of mile-a-minute and common asystasia was about 70% (Fig. 3). Our mixture again was superior to dicamba (180 g ai/ha) and glyphosate (360 g ai/ha) and glyphosate (360 g ai/ha).

Heavy shade of 60 to 90%. Under heavy shades, cinosulfuron and glyphosate maintained effective control of more than 80% slender panic grass,

buffalo grass and common asystasia for six months (Fig. 4). An adjuvant was not necessary. Weed control with our mixture was similar to both mixtures of dicamba and glyphosate and of metsulfuron and glyphosate.

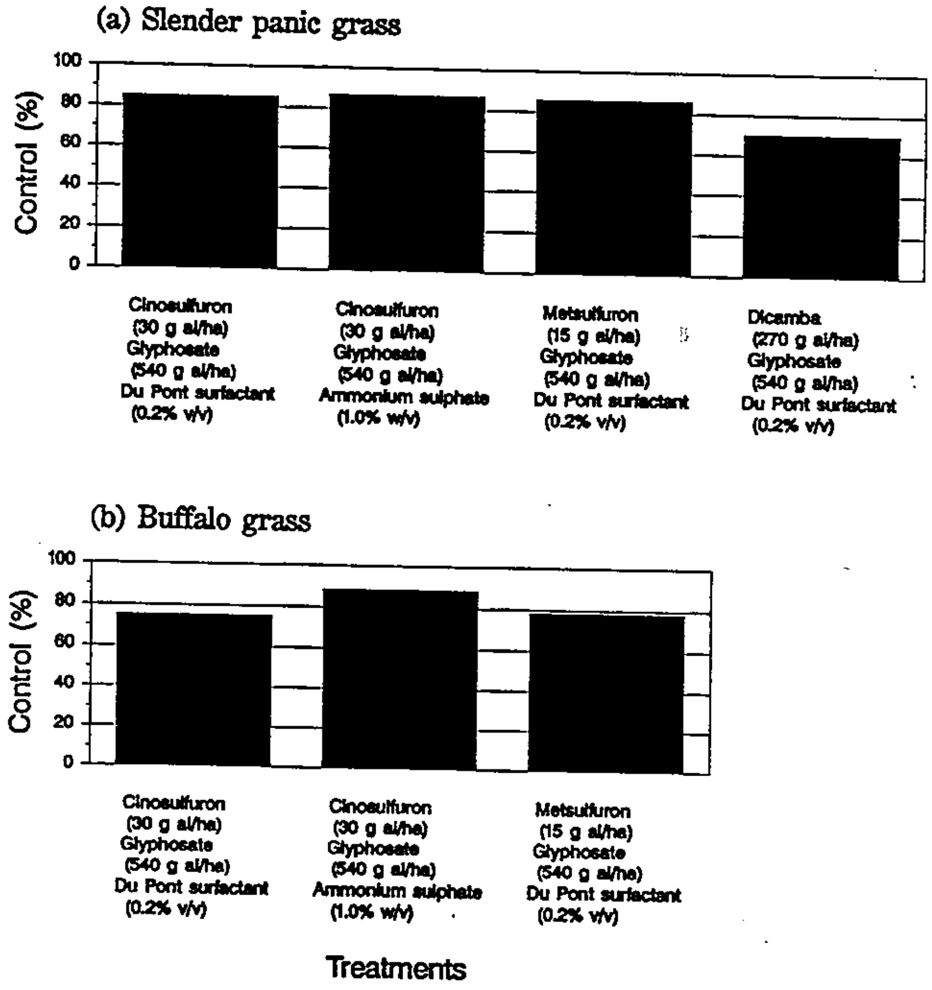

Figure 1. The activity od cinosulfuron and glyphosate with adjuvants on grasses under 0 to 30% shade at 90 DAA.

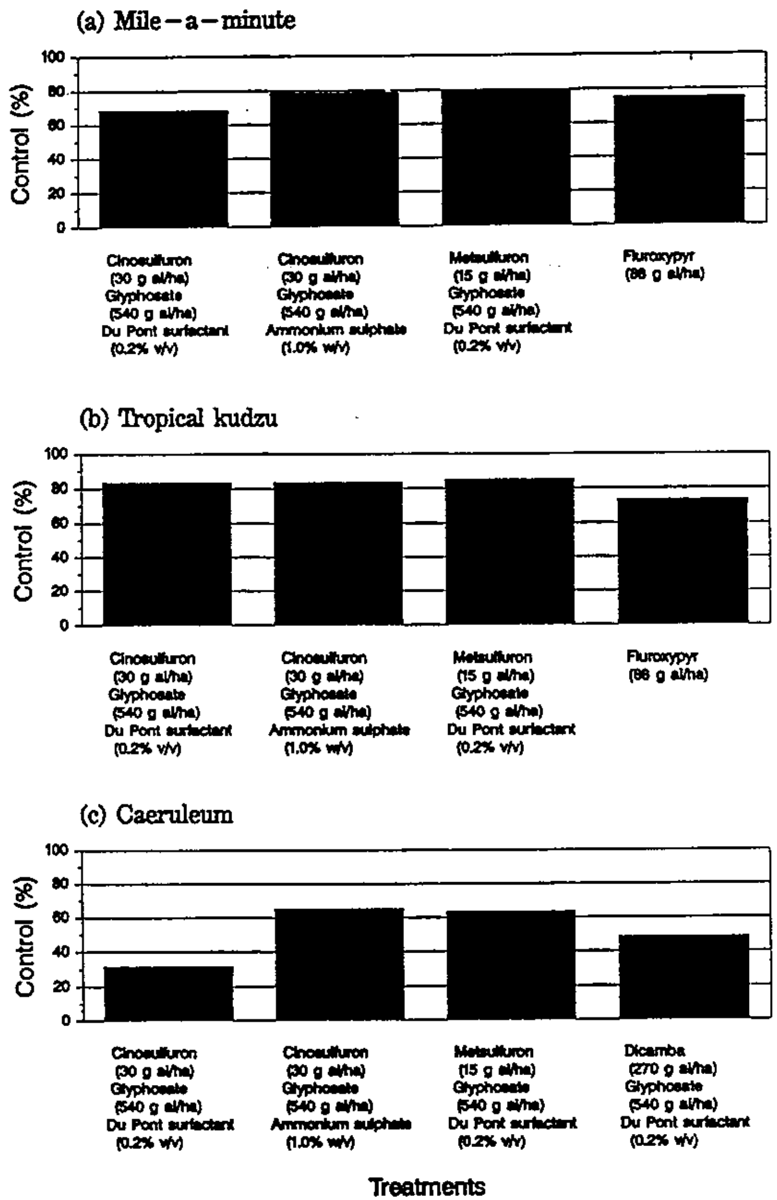

Figure 2. The activity of cinosulfuron and glyphosate with adjuvants on broad-leaved weeds under 0 to 30% shade at 90 DAA.

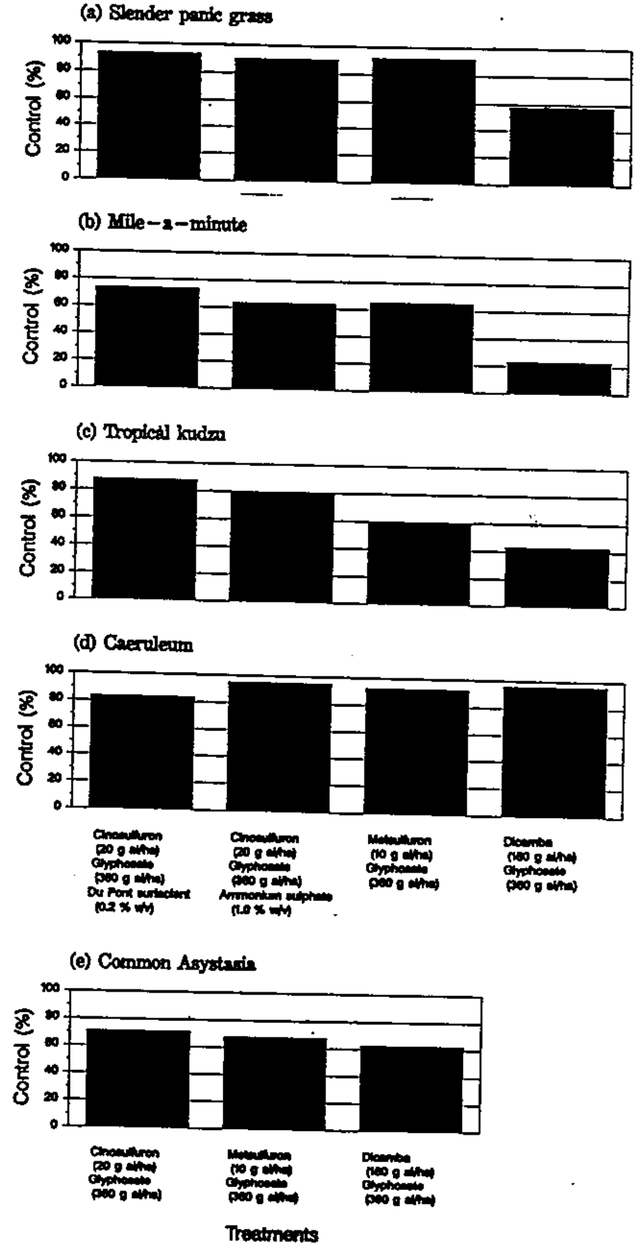

Figure 3. The activity of cinosulfuron and glyphosate with adjuvants on slender panic grass and broad-leaved weeds under 30 to 60% shade at 90 DAA.

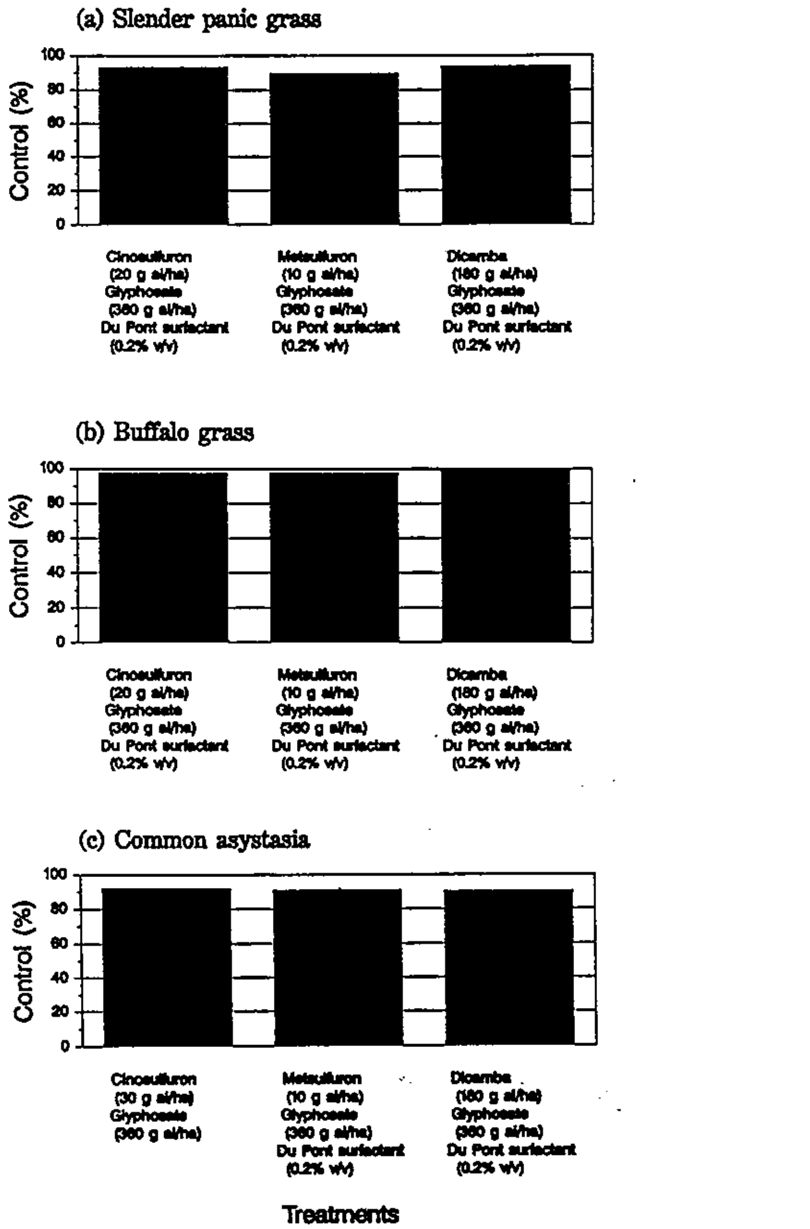

Figure 4. The activity of cinosulfuron with glyphosate and adjuvants on grasses and common asystasia under 60 to 90% shade at 180 DAA.

Crop Tolerance

Young rubber of 4.5 months old tolerated cinosulfuron up to 120 g ai/ha; both plant height and diameter of stems were not affected (Table 3). Similarly, seven-month-old oil palm tolerated cinosulfuron up to 60 g ai/ha with no apparent reduction in frond length (Table 3). There was also no observed abnormality in leaf development in both crops.

The results from polybags were confirmed in long-term field trials of over a year. Repeated applications of cinosulfuron every 90 days were not phytotoxic to both rubber and oil palm (Table 4). The plants developed normally and frond production were not affected even at 60 g ai/ha of the herbicide (Table 4).

Table 3. Tolerance of rubber and oil palm to cinosulfuron in polybag trials. Results are expressed as means and standard deviations.

Measurements	Time of evaluation (DAA)	Cinosulfuron (g ai/ha)			
		0	30	60	120
Height of rubber (cm)	0	39± 5.8	41± 5.9	33± 4.6	41± 3.1
	30	43± 6.5	52± 7.6	48± 7.4	50± 4.0
	90	55±14.5	72± 2.0	64± 6.0	62± 8.1
	120	54±16.6	101±31.1	76± 6.7	60± 9.2
Final length of first frond of oil palm (cm)	0	30± 2.5	35± 4.1	32± 6.1	31± 6.1
	30	38± 5.9	44± 2.7	43± 4.0	47± 0.6
	60	60± 2.1	56± 2.0	56± 1.0	52± 1.5
	120	69± 2.5	67± 0.6	65± 2.0	65± 4.5

Table 4. Tolerance of rubber and oil palm to cinosulfuron in long-term field trials. Results are expressed as means and standard deviations.

Measurements	Time of evaluation (DAA)	Cinosulfuron (g ai/ha)		
		0	30	60
Height of rubber (cm)	0	37± 3.6	40± 2.9	38± 4.0
	90	51± 7.2	53± 7.3	58± 9.5
	180	94± 16.3	104± 18.2	142±20.8
	270	200± 20.8	237± 24.0	291±31.6
	360	348±15.6	353±36.3	413±29.3
Girth of rubber (mm)	270	55± 3.6	60± 7.0	70± 7.8
	360	85± 1.6	86± 2.0	98± 9.7
Final length of third frond of oil palm (cm)	0	51± 5.9	56± 1.6	53± 1.8
	90	77± 4.7	79± 3.9	75± 4.2
	180	98± 4.3	100± 1.9	96± 5.9
	270	128± 6.0	129± 0.3	123± 13.0
	360	155± 7.3	156± 1.3	145± 18.9
Number of oil palm fronds	0	7	5	7
	90	11	9	11
	180	21	19	22
	270	30	27	31
	360	40	37	41

DISCUSSION

Herbicides are tank-mixed to improve the weed spectrum and increase the durationn of control in plantation crops. The older generation of tank-mixtures such as diuron/paraquat and 2,4- D/paraquat gradually are being replaced with newer mixtures such as dicamba/glyphosate. However, herbicide technology is changing rapidly, and we now have the low-rate mixtures such as metsulfuron-methyl/glyphosate and fluroxypyr/glyphosate, in which the rate of one component is lower than 100 g ai/ha. These low- rate mixtures are also more effective in weed control than the dicamba/glyphosate mixture (Khairuddin and Teoh, 1989).

Long duration of weed control at low rates is a strong feature of our cinosulfuron/glyphosate mixture. A mixture of 30 g ai/ha, cinosulfuron and 549 g ai/ha of glyphosate, with an adjuvant, effective controlled the major broad-leaved species and grasses and under the more open conditions up to 90 days. The rates of this mixture were reduced further under shade of greater than 30%; the mixture of 20 g ai/ha of cinosulfuron and 360 g ai/ha of glyphosate controlled many species for as long as three to six months. Possibly, lower rates of cinosulfuron were required under shade conditions because the weeds had less cuticular wax and thus the rate of herbicide uptake was greater. The excellent activity of cinosulfuron on the broad-leaved weeds at very low rates is due to the herbicide's specific and potent action on the acetolactate synthase enzyme in the biosynthesis of isoleucine and valine; subsequently, cell division is arrested (Quadranti *et al.*, 1987). The additive behaviour of the cinosulfuron/glyphosate mixture reflected their complementary modes of action; glyphosate inhibits the EPSP synthase enzyme in the shikimate acid pathway (Duke, 1988). Cinosulfuron was not antagonistic to glyphosate on grasses.

Under the more open conditions, an adjuvant was necessary to improve the activity of the cinosulfuron/glyphosate mixture. The best and cheapest adjuvant was the fertilizer, ammonium sulphate. Ammonium sulphate probably increased the rate of leaf absorption of glyphosate and cinosulfuron through the thick cuticular waxy layer to the weed species. Such an improvement in foliar uptake with ammonium sulphate has been reported for several herbicides including glyphosate (Turner, 1984; Salisbury *et al.*, 1991). Under heavy shades, weeds have less cuticular wax and this could explain why an adjuvant was not needed to improve herbicide efficacy. Further work on the interactions between adjuvants and cinosulfuron are in progress.

Common asystasia was more difficult to manage with one spray of herbicide because of regeneration through new seedlings from the dormant seed bank. The cinosulfuron/glyphosate mixture killed the adult plants thus allowing penetration of more light that stimulated the germination of new seeds of common asystasia (Ismail *et al.*, 1990). One effective method to manage this weed is to exhaust the seed bank with more frequent and regular spray rounds in the first year of management.

The low-rate mixture of cinosulfuron/glyphosate featured broad-spectrum activity on the major grasses and broad-leaved weeds, and improved the duration of weed control over some of the common mixtures available today; it was not phytotoxic to young rubber and oil palm. The established biological profile was consistently superior to that of the mixture of dicamba and glyphosate, and comparable to the mixture of metsulfuron-methyl and glyphosate. In addition, cinosulfuron is safe to applicators, animals, crops, and the environment when used according to the safety guidelines and recommendations of CIBA-GEIGY. The use recommendations for the mixture cinosulfuron/glyphosate in plantation crops in Malaysia are summarized in Table 5. Extension trials in the field are in progress to gather more information on the performance of the mixture on rubber, oil palm and cocoa in various soil and climatic conditions.

Table 5. Use recommendations for the mixture of cinosulfuron and glyphosate in estate crops in Malaysia.

	Young crop (< 30% shade)	Mature crop (30-60% shade)	Mature crop (> 60% shade)
Use rates (g ai/ha) of cinosulfuron and glyphosate	30 + 540	20 + 360	20 + 360
Surfactant	Yes	Yes	No
Application timing	Post-emergence to weeds (following recommendation for glyphosate)		
Weed control spectrum	Legume cover crops: *Pueraria phaseoloides, Calopogonium caeruleum* Broad leaved weeds: *Asystasia gangetica, Mikania micrantha* Grasses: *Ottochloa nodosa, Paspalum conjugatum*		
Duration of activity (expected)	2-3 months	3-4 months	4-6 months

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EVALUATION OF PROPAQUIZAFOP FOR GRASS CONTROL IN LEGUME COVER CROP ESTABLISHMENT IN RUBBER PLANTATIONS

USMAN NASUTION[1]

ABSTRACT

A field experiment was conducted to evaluate the efficacy of propaquizafop (Agil 100 ec) for gramineous weed control in legume cover crop establishment in rubber plantations. A mixture of *Pueraria javanica, Calopogonium mucunoides* and *Centrosema pubescens* seeds were sown on bare soil of young rubber planting strips. Three weeks later the strips were sprayed with propaquizafop at 0.05, 0.1, 0.15, 0.20, and 0.25 kg ai/ha.

Propaquizafop at 0.1, 0.15, 0.20, and 0.25 kg/ha gave 94 - 100% control of *Eleusine indica, Paspalum conjugatum* and *Digitaria adscendens* at the 4 - 6 leaf stage, while the lower dosage gave inadequate control. Propaquizafop at 0.05 and 0.1 kg/ha caused slight toxicity to the legumes, while higher rates caused slight to medium toxicity 2 - 4 weeks after application. Chlorosis of young leaf margins, did not appear in new shoots formed 6 weeks after application. Among the three legumes, *C. pubescens* proved to be the most tolerant. Propaquizafop application did not cause deleterious effect on rubber which was planted in the plot.

Propaquizafop at 0.1 to 0.15 kg/ha is an effective herbicide for grass weed control in legume establishment in rubber plantations.

INTRODUCTION

Legume cover crop establishment provides benefits in rubber plantations by protecting soil from erosion, increasing organic matter of soil, improving chemical and physical properties of soil, and suppressing the growth of weeds (Broughton, 1976; Nasution, 1984).

During establishment of the legume cover crop weeds compete with the legumes, and control must be carried out to prevent them from suppressing the growth and eventually succeeding the legumes.

Chemical weed control in legume establishment has been practised in rubber plantations, especially when manual techniques are not applicable due to the shortage of or expensive labour. Both pre- and post-emergent herbicides such as alachlor, paraquat + diuron (Tan and Pillai, 1977) and oxyfluorfen (Teoh *et al.*, 1977) have been recommended for legume establishment, whilst in North Sumatra methabenzthiazuron and ametryn (Nasution and Basuki, 1979) and paraquat + diuron have also been recommended (RRC Tanjung Morawa, 1981).

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This paper reports on an effort to obtain more effective, efficient, and less injurious herbicides to anticipate the increasing cost of legume establishment.

MATERIALS AND METHODS

The experiment was conducted on red-yellow podsolic soil at Sarang Giting estate, North Sumatra, using a non factorial randomized block design with four replications. The seven treatments were five rates of propaquizafop, manual weeding, and an untreated check plots. Plot size was 3 m x 10 m.

The soil was cultivated by plowing and harrowing, two times respectively, followed by manual removing of debris. Rubber (BPM 1 clone) at one leaf whorl stage was planted from polybags at 4.25 m x 4.25 m. The experimental plots were placed in rubber planting rows to facilitate the recording of herbicide phytotoxicity on young rubber.

One week after soil cultivation, the plots were hoed. Seeds of creeping legumes consisting of *Pueraria javanica* Benth., *Calopogonium mucunoides* Desv. and *Centrosema pubescens* Benth. at 4, 8, and 8 kg/ha respectively were premixed with rock phosphate fertilizer at 15 kg/ha and sown at 0.6 m x 0.5 m. After three weeks, propaquizafop (isopropylidene amino) oxyl ethyl-D- (+) - 2 - p - (6 - chloro - 2 - quinoxalinyl) oxyl phenoxy propionate (Bayer Indonesia, 1991) was sprayed at 0.05, 0.1, 0.15, 0.20, and 0.25 kg ai/ha. Spraying was done with a knapsack sprayer with ICI blue nozzle at 500 l/ha of water. Manual weeding was done by hoeing at three weeks intervals. Recordings were done on weed control, legume coverage, herbicide toxicity on legumes and rubber, as well as weed and legume top dry weight 2, 4, 8, and 12 weeks after application (WAA).

Weed control percentage was rated by comparing an area of 2 m x 2 m in the centre of the plot before and after herbicide application. Percentage of legume coverage was recorded visually at the same time.

Herbicide phytotoxicity to legumes and rubber was recorded 2, 4, 6, and 8 WAA using 0 - 4 scales (Komisi Pestisida Indonesia, 1984) where :

0 = no symptoms to 5% abnormal color and shape of young leaf,
1 = slight toxicity, 5% - 10% abnormal color and shape of young leaf,
2 = medium toxicity, 10% - 20% abnormal color and shape of young leaf,
3 = severe toxicity, 20% - 50% abnormal color and shape of young leaf, and
4 = very severe toxicity, > 50% abnormal color and shape of young leaf.

Weeds and legumes top dry weight were observed 2, 3 and 4 months after application (MAA) on different areas of 0.5 m x 1.8 m.

Growth of rubber in terms of stem diameter (mm) at 10 cm height from the soil and stem height (cm) measured from the union to the apical bud were recorded 2 and 4 MAA.

RESULTS AND DISCUSSION

The predominant weeds in the plots before herbicide application were *Eleusine indica* (L.) Gaertn. which covered 20 - 25% of the plot, *Paspalum conjugatum* Berg., and *Digitaria adscendens* (H.B.K.) Henr.

Weed Control

Mean weed control and the result of statistical analysis is presented in Table 1.

Table 1. Effect of propaquizafop dosages on gramineous weed control in legume establishment

Treatments	Weed control (%)			
	2 WAA	4 WAA	8 WAA	12 WAA
Propaquizafop 0.05 kg/ha	68 c	74 b	66 b	58 b
Propaquizafop 0.10 kg/ha	80 bc	91 a	93 a	94 a
Propaquizafop 0.15 kg/ha	85 abc	97 a	98 a	99 a
Propaquizafop 0.20 kg/ha	88 ab	97 a	100 a	100 a
Propaquizafop 0.25 kg/ha	97 a	99 a	100 a	100 a
Manual weeding	85 a	74 b	81 b	93 a
Untreated	0 d	0 c	0 c	0 c

WAA : Week After Application.
Means in the same column followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test.

At 2 WAA propaquizafop at all rates tested showed control of gramineous weeds. Weed control provided by the lowest to the highest rates of propaquizafop ranged from 68 to 97%. This indicated that propaquizafop provided relatively fast action against gramineous weeds.

Weed control at all rates of propaquizafop increased with time until 8 WAA except for the lowest rate (0.05 kg/ha) which reached maximum control at 4 WAA, when it still provided inadequate control (74%). This suggested that the dosage was insufficient for the death of weeds while the development of new shoots continued.

In contrast, weed control in the 0.1, 0.15, 0.20, and 0.25 kg/ha treatments ranged from 93% - 100% at 8 and 12 WAA. The three higher rates of propaquizafop provided satisfactory to excellent efficacy against gramineous weeds. At 8 WAA weed control of the three higher rates was significantly higher than for manual weeding, while at 12 WAA the differences were not significant. Weed control by manual weeding at 12 WAA was notably higher than that at 8 WAA, probably due to the additional supression effect of the legumes.

Based on these data, it can be concluded that the best dosages of propaquizafop for controlling gramineous weeds are 0.15 - 2.5 kg/ha.

Toxicity to Legumes

The three legumes showed toxicity symptoms at all propaquizafop rates tested, but only at 2 and 4 WAA. All legumes showed chlorosis of young leaf margins, whilst at high herbicide rates necrotic signs also appeared. Toxicity ratings are presented in Table 2.

Table 2. Phytotoxicity effect of propaquizafop on legumes

Treatment	Mean of toxicity ratings based on 0-4 scale								
	2 WAA			4 WAA			6 WAA		
	P.j	C.p	Ca.m	P.j	C.p	Ca.m	P.j	C.p	Ca.m
Propaquizafop 0.05 kg/ha	0.6	0.2	0.7	0.3	0.4	0.7	0	0	0
Propaquizafop 0.10 kg/ha	0.9	0.5	1.1	0.8	0.6	1.6	0	0	0
Propaquizafop 0.15 kg/ha	1.5	0.6	1.6	1	1.2	1.7	0	0	0
Propaquizafop 0.20 kg/ha	1.5	1.2	1.6	0.8	1.2	2.1	0	0	0
Propaquizafop 0.25 kg/ha	1.7	1.2	1.6	1.2	2	2.1	0	0	0
Manual weeding	0	0	0	0	0	0	0	0	0
Untreated	0	0	0	0	0	0	0	0	0

WAA = Week After Application
P.j = *Pueraria javanica*
C.p = *Centrosema pubescens*
Ca.m = *Calopogonium mucunoides*

Two WAA propaquizafop at 0.05 and 0.10 kg/ha caused slight toxicity (scale 0.6 to 1.1), while 0.15 to 0.25 kg/ha caused medium toxicity (scale 1.5 to 1.6) to *P. javanica* and *Calopogonium mucunoides*. *Centrosema pubescens* at the higher rates only suffered slight toxicity (scale 0.6 to 1.2), suggesting that *Centrosema pubescens* was more tolerant to propaquizafop than the other two legumes.

At 4 WAA toxicity symptoms increased on all legumes. Nevertheless, the degree of toxicity was still only slight to medium. Toxicity symptoms did not appear on young shoots of any legumes at all rates of propaquizafop 6 WAA.

Legume Coverage

Legume coverage before propaquizafop application was ranged from 3 to 4 % (Table 3).

Table 3. Effect of propaquizafop on legume coverage

Treatment	Legume coverage (%)				
	Before application	4 WAA	8 WAA	12 WAA	16 WAA
Propaquizafop 0.05 kg/ha	4 a	12 ab	22 a	52 b	66 b
Propaquizafop 0.10 kg/ha	3 a	15 ab	35 a	84 a	91 a
Propaquizafop 0.15 kg/ha	4 a	14 ab	31 a	82 a	87 a
Propaquizafop 0.20 kg/ha	4 a	12 ab	31 a	71 a	81 a
Propaquizafop 0.25 kg/ha	4 a	12 ab	29 a	69 a	79 a
Manual weeding	4 a	26 a	42 a	85 a	90 a
Untreated	3 a	4 b	9 b	11 c	17 c

WAA : Week After Application

Means in the same column followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test.

At 4 WAA legume coverage at all rates of propaquizafop was much lower than that after manual weeding, due to toxicity to the legumes. In untreated plot the legume coverage was even due to the suppression by weeds.

From 4 WAA the growth of legumes after propaquizafop treatments increased from 80 to 140%, which was much higher than that for manual weeding which was only 60%. The higher growth rate of legumes after propaquizafop treatments could be due to the cessation of herbicide toxicity on legume together with the suppression of weed growth by the herbicide. In manual weeding the beneficial effects of weeding on the growth of legumes was possibly slowed down by the disturbance of their roots.

At 12 and 16 WAA the legume coverage at 0.1 - 0.25 kg/ha propaquizafop treatments were not significantly different from those of manual weeding. Among the propaquizafop rates tested, 0.1 and 0.15 kg/ha were thought to be the best treatments since legume coverage was comparable with manual weeding.

Legume Top Dry Weight

Data on legume top dry weight confirmed the data on legume coverage mentioned previously at 2, 3, and 4 MAA (Figure 1).

At 2 MAA legume top dry weight after manual weeding was slightly higher than any propaquizafop treatments, and among propaquizafop treatments 0.1 and 0.15 kg/ha provided higher legume dry weight. At 4 MAA the 0.1 kg/ha rate of propaquizafop provided 10 % higher legume top dry weight while at 0.15 kg/ha it was slightly higher than that of manual weeding.

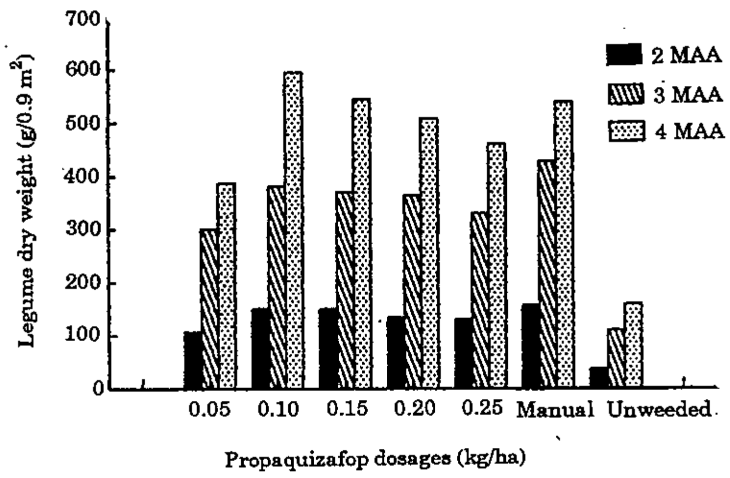

Figure 1. Effect of propaquizafop on legume top dry weight.

Weed Dry Weight

Gramineous weed dry weight observed at 2, 3, and 4 MAA supported the trend of weed control provided by propaquizafop mentioned earlier (Figure 2).

The lowest rate of propaquizafop provided the highest weed dry weight 2 MAA, with sequentially higher rates giving lower gramineous weed dry weights. At 3 and 4 MAA no gramineous weed was observed in the four highest rates of propaquizafop.

These data together with the significantly higher gramineous weed dry weight in the unweeded plot proved the control action of propaquizafop against gramineous weeds.

Broadleaf weeds found either in propaquizafop or manually weeded treatments were *Borreria latifolia* (Aubl.) K.Sch, *Amaranthus* sp., *Synedrella* sp., *Phyllanthus niruri* L, and *Mimosa pudica* L. Complete data of broadleaf weed dry weight is not depicted here, only related data are presented and discussed. At 2, 3, and 4 MAA mean broadleaf weed top dry weights in all propaquizafop rates were 20, 23, and 14 g/0.9 m^2 respectively, while in manually weeded plots it was 9, 7, and 7 g/0.9 m^2 respectively. These data again suggest that propaquizafop had no control action against broadleaf weeds. The decreasing broadleaf weed dry weight at 3 MAA compared to that at previous months was due to suppression effect of legumes.

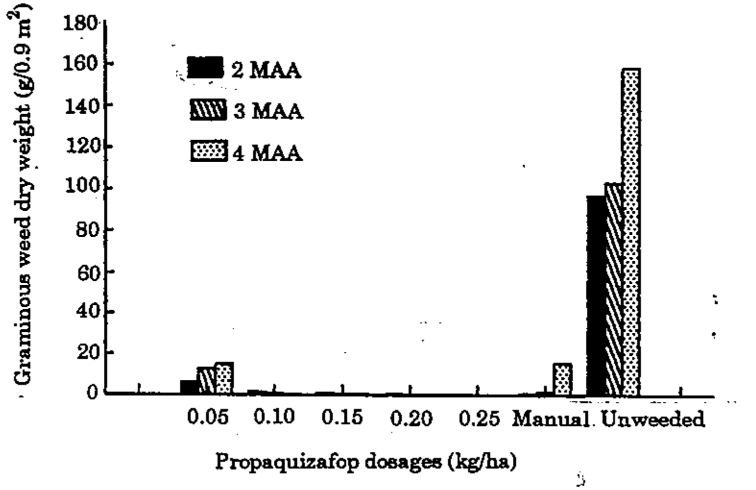

Figure 2. Effect of propaquizafop on gramineous weeds top dry weight.

Toxicity Effect on Young Rubber

Observation of girth and stem height increment at 2 and 4 MAA (Table 4) strongly suggested that propaquizafop at all rates tested had no detrimental effect on the growth of young rubber.

Table 4. Effect of propaquizafop on stem diameter and height of young rubber

Treatment	Stem diameter (mm)			Plant height (cm)		
	Before application	Increment 2 MAA	Increment 4 MAA	Before application	Increment 2 MAA	Increment 4 MAA
Propaquizafop, 0.05 kg/ha	5.60	0.21	0.22	26.55	0.40	0.31
Propaquizafop, 0.10 kg/ha	6.80	0.16	0.21	28.00	0.27	0.30
Propaquizafop, 0.15 kg/ha	6.51	0.16	0.19	27.70	0.30	0.31
Propaquizafop, 0.20 kg/ha	6.0	0.20	0.21	27.60	0.37	0.29
Propaquizafop, 0.25 kg/ha	5.70	0.21	0.24	30.00	0.34	0.41
Manual weeding	5.77	0.17	0.23	26.70	0.30	0.22
Untreated	6.21	0.14	0.17	29.50	0.29	0.22

MAA = Month After Application

No significant difference was found among means in the same column due to Duncan's Multiple Range Test at 5% level.

CONCLUSIONS

Based on weed control provided by propaquizafop, toxicity effect on legume, legume coverage, and rubber tolerance mentioned above, it can be concluded that the 0.1 and 0.15 kg/ha are the best rates of propaquizafop for weed control in legume establishment. This herbicide is particularly effective against gramineous weeds, i.e. *E. indica*, *P. conjugatum*, and *D. adcendens*.

According to Bayer Indonesia (1991) propaquizafop is also effective against other gramineous weeds which are common in rubber plantation such as *Brachiaria* sp., *Echinochloa* sp., *Setaria* sp. and *Cynodon dactylon*. Therefore, propaquizafop could be expected to solve gramineous weed control problem in rubber plantations in Indonesia.

Slight to medium toxicity on young legume leaves disappeared by 6 weeks after application and did not alter the ultimate growth of legume. Propaquizafop applied on the soil surface is safe to young rubber.

Further studies including the herbicide cost-effectivenees are still needed to develop the use of propaquizafop on a commercial scale.

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PEROXIDASE ACTIVITY AND ISOZYME PATTERNS OF SOME AQUATIC WEEDS IN THAILAND

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ABSTRACT

Peroxidase activity and isozyme patterns of some aquatic weeds commonly found in Thailand were investigated. In the assay of peroxidase activity, pyrogallol, guaiacol and gallic acid were used as substrates. The peroxidases of *Echhornia crassipes*, *Spirodella* sp. and *Salvinia* sp. were most active with guaiacol as the hydrogen donor, followed by the activities with pyrogallol. Much less activity was given with gallic acid. The peroxidases of the *Azolla* species exhibited relatively very low activities, were more active with pyrogallol than with guaiacol, and gave only slight reaction with gallic acid. The polyacrylamide gel electrophoretic patterns of the peroxidases of *E. crassipes* and *Salvinia* sp. were similar, both having four bands with equal mobilities. The peroxidase pattern of *Spirodella* sp. showed five isozyme bands. The densitometer tracings of the electrophoretic bands of the *Azolla* species revealed similar isozyme patterns for *A. caroliniana*, *A. filiculoides* and *A. nilotica*. In addition to two common small peaks, the peroxidase pattern of *A. mexicana* showed two high peaks while that of *A. microphylla* had a single low peak.

INTRODUCTION

Weeds, in general and not disregarding aquatic weeds, are hardy, ubiquitous plants. Peroxidases are well known to play important roles in the defence mechanisms of plants against environmental stresses, so it was deemed worthwhile to investigate the activity and isozyme patterns of some aquatic weeds in Thailand. The peroxidase gene of a highly resistant aquatic weed might then be transferred by genetic engineering to confer resistance to economically important crops such as rice.

MATERIALS AND METHODS

Samples of aquatic weeds were collected from ponds in the Kasetsart University compound. Whole plants were washed free of mud and dirt under running water and then were finally rinsed with distilled water. Using cooled mortar pestle, plant tissues to be assayed were ground at a ratio of one gram

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sample to 5 ml of 0.01 M phosphate buffer, at pH 6.0. The homogenate was centrifuged for 30 minutes at 15,000 rpm in a Sorvall refrigerated centrifuge. The supernatant was used as a source of peroxidase (Hammerschmidt *et al.* 1982) and for polyacrylamide gel electrophoresis. Peroxidase activity with pyrogallol and gallic acid as substrates were assayed according to the method of Clare *et al.* (1966), and with guaiacol as substrate by the method of Nadolny and Sequeira (1980).

RESULTS AND DISCUSSION

The peroxidase of *Salvinia* sp. leaves and roots as seen in Table 1 has about the same activities with pyrogallol as substrate, but with guaiacol that of the roots has higher activity than that of the leaves. The peroxidase of *Spirodella* sp. is more active with guaiacol than with pyrogallol, probably because the roots are included in the whole plant.

Table 1. Average peroxidase activities of *Salvinia* sp. and *Spirodella* sp. with pyrogallol and guaiacol as substrates.

Aquatic weeds	Peroxidase activities*	
	pyrogallol	guaicol
Salvinia sp.		
leaves	1.2	1.0
roots	1.7	2.7
Spirodella sp.		
whole plant	2.8	3.9

* Change in absorbance $min^{-1}mg^{-1}$protein at 420 nm for pyrogallol, at 470 nm for guaiacol.

The peroxidase in the *E. crassipes* roots is more active with pyrogallol than that in the leaves, but with guaiacol the enzymes in both leaves and roots have the same high activity (Table 2). With gallic acid, the root peroxidase is more active than the leaf enzyme.

The peroxidase activities of the *Azolla* species given in Table 3 are relatively low with all three substrates. However, the activities with pyrogallol are higher than with guaiacol and very slight with gallic acid. *A. microphylla* has the lowest peroxidase activity of all the *Azolla* species.

Figure 1 shows the electrophoretic patterns of the peroxidases of *Spirodella* sp. and *Salvinia* sp. The peroxidase of *Spirodella* sp. has five bands while that of *Salvinia* sp. has four bands. Of all the bands, two of those belonging to *Spirodella* sp. have the highest mobilities.

Table 2. Average peroxidase activities of *E. crassipes* with pyrogallol, guaiacol and gallic acid as substrates.

	Peroxidase activity*		
	pyrogallol	guaiacol	gallic acid
leaves	6.3	10.0	0.9
roots	8.3	10.0	1.6

* Change in absorbance $min^{-1}mg^{-1}$protein at 420 nm for pyrogallol and gallic acid, at 470 nm for guaiacol.

Table 3. Average peroxidase activities of *Azola* species with pyrogallol, guaiacol and gallic acid as substrates.

Weed species	Peroxidase activity*		
	pyrogallol	guaiacol	gallic acid
A. caroliniana	0.49	0.10	0.05
A. filiculoides	0.57	0.29	-
A. mexicana	0.33	0.11	0.08
A. microphylla	0.25	0.02	0.04
A nilotica	0.53	0.15	0.07

* Change in absorbance $min^{-1}mg^{-1}$protein at 40 nm for pyrogallol and gallic acid, at 470 nm for guaiacol.

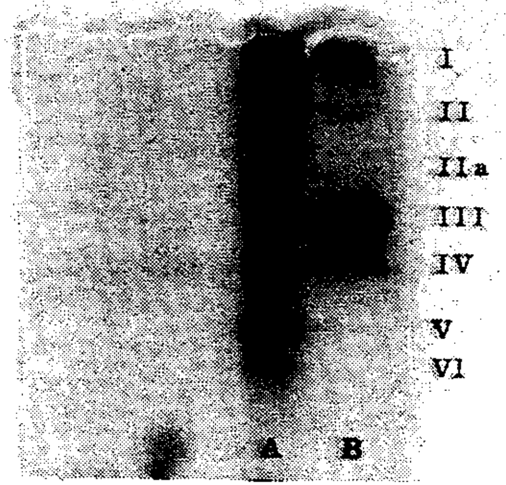

Figure 1. Electrophoretic patterns of the peroxidases of A) *Spirodella* sp. and B) *Salvinia* sp.

The densitometer tracing of the gel electropherogram of the peroxidase of five *Azolla* species is shown in Figure 2. The peroxidase of *A. caroliniana, A. filiculoides* and *A. nilotica* have almost identical patterns while that of *A. mexicana* and *A. microphylla* have two low peaks common to both of them. However, while *A. mexicana* has in addition, two distinct peaks *A. microphylla* has only one.

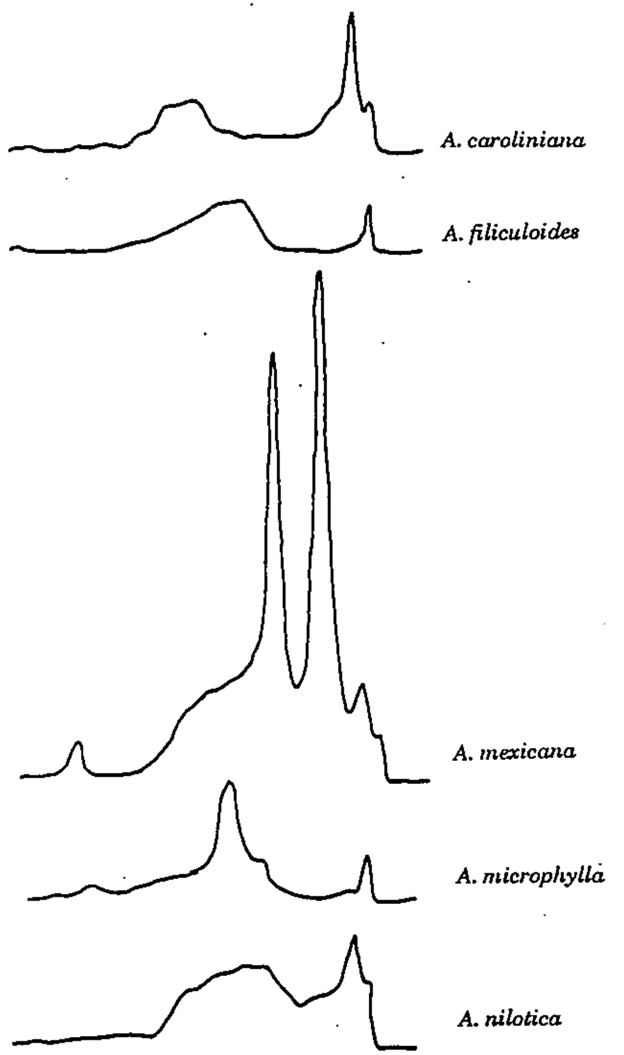

Figure 3. Densitometer tracing of gel electropherogram of *Azolla* spp.

It is interesting to note that the aquatic weeds herein studied have bands II and III. These peroxidase bands have been observed by Farkas and Stahmann (1966) and Solymosy *et al.* (1967) to be present only in virus-infected and senescent Pinto bean leaves but not in healthy tissues. These isozyme bands were also found to be most active with guaiacol as substrate (Farkas and Stahmann 1966). The prominent presence of these bands in *Eichhornia crassipes, Spirodella* sp. and *Salvinia* sp. and their high peroxidase activities could be a contributing factor to the hardy nature of these aquatic weeds. *Azolla* is not so ubiquitous as the other samples, indicating that it is not so hardy a plant. It so happens that the peroxidase activity of *Azolla* is very weak. At present, *Azolla* is cultivated as a source of fertilizer and for feeds. *A. nilotica* is even used as human food.

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WEED UTILIZATION

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ABSTRACT

Advocating that weeds be used presents a dilemma as these plants are, by definition, not wanted and generally considered to be useless or a nuisance. However, some weeds can be beneficial in some situations. This is particularly so for aquatic weeds. Examples of such situations are examined and the range of uses to which weeds can be put is outlined. Particular emphasis is given to water hyacinth and the use of wetland ecosystems for the treatment of wastewaters.

It is concluded that utilization of a weed should be encouraged where it can contribute to its control. However, care should be taken that this does not foster alien weeds that have the potential to be a considerable nuisance elsewhere.

INTRODUCTION

However we define weeds, whatever words we choose to distinguish them from other plants, whatever language we use to describe what weeds are, it is universally agreed that weeds are plants that are not wanted and consequently have no value. It is a contradiction in terms to find weeds useful, for then they are no longer weeds. In contrast, plants for which there is an identified use are beneficial and are often planted or harvested in order to obtain that benefit.

Unfortunately for those who like things to be well ordered, there are some plants that are highly desirable in some situations and most unwelcome in others. For example, self-seeded rice plants in irrigation drains can inhibit the flow of water from rice paddies, where the same species is being cultivated for its grain. In this case, the feature of the plant which causes it to be beneficial is not the one causing it to be a problem.

In other cases where the same species may be a nuisance in one situation and a benefit in another, it can be the same characteristic of the plant which brings about both effects. For example, the capacity for vigorous growth in shallow waters of many emergent aquatic plants, such as *Typha*, cause them to be a weed problem in ditches and drains on one hand, and on the other to stabilise wetland systems, preventing erosion, promoting good water quality and providing a habitat for many desirable birds and animals.

The capacity of some plants to be weeds in one situation and beneficial in another seldom provides a difficulty in the short term, or when dealing with

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single purpose systems. However, serious dilemmas can result when resource managers are concerned with longer term issues or with formulating strategic management plans in regions where there are a range of systems with different purposes for human communities.

In this paper I propose to outline some of the uses that have been advocated for weeds. Because of the nature of this conference and the types of situations and plants with which we are mainly concerned, I shall emphasise the plants which are most often weeds but for which uses can be found, rather than which are widely recognised to be beneficial but which may occasionally be a nuisance. Furthermore, I am concerned with the management of weed problems on a regional and national basis rather than in restricted localities.

I propose to illustrate some of the complexities of these situations by reference to examples of weed plants that have been found to be useful while continuing to be regarded as weeds by most managers. I will also refer to whole ecosystems which are clearly beneficial but which may harbour weedy species. Most of my examples will be drawn from aquatic plants as the distinction between weed and beneficial plants is often most confounded in aquatic situations.

Following this, I will explore some of the different attitudes that are taken towards weeds and weed management by different cultures and different communities. This will allow me to examine the use of weeds as a component of a weed management program.

Finally, I will attempt to outline a philosophy which reconciles the need for human beings to develop and manage environmental resources for their own interests, and the need for human beings to recognize their ultimate dependence on those environmental resources which must consequently be managed sympathetically and with understanding.

WEED UTILIZATION IN GENERAL

Many weed plants have a capacity for high reproductive and vegetative growth. The former leads to rapid spread of the infestation or re-infestation following control, and the latter to the establishment of vigorous populations that often interfere with the desired use of the infested system. However, both these attributes are highly desirable for plants that have an identified use. Thus it is not surprising that managers cursed with a weed problem have sought to change curse to benefit.

This approach is particularly applicable to plants that are alien to the region, because the benefits of native plants have usually been established by the people who live there. Indeed, I contend that there is little sense in making use of native plants when they occur as weeds. If they have a worthwhile value, it would be more efficient to cultivate them for that purpose, or to collect the

material from naturally occurring stands. In either case they no longer meet the definition of a weed and should concern us no further.

Potential uses of aquatic weeds have received particular attention (Boyd, 1972, 1974; Little, 1968, 1979; Rudescu *et al.*, 1965; Sculthorpe, 1967; National Academy of Sciences, 1976; Edwards, 1980; Thyagarajan, 1984; Gopal, 1987; Joyce, 1990). For example, suggestions for use of aquatic weeds have included: composting and soil conditioning, seed bed and growing medium for vegetables and mushrooms, food for a wide range of animals, human food, paper and fibre production, construction of baskets and mats, thatching, waste water treatment, biogas production, in aquaculture, and as sources of chemicals.

In addition, some species are desired for their aesthetic beauty while others have religious significance (Sculthorpe, 1967; Mitchel, 1986). Moreover, naturally occurring plant populations are important components of aquatic ecosystems (Gaudet, 1974; Wade, 1990).

Examples of utilization of terrestrial weeds are more difficult to find, but two examples can be cited. In Australia the attractive blue-flowered alien weed of annual pastures, *Echium plantagineum* L., is variously given the common names Paterson's Curse or Salvation Jane, depending on the natural fertility of the infested pasture. When this is normally high, as in higher rainfall areas, the plant is regarded a curse. By contrast poor pastures can be improved by the presence of the plant, especially in dry periods. Indeed, Piggin (1977) showed that the so-called weed had a similar nutritive value to subterranean clover, *Trifolium subterraneum* L., and was more resilient under heavy grazing. Furthermore, apiarists have opposed programs to introduce biological control of the plant on the grounds that it is important for honey production (Delfosse & Cullen 1980). Another example is provided by alang-alang (*Imperata cylindrica* (L.) Beauv.), which infests many areas of Indonesia. Rhizomes of this plant are used to prepare a medicine for stomach disorders and a refreshing drink, while the leaves are used for thatching (Rifai & Widjaja, 1979).

Utilization of weeds can involve single species, as in the preceding two examples, or vegetation communities, as in the use of wetland systems to treat wastewaters. Some species may be used for several purposes, as in the case of the water hyacinth *Eichhornia crassipes* Mart. Solms-Laubach (Gopal, 1987), while some uses may involve a number of species as in the case of fibre production (Rudescu *et al.*, 1965.

Some forms of utilization are passive and require little if any technical input, such as disposal of waste waters into natural swamp systems. However most uses require harvesting of material either manually (low-tehnology) or mechanically (high-technology). The former is appropriate where labour costs are low. The latter should only be advocated when there is sufficient back-up to maintain machinery in good working order in a cost effective way.

In the same way some uses of harvested material require little technological input and are appropriate where labour costs are low and commercial opportunities favour the development of village industries. Uses such as drying reeds to make mats comply well with these situations but are not economically sustainable when labour costs are high, as in Australia. Other uses require the development of technical skills and experience. The most outstanding example of this is the exploitation of reed plants (principally *Phragmites australis* (Cav.) Trin. ex Steud.) in swamps of the Danube delta (Rudescu *et al.*, 1965; Rudescu pers. comm.). Large quantities of material are required for the industrial processing of fibre and a number of side products, including furfurol, alcohol, yeast and fertilizers. Access to the swamps by conventional harvesting equipment is possible when water levels are low, but the wheels on these machines initially damaged the rhizomes and new wheels had to be developed that could spread the weight over large areas of ground. Plants are harvested in the winter by cutting the canes above the rhizomes. No special husbandry techniques are required as a crop of new canes grows in the following spring. In the mid 1970s some 20 years after this pattern of intensive utilization commenced, 12,500 ha of reed swamp yielding about 10 tons ha^{-1} were being harvested (National Academy of Sciences, 1976).

EXAMPLES OF UTILIZATION

Two contrasting examples of utilization of aquatic weeds serve to illustrate the potential. The first is the use of water hyacinth, a single species which is a notorious weed of tropical and sub- tropical freshwaters, typically where it is an alien plant. The second example is a brief review of the use of swamp systems for the treatment of wastewaters. This example concerns a complex of species which are generally native, although many have the capacity to grow vigorously in constructed waterways and reservoirs, thereby interfering with the designed use of these water bodies and behaving as weeds.

Water hyacinth

Water hyacinth was among the first weeds to be investigated for possible uses. The species comes from South America and was spread from there in the later part of the last century in USA, SE Asia and Australia. The plant reproduces vegetatively by producing horizontal stolons which develop daughter plants from terminal buds. Perkins (1972) recorded that in Louisiana, USA, one plant multiplied to 248,181 plants in 90 days - equivalent to a doubling time of 5.0 days, while Westlake (1963) has estimated that this species has an annual mean production of 15-44 t dry matter ha^{-1}.

The first recorded suggestion for using water hyacinth vegetative material was in 1917, when Finlow & McLean (1917) reported on their investigations near Dacca in Bangladesh on the value of rotted or dried water hyacinth as a soil fertilizer. Since then there has been a very large number of investigations that have encompassed the whole gamut of possibilities listed earlier for aquatic weeds except for thatching, though its uses as human food can cause itching (Burkhill, 1966). The possibilities have been extensively reviewed by Little (1979), Philipp *et al.* (1983), Thyagarajan (1984), and Gopal (1987). Most attention has been paid to use of the plant as animal fodder, as a soil conditioner, for making paper or boards, for the generation of biogas, and for the control of water pollution. The main problem for all these forms of use except the last is that 90%-95% of the living plant is water. Thus 100 t of living matter has to be harvested or eaten to obtain 5-10 t of dry matter, most of which is of limited value. This problem is exacerbated when material has to be transported from the harvesting site to the place where it is to be used or processed, even if it is partially dried beforehand.

Despite numerous tests, water hyacinth has to be supplemented with other substances for it to be effective as animal fodder: animals fed only on water hyacinth, even when dried, generally lose weight and condition. However, pigs and chickens seem to benefit from freshly harvested or dried water hyacinth material placed in their pens, but not to the extent to make it worthwhile to transport the material any distance. Paper and board made from dried water hyacinth is generally of poor quality and does not compete with paper made from wood fibre. However, the weed is an appropriate soil conditioner, and can provide economic benefits if used properly on farms close to the site where it is harvested.

During the last two decades, water hyacinth has been extensively investigated for treating wastewaters of various sorts, though most studies have concerned sewage. Gopal (1987) provides summary tables of a number of such investigations. The plant has a number of attributes that make it particularly suitable for wastewater treatment systems. It grows rapidly, has a high demand for nutrients including a luxury uptake for phosphorus (Haller *et al.*, 1970), is capable of taking up heavy metals and is readily harvested. Unfortunately it does not appear to provide oxygen into the water as do some emergent plants, and frequent harvesting of large areas is needed to remove sufficient nutrients to make the system effective. Estimates of the population whose sewage could be treated by one hectare of water hyacinth vary from 100 to 800 persons (Gopal, 1987). Perhaps it is significant that, in spite of all these studies and a considerable demand for low cost, low-technology methods of treating human sewage, no such system employing water hyacinth is widely used.

The use of water hyacinth to generate biogas (a mixture of methane and carbon dioxide produced by anaerobic digestion of organic matter) has attracted considerable attention. Much effort has been directed at developing a household size digester that could be used at village level. Other studies have examined the possibility of high technology plants such as the one at Disney World in Florida, which used water hyacinth harvested from sewage lagoons (Gopal, 1987). Unfortunately the literature on this topic is confusing. Some studies report enhanced production if cow dung is added and others found no difference. Loading rates and methods, the nature of additions and system designs all differ and there is clearly more work to be done before a system that is suitable for wide acceptance and use is available.

Swamp systems for the treatment of sewage

Swamps or marshes are shallow wetlands dominated by emergent aquatic plants, such as *Typha* (cumbungi) or *Phragmites* (common reed), which in other situations are serious weed. Swamps are generally formed in shallow depressions in the landscape where water accumulates over impermeable soils, and are therefore natural sinks where matter transported by water from the catchment will accumulate. The substratum is characterized by high organic matter, low or no oxygen, and relatively high concentrations of plant nutrients such as nitrogen and phosphorus. This substratum is consolidated and bound together by the rhizomes and roots of the emergent swamp plants that are adapted to grow in such anoxic conditions, principally by a combination of anatomical and physiological modifications which transport oxygen down the erect serial stems into the submerged rhizomes and roots. Indeed sufficient oxygen is provided for it to leak into the surrounding material in the immediate vicinity of the roots to create a network of oxic rhizospheres permeating the otherwise anoxic substratum.

The presence of oxic microsites in predominantly anoxic conditions provides the mix of conditions necessary for the bacterially mediated nitrogen cycle to operate. Thus ammonifying bacteria produce ammonia from proteins derived from decay of organic matter, nitrifying bacteria mediate the change of ammonia to nitrite and nitrate in oxic conditions, and denitrifying bacteria reduce nitrate to dinitrogen gas and nitrous oxide which are released into the atmosphere. The plants also assimilate nitrogen and phosphorus, often in luxury amounts, while phosphorus can be adsorbed by inorganic and organic particles in the substratum.

In addition to these mechanisms which can oxygenate wastewater passing through a swamp and remove phosphorus and nitrogen from it, swamps also clarify through-flow wastewater and, markedly reduce the numbers of faecal coliform bacteria in it. Furthermore the nature of the system and the

adaptations of the plants in it enable swamps to receive and treat wasterwaters with high biochemical oxygen demand that are harmful to other aquatic systems.

Systems to take advantage of these mechanisms were first constructed by Seidel (1976) and Seidel *et al.* (1978), while Kickuth (1984) was the first to emphasize the importance of the rootzone as the site for most treatment processes. The first systems consisted of trenches through which the wastewater flowed, sometimes above the surface. In some cases wastewater was sprayed onto the surface so that it percolated downwards. A novel system with a vertical uplow has been developed by CSIRO in Australia (Breen *et al.*, 1989; Breen abd Chick, 1989; Breen, 1990; Mitchell *et al.*, 1990).

Systematic studies of the effectiveness of natural swamps for treatment of sewage, for example by Van der Valk *et al.* (1978), have shown that they are not consistently reliable in removing polluting substances. Their performance tends to alter with the seasons and to be affected by climatic conditions. While they may remove high propertions of phosphorus and nitrogen during the summer, they generally remove less nitrogen and may even release phosphorus during the winter. Thus, of eleven swamps which had been sampled over a full annual cycle and for which Van der Valk *et al.* examined published data, five were net sinks and three were seasonal sinks for nitrogen, while six were net sinks and four were seasonal sinks for phosphorus. One swamp did not trap nitrogen and two had no data on this element, while one had no data for phosphorus.

Finlayson *et al.* (1986) investigated the capacity of a natural swamp to treat secondary sewage effluent from Thredbo Village in the Snowy Mountains, Australia. They found that most of the effluent travelled through the swamp in surface channels and therefore was not in effective contact with the substratum and root zone of the swamp. Thus while there was some evidence of amelioration of water quality parameters in the effluent (Table 1), it was almost certainly below the capacity of the system.

Table 1. Comparison of the mean values and 95% confidence limits (in parentheses) for the inflow and outflow effluent from the wetland below Thredbo Sewage Treatment Works during 1982 and 1983. (Taken from Finlayson *et al.*, 1986.)

	Inflow		Outflow	
Temperature (° C)	11.4	(3.9)	11.2	(2.6)
Dissolved oxygen (mg L^{-1})	8.4	(1.5)	5.9	(1.2)
Turbidity (NTU)	4.7	(1.5)	2.9	(1.1)
pH	7.6	(0.3)	6.6	(0.2)
Conductivity (1 S m^{-1})	27	(58)	214	(48)
Total phosphorus (1 g L^{-1})	2926	(724)	2064	(660)
Nitrate-nitrite nitrogen (1 g L^{-1})	10665	(8171)	6968	(6017)
Ammonia nitrogen (1 g L^{-1})	15369	(7318)	9887	(5512)

There are three broad types of constructed wetlands that have the capacity to successfully treat sewage effluent, though performance is seldom consistent. These types are:

- artificial wetlands with a horizontal flow through trenches filled with gravel and planted with emergent aquatic macrophytes,
- artificial wetlands consisting of a gravel-filled trench planted with emergent aquatic macrophytes with a vertical downward flow of effluent distributed along the length of the trench and collected from a bottom outlet at one end, and
- gravel-filled systems supporting emergent aquatic macrophytes where the effluent is delivered into the bottom of the system so that it flows vertically upward through the root-zone and is collected from one or more points around the upper edge of the system.

Examples of performance for various constructed wetland systems in treating wastewaters are given in Table 2. In general, all constructed systems are capable of reducing suspended solids and biochemical oxygen demand and decreasing total nitrogen and numbers of faecal coliform bacteria. Reduction of total phosphorus levels is, however, very variable. Performance is also substantially affected by the hydraulic nature of the system in terms of flow through it, the degree of mixing and retention times. Of principal importance is the extent to which the wastewaters pass through the root zone or are able to by-pass it.

Table 2. Treatment of wastewaters in constructed wetlands of various types

	Horizontal flow[1]	Vertical upflow[2]	Vertical downflow[3]
Chem. Oxygen Demand[4]			
IN (mg L^{-1})	161.1	391.2	720
OUT (mg L^{-1})	79.1	50.4	245
% load reduction[5]	58.8%	91.4%	68%
Total Nitrogen			
IN (mg L^{-1})	57.9	31.7	54.2
OUT (mg L^{-1})	47.1	1.4	26.4
% load reduction[5]	32%	97%	43%
Total Phosphorus			
IN (mg L^{-1})	8.8	5.4	16.7
OUT (mg L^{-1})	10.1	0.2	11.8
% load reduction[5]	2.9%	97.1%	31%

1. Chicken abattoir effluent (Breen & Chick, 1989)
2. Primary settled sewage in experimental microcosmos (Breen & Chick, 1989)
3. Raw sewage in cascade of eed beds (Lienard *et al.*, 1990)
4. Chemical oxygen demand is very similar to Biochemical Oxygen Demand but can be measured more precisely
5. Calculated from total amounts obtained by multiplying concentration by volume.

Although the performance of these swamp systems in treating wastewaters is variable and generally better in warmer than cooler conditions, they are low cost, low technology systems that are affordable by communities which currently are able to take advantage of the highly engineered systems that are widely used in large cities.

USING WEEDS: A CONUNDRUM FOR MANAGEMENT

The whole concept of assigning weed status to a plant is a consequence of human exploitation of the environment, either because the weed interferes with human purposes or because it is present in unusually large numbers as a result of human manipulation of the environment. In the latter cases the "weed" is an ecological symptom of a disturbed ecosystem (e.g. *Salvinia molesta* D S Mitchell on Lake Kariba, Africa on the border between Zambia and Zimbabwe - Mitchell, 1969). The principles of weeds and weed management are not evident in human history until the advent of agriculture with its development of systems in which unwanted plants are a nuisance. Even so, human societies which tend to live in harmony with their environment generally exercise a less rigorous approach to the maintenance of monocultures through the practise of multiple cropping and tolerance of non-crop plants that are perceived to have some use.

The logical extension of this approach is the disappearance of weed problems merely by changing human attitudes. However such an extension would neglect the real harm that can be done by weeds in terms of reduced productivity. It follows that weed management programs should primarily aim at achieving a situation in which there is minimum interference with intended purposes of the weed-infested system. If this aim can be assisted by promoting use of the weed, then it is sensible to include this as a component of the program. However, in many cases the situation is far from straightforward as the examples I have provided illustrate. In these situations it is necessary to distinguish primary purposes from potential consequences. Thus, for example, a swamp system that is feasible, should not be excluded from being used even though it may harbour some potential weeds. In the event that the swamp provides a possible source of weed infestations, it should be possible to devise a management program to minimize or prevent the weed problem while allowing the swamp to continue to operate as a wastewater treatment system.

Alien weeds provide a more complex problem, as Gopal and Sharma (1979) and Gopal (1987) have pointed out. If an effective use is found for a weed, in a country where it is alien, there is a real possibility that an industry may develop that is dependent on the plant, so that pressure builds up against its control, even though the problems caused by its infestation continues. The continuing presence of an alien population of plants also increases the risk of spread to previously uninfested systems. This is most serious in the case of water weeds, as the water resources that are adversely affected are often in limited supply.

CONCLUSION

Ever since human populations began to manage their environment to exploit it more efficiently, they have faced the dilemma of balancing their demands on the environment against the need to sustain the environmental resources on which they ultimately depend for survival. Elements of this dilemma are manifested in the conflict between controlling weed plants that are also potentially useful. Unfortunately, there is no sure recipe for consistenly taking the right decisions in these situations. However a sensible principle that can be used as a guideline to decision making is to test the sustainability of the proposed action. Actions that are sustainable and do not lead to serious or irreversible environmental degradation could be instituted - with adequate monitoring if there is any uncertainty. Actions that are probably not sustainable should be avoided.

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WEED CONTROL IN SOYBEAN WITH REFERENCE TO CROP-WEED COMPLEXITY

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ABSTRACT

Agroecosystem is a domesticated ecosystem: it is controlled externally to be able to produce yield. Yield or food is produced by primary producers, and weeds are also primary producers. They compete for the same environmental factors. Nutrient and soil moisture once absorbed by weeds can not be utilized anymore by crops. The development of a critical period for weed control and its economic threshold in soybean cropping system are discussed.

INTRODUCTION

Agroecosystems are domesticated ecosystems that are intermediate between natural ecosystems, such as grasslands and forests on the one hand, and man-made ecosystems such as cities on the other.

Like natural ecosystems they are solar powered, but differ in that: the auxilliary energy sources that enhance productivity are processed fuels, animal and human labor rather than natural energies. Diversity is greatly reduced by human management to maximize yield of a specific product. The dominant plants are under artificial rather than natural selection, and control is external and goal oriented rather than internal via subsystem feedback (Odum, 1984).

Figure 1 contrasts the relationships between components of natural and agro-ecosystems. Figure lA illustrates the nutrient-flow between major components of a natural ecosystems, whilst Figure 1B shows how nutrient flows are changed by agricultural management. This four-compartment model is an oversimplified abstraction of ecosystem nutrient cycling, but it serves to illustrate the impact of some management technologies. In this paper the impact of weeds as a component of primary producers and agroecosystem management will be discussed with soybean as the crop.

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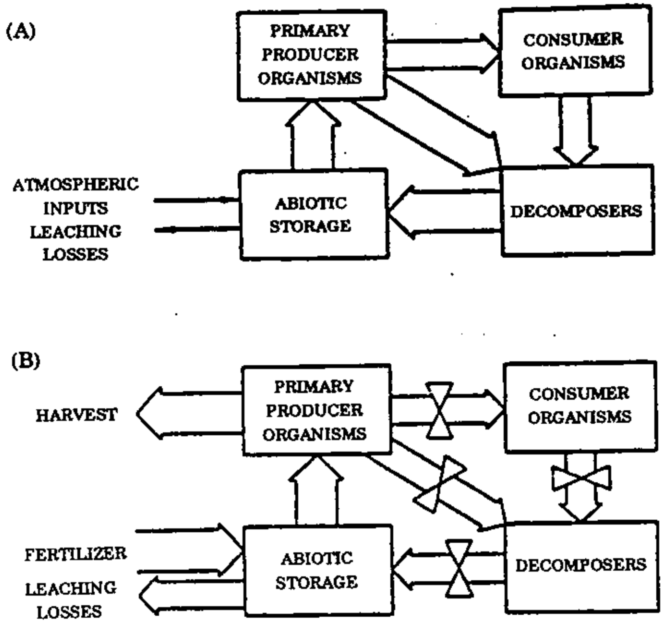

Figure 1. Nutrient circulation through major components of (A) natural ecosystems and (B) agroecosystems. In natural systems internal cycling of nutrients greatly exceeds flowthrough expressed as atmospheric inputs and leaching losses (top). In agroecosystems, management techniques include control of consumer organisms with insecticides, control of primary producers with herbicides as well as cultivation and harvest, and control of decomposition through cultivation and plowing. Fertilizer becomes the major nutrient input to the agroecosystem, and harvest constitutes a major output, but leaching losses become larger also. (From Odum, 1971).

WEED INTERFERENCE

Of the 10 possible interactions specified by Odum (1971) three represent the negative effects of association - competition, amensalism and parasitism. Weeds interfere with crops, by competing for resources, and excessive populations of weeds may reduce soybean yield by 20 - 90 % (Sundaru & Syam, 1977; Tjitrosemito, 1987).

Weed Species in Soybean Crop

Soybeans in Indonesia may be planted in either lowland rice or upland areas, and the composition of weeds varies depending on where soybean is planted (Table 1).

Table 1. Weeds in soybeans in Indonesia

Species	Lowland	Upland
Grasses		
Oryza sativa	+	-
Echinochloa crus-galli	+	-
E. colonum	+	+
Digitaria adscendens	+	+
D. ciliaris	-	+
D. setigera	-	+
Cynodon dactylon	+	+
Eleusine indica	+	+
Polytrias amaura	+	+
Leersia hexandra	+	-
Imperata cylindrica	-	+
Paspalum paspaloides	+	-
Broadleafs		
Crotalaria anagyroides	+	+
Borreria alata	-	+
B. laevis	-	+
Ageratum conyzoides	+	+
Eleutheranthera ruderalis	+	+
Phyllanthus niruri	+	+
Physalis minima	+	+
Celosea argentea	-	+
Cleome rutidospermum	-	+
Heliotropium indicum	+	+
Mimosa pudica	+	+
Emilia sonchifolia	-	+
Oxalis spp.	+	+
Ipomoea triloba	-	+
Croton hirtus	-	+
Porophyllum ruderale	-	+
Portulaca oleraceae	-	+
Sedges		
Cyperus rotundus	+	+
C. difformis	+	-
C. iria	+	-
Fimbristylis dichotoma	+	-
F. miliacea	+	-

Sources : Sundaru & Syam, 1977; Tjitrosemito *et al.*, 1987; Sardjono *et al.*, 1990.

In lowland rice areas the major weeds are ratooned rice (*Oryza sativa*), *Echinochloa colonum, Paspalum paspaloides, Cyperus iria* and *C. difformis*, while in upland conditions the main weeds are *Cyperus rotundus, Digitaria ciliaris, D. setigera, Borreria alata, B. laevis*, and *E. indica* (Sundaru & Syam, 1977; Tjitrosemito, 1987; Sardjono *et al.*, 1990).

In upland conditions Sastroutomo and Yusron (1987) noticed that the first weeds to germinate were *Euphorbia prunifolia* followed by *B. alata, D. ciliaris, Phyllanthus niruri, C. rotundus, Eleutheranthera ruderalis, Fimbristylis miliacea* and *Hedyotis corymbosa*. These weeds constitute strong competitors for soybean.

Critical Period for Weed Control

Spitters and van den Bergh (1982) indicated two kinds of natural resources : those continuously available in limited amounts (i.e. light, CO_2, O_2) and those which are available as a limited stock (i.e. mineral nutrients and water). The concept of a critical period for weed control was reported by Nieto *et al.* (1968) as the period in which weeds must be controlled to avoid losses, by ensuring that the crop obtains the limited stock of resources. If this resource is utilized by weeds it is unavailable anymore for the crop.

In soybean, the following results were reported (Tjitrosemito, 1991).

Table 2. Mean yield of soybean (kg/ha) and dry weight of weeds (g/50 x 50 cm^2), under various control treatments (Tjitrosemito, 1991)

Treatments	Yield (kg/ha)	Weed dry weight (g)
1. Weeded up to 10 DAP	452	54.50
2. Weeded up to 20 DAP	583	43.50
3. Weeded up to 30 DAP	972	21.30
4. Weeded up to 40 DAP	1338	8.80
5. Weeded up to 50 DAP	1392	5.50
6. Weeded up to 60 DAP	1506	0.83
7. Weeded up to harvest	1504	1.00
8. Weeded from 10 DAP up to harvest	1364	1.70
9. Weeded from 20 DAP up to harvest	1368	1.21
10. Weeded from 30 DAP up to harvest	968	1.12
11. Weeded from 40 DAP up to harvest	608	0.99
12. Weeded from 50 DAP up to harvest	450	0.81
13. Weeded from 60 DAP up to harvest	405	0.60
14. No weeding	415	69.90
LSD (5%)	169	
CV	17%	

DAP = Days After Planting

From this data the critical period for weed control was calculated to be 20 - 40 DAP (Figure 2). This means that weeding can be delayed until 20 DAP, and provided that after 20 DAP weeds are controlled the crop will perform well. Munandir and Kujaeni (1990) reported that the critical period for weed control in soybeans was 30 - 45 DAP. It is understandable considering different soybean varieties, planting distance, weed composition, soil types and climate as well as time of planting.

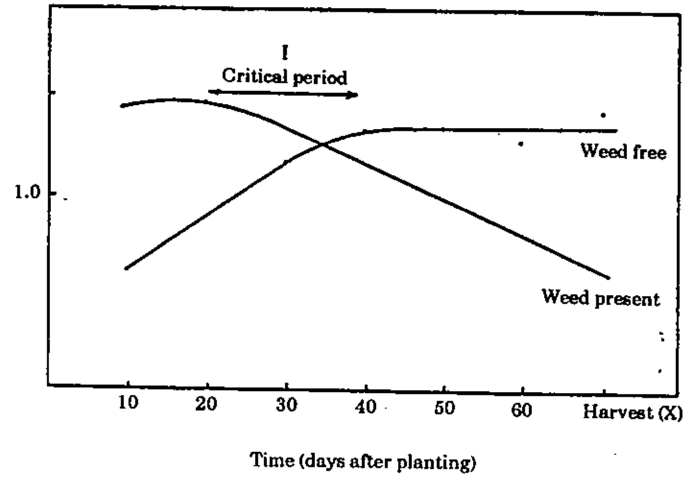

Figure 2. The effect of "weed free" and "weed present" periods on yield of soybean. The critical period is 20-40 DAP (Tjitrosemito, 1991).

Threshold level

The relationship between soybean yield under treatments where weedings were not carried out up to harvest and weed dry weight was shown by Y = 1499.69 - 20.28 X (r^2 = 0.99) where Y = soybean yield (kg/ha) and X = weed dry weight (g/50x50 cm), to be linear.

The higher the weed dry weight, the smaller was the yield. The soybean yield could theoretically reach a maximum of 1499.69 kg/ha when weed control is complete (X = 0).

From the relationship between yield of soybean and dry weight of weed, it is possible to derive the relationship between yield increment and dry weight of weed: Z = 20.28 X, where Z = yield increment (kg/ha) and X = dry weight of weeds.

When Z is multiplied by the price of soybean, the equation shows the relationship between income increment (I) and dry weight of weeds: I = 14196 X, where I = Income increment (in rupiah) assuming the price of soybean is Rp 700/kg.

Arjasa & Bangun (1985) in Indonesia reported that weed control in the soybean crop required 40 - 50 man working days/ha. If weedings are done twice and the cost per man working day is Rp 1000 then the total cost of manual weed control (C) is Rp 80 - 100,000. With this information it is possible to calculate the economic threshold of weed control in soybean by equating the income increment and the cost of weeding (Auld *et al.*, 1987): Since I = 14196 X, and C = 100,000, if I = C, then X = 7.00.

So in this particular situation, the economic threshold was 7.00 g/50x50 m^2, at time of harvest. This value is meaningless in itself because it refers to weed dry weight at harvest, but referring to treatments that are able to produce such results, it points to hand weeding up to 40 - 50 DAP. Soybean weeding up to 40 - 50 DAP is still profitable providing the price of soybean is Rp 700/kg, the cost of weeding is Rp 100,000/ha, and the yield is approximately 1,500 kg/ha.

INTERACTIONS BETWEEN WEEDS AND INSECT PESTS

The interaction between soybean crop weed complexity and insect pests was studied by Budiyanto *et al.* (1990). They planted soybean in lowland rice immediately after harvesting the rice and compared the effect of paraquat + diuron, fluazifop-butyl and unweeded control.

The composition of weeds under fluazifop-butyl differed from those of paraquat + diuron or control (Figure 3), because fluazifop-butyl is a grass herbicide. Plots under paraquat + diuron or unweeded control were infested dominantly by *Echinochloa colonum* and *Leptochloa chinensis*.

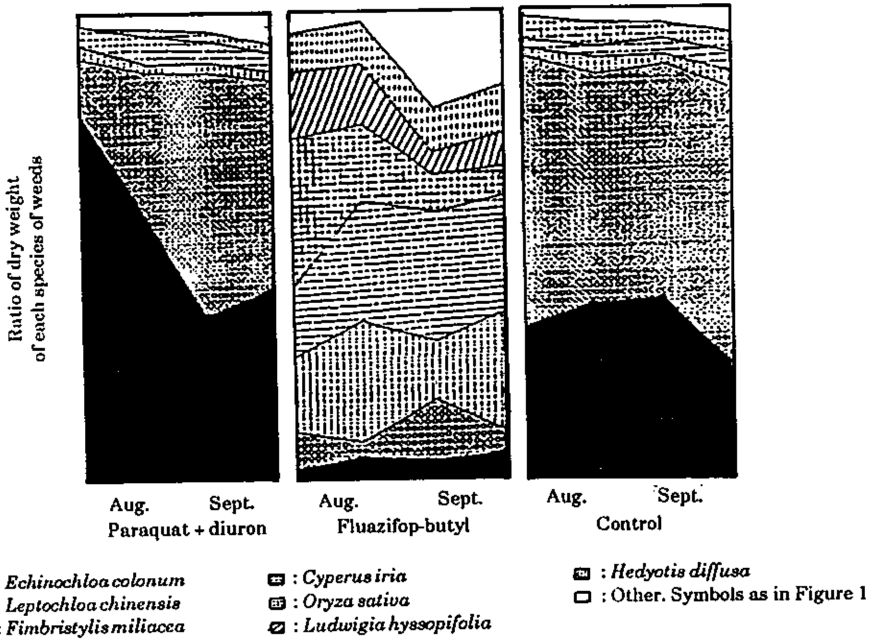

Figure 3. Changes in the ratio of dry weight of each species to total dry weight of weeds in each treatment plot (Budiyanto *et al.*, 1990).

However, the difference was not only in the botanical composition of weeds, but also the level of insect pest attack, mainly by *Etiella hobsoni, E. zinckenella* and *Heliothis armigera*. More than 50% of pods in each plot were attacked by these pests, with about 97% of the infestation due to *Etiella* spp. (Figure 4).

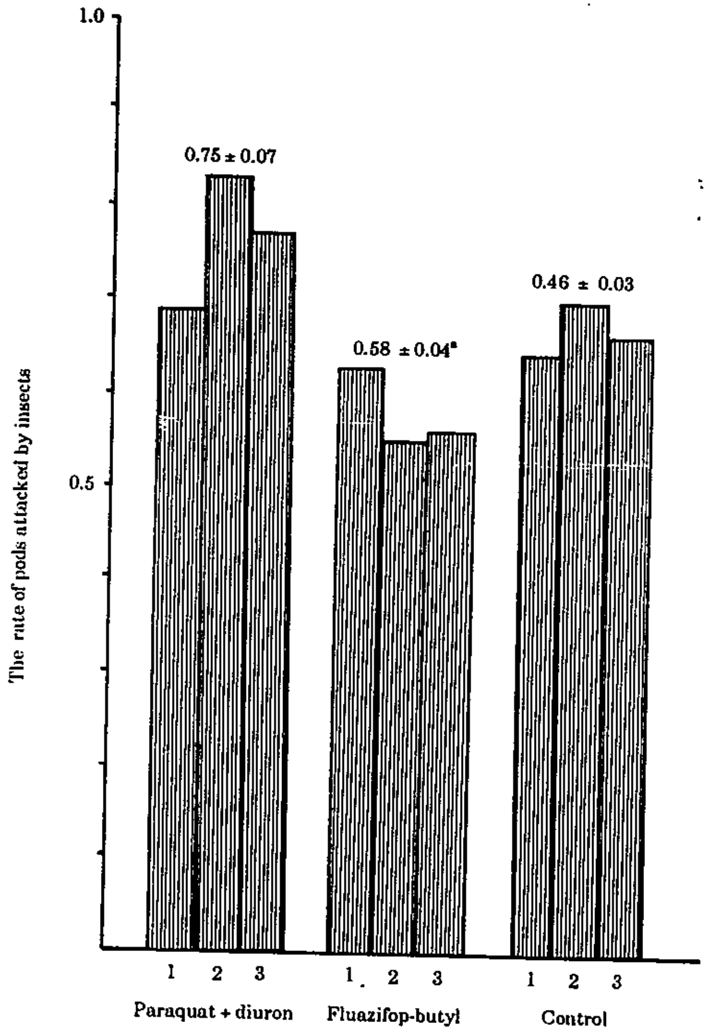

Figure 4. The rate of attack on pods by insects in each treatment (Budiyanto *et al.*, 1980).

Because of the combination of weed infestation and insect pest attacks the yields in the plots dominated by grass weeds were very low (Figure 5), suggesting that excesive weeds in this particular situation offered a shady situation for the insect pests to hide during hot days.

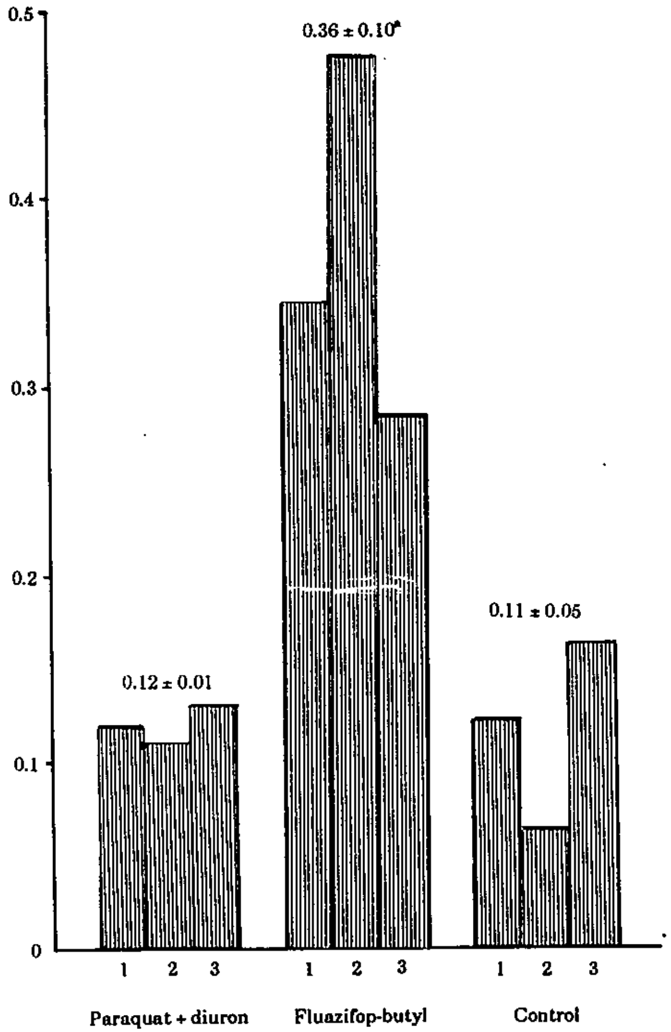

Figure 5. Yield of soybeans in each treatment (Budiyanto *et al.*, 1990).

INTERACTIONS BETWEEN WEEDS AND PATHOGENS

When the stand of soybean is attacked by *Sclerotium rolfsii* the population of soybean will be greatly reduced. This reduction of soybean population will open up space for weeds to infest and proliferate, resulting in low yields due to the reduction of population and the heavy growth of weeds.

Weeds are common hosts of pathogens, e.g. *A. conyzoides* is an alternate host of soybean mosaic (Sinclair, 1983).

IMPACT OF WEED CONTROL ON THE SOYBEAN-WEED COMPLEX

Weed control practices affect the soybean crop-weed complex in two points. Firstly weed control reduces the total plant density in the soybean crop and secondly it increases the value of SDR (Sum Dominance Ratio) of soybean as shown by Tjitrosemito (1987).

The essence of weed control is actually directed toward establishing crop dominance as early as possible. The potentially improved crop production resulting from weed management does not occur as a direct result of the control measure, but it is due to the concomitant availability of resources that resulted from the suppression of weed growth and population. As soybean continues to occupy more space it becomes increasingly difficult for weeds to invade or to have detrimental effects on crop productivity.

Soybeans and other crops can act as a powerful weed control agent by causing a reduction in weed density or shift in weed species composition by causing a biological limitation of resources and reduction in conditions. This is exemplified by the different dry weight of weeds and their composition under different control methods.

When manual weedings were carried out up to 50 DAP the population of *B. alata* was greatly reduced while *E. ruderalis* disappeared altogether and when continuously weeded the population of weeds decreased considerably and *D. ciliaris* also disappeared. While this control seems excessive for this cropping season, the crops in the following season may have smaller problems from weeds provided there is no immigration into the field.

A notable impact of weed control on weeds is the changes in weed botanical composition. Establishment of soybean in areas dominated by alang-alang (*Imperata cylindrica*) using zero tillage alters weed vegetation from one which is dominated by alang-alang into one which is dominated by *B. laevis, A. conyzoides* and *C. hirtus*.

The application of alachor also alters the botanical composition of weeds from one dominated by *D. ciliaris* into one dominated by *B. alata* (Tjitrosemito, 1988).

Shifts in weed species composition within a crop/weed community are relatively common following repeated annual herbicide application.

CONCLUSION

Weeds are always present in agricultural ecosystems, since they constitute the bulk of the seed bank in the soil. The population of soybean relative to the existing weed population is small. The competitive edge for either crop or weed is based on the probability of an initial interaction encountered and the subsequent ability of individuals to grow. The three main factors which affect the outcome of this interference (competition) are spatial arrangement, timing of germination and growth rate of plants.

A soybean plant that is separated from, establishes before, and grows faster than weeds should have the competitive advantage over weeds. If the resources which exist in a limited stock can be absorbed by the soybean and none is available for weeds then the soybean should be most competitive. However, in most situation the population of weeds is always greater than that of soybean and unless the weeds are controlled soybean plants will always be in a disadvantaged position.

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COMPARISON OF GROWTH CHARACTERISTICS OF EARLY MATURING RICE VARIETIES IN SRI LANKA

KATSUYOSHI NOGUCHI[1] AND W.M.D. WASALA[2]

ABSTRACT

There are three kinds of rice varieties in Sri Lanka, i.e., traditional, old improved and new improved varieties. Growth characteristics of these varieties concerning competitive ability to weeds were investigated. One old improved variety, i.e., H-4(4 months variety) and five new improved varieties, i.e., Bg379-2(4 1/2 months), Bg380(4 months), Bg94-1 (3 1/2 months), Bg300(3 months) and Bg750(2 1/2 months) were used in this experiment. The paddy seeds were sown directly by row of 20 cm in width.

H-4 had desirable plant type such as fast stretch at its early stage, the highest growth expectancy, and LAI was comparatively large. The leaves were distributed among upper part of crop canopies in horizontal direction. The higher part from ground surface was kept with relative light intensity under reduced condition. In the case of Bg750, the early growth was remarkable, the plant height was high, although the LAI was small. Then, weed competing ability in Bg750 was somewhat inferior to H-4. Growth characteristics of Bg300 showed relatively strong weed competing ability among new improved varieties owing to its early growth and shading ability. Weed competing abilities of Bg379-2, Bg380 and Bg94-1 were inferior to the above mentioned varieties.

INTRODUCTION

Paddy weeds have been recognized as one of the major problems to increase rice production in Sri Lanka, especially in direct sowing paddy fields. According to the research works at Maha Illuppallama Agricultural Research Station, paddy losses due to weeds ranged from 50% to 74% at no weeding plots (Amarasinge, 1987).

Crops grow in competition with weeds in the field. When crops grow vigorously, weeds growth are retarded. On the other hand, when crops lack vigor, weeds flourish. So, it is very important to make clear the competitive relationship between crops and weeds (Craft, 1975).

There are three kind of rice varieties in Sri Lanka, namely, traditional, old improved and new improved varieties. Presently, over 90% of the entire cultivated extent is under new improved varieties (Herath, 1987). These varieties have played a significant role for contributing higher national yields (Herath, 1987). It was found that there were some different growth charac-

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teristics among these varieties from a point of view of weed control (De Datta, 1979). It would be necessary to look at traditional or old improved varieties again from a viewpoint of competition between crops and weeds. This experiment was carried out in order to make clear among growth characteristics of old improved and new improved varieties concerning the competitive ability of paddy rice to weeds.

MATERIALS AND METHODS

One old improved variety and five new improved varieties having different growing period were used in this experiment, as follows: old improved variety: (1)H-4(4 months variety) New improved varieties: (1)Bg379-2(4 1/2 months variety), (2)Bg380(4 months), (3)Bg94-1(3 1/2 months), (4)Bg300(3 months), (5)Bg750(2 1/2 months).

The paddy seeds were sown directly by row of 20 cm in width on 21st November 1987 after pretreatment for germination. Sowing rate was $10g/m^2$ of air-dried paddy rice. Plot size was 3 m x 2 m with two replications. Management practices and fertilizer application followed the usual procedure recommended by the Department of Agriculture, Sri Lanka. Relative light intensity was measured by a Photometer(NS-2 type, Sansin Kogyo, Japan) with every 10 days interval from 30 days after sowing. Productive structure was investigated by stratified clip method at heading stage of each variety. This experiment was carried out at the Central Agricultural Research Institute in 1987/88 Maha season.

RESULTS AND DISCUSSION

Emergence and growth of paddy rice was favored by moderate rainfall occured in this season. Damage by paddy bug occurred after heading in spite of insecticide application, and paddy yield of some varieties was reduced.

Crop plants, generally grow in competition with weeds in the field. The major environmental factors affecting plant competition are water, light and mineral nutrients (Craft, 1975). Light is the most important factor among them (Noguchi, 1980). Height growth of plant is greatly influenced by the competition for light. The changes of plant length among varieties were shown in (Fig. 1). Early stage of growth and plant length of Bg750 was the most superior compared to other varieties. Growth of H-4 were the second and its plant length got ahead of that of Bg750 at maturing stage. Growth of Bg379-2 and Bg94-1 were inferior to those of other varieties and the final plant length was only about 50 cm. Growth of Bg300 and Bg380 was medium among the varieties, but the former was superior to the latter.

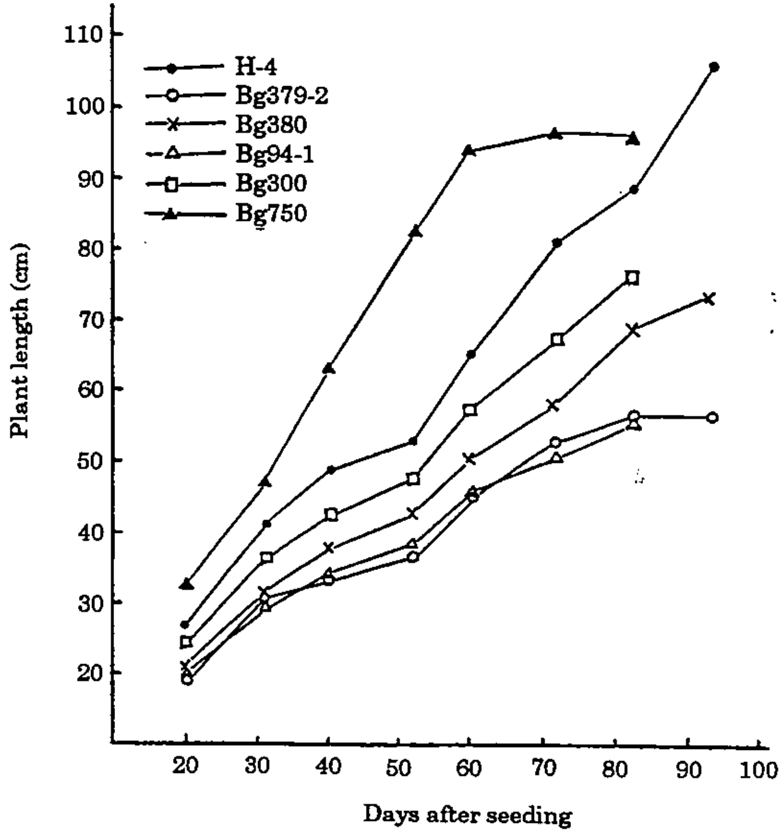

Figure 1. Changes of plant length.

Yield and growth characteristics are shown in Table 1. Culm length generally corresponded to plant length. There was no large difference in the culm length between Bg300 and other Bg varieties of 3 1/2 - 4 1/2 months, as compared to some growth differences in the plant length which was indicated among these varieties. Leaf blade of Bg300 were longer than those of other Bg varieties. Paddy yield of 3 1/2 - 4 1/2 months varieties were $455-549g/m^2$ and those of 2 1/2 - 3 months were $257-330\ g/m^2$. The former showed relatively higher level of paddy yield, while the latter was of low level. This was mainly due to damage caused by paddy bug in addition to varietal characteristics. Paddy-straw ratio was less than 90% in each variety. Those of Bg300 and Bg750 were below 50% owing to the damage caused by bug.

Table 1. Yield and growth characteristics

Variety	Heading date	Length of		Panicle	Weight of		Paddy/ straw
		culm cm	panicle cm	number /m^2	paddy g/m^2	straw g/m^2	%
H-4	2.20	60.2	20.6	553	536	725	74
Bg379-2	2.26	47.8	19.3	572	549	628	87
Bg380	2.18	47.3	18.9	468	473	583	81
Bg94-1	2.15	49.4	19.2	578	455	542	84
Bg300	2. 5	50.7	20.1	600	330	838	39
Bg750	1.16	71.5	15.9	461	257	548	47

Changes of relative light intensity on the ground surface at the center of the inter-row space are shown in Fig. 2. The start of shading over the ground surface by crop canopies was observed at first in Bg750, and the relative light intensity was reduced to 38% and further below 20%, on 40 and 52 days after sowing, respectively. However, further reduction of the relative light intensity was not observed thereafter. The start of shading by other varieties followed a few days later as compared with that of Bg750, but reduction of relative light intensity in H-4 and Bg300 proceeded rapidly since 40 days after sowing and the relative light intensity was reduced below 20% and 10% on 60 and 73 days after sowing, respectively. The speed of shading in Bg94-1 and Bg379-2 were a few days later as compared to the above varieties, but the relative light intensity was reduced below 10% during 83-90 days sowing. The shading characteristic of Bg380 was the slowest among these varieties, and the relative light intensity was reduced below 10% on 90 days after sowing.

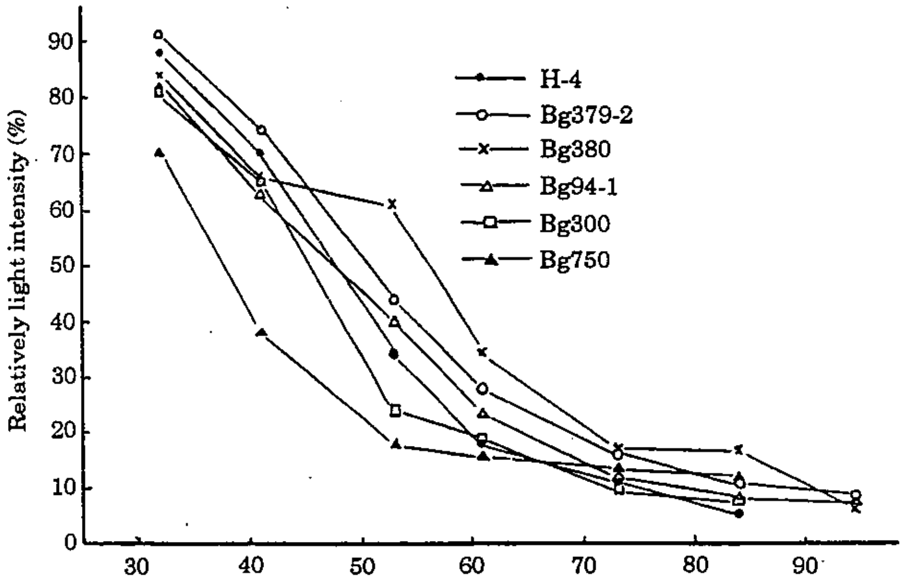

Figure 2. Changes of relative light intensity on the ground surface at the center of inter-row space.

Vertical changes of the relative light intensity and the productive structure at heading stage are shown in Fig. 3. Plant height of H-4 was 120 cm which was the highest among these varieties and the leaf area index(LAI) was also large. Additionally, leaves of H-4 were distributed relatively in the upper part of the crop canopies as compared to other varieties. Therefore, higher space of 40-50 cm from ground surface was maintained under reduced relative light intensity. Plant height of Bg750 was the second among varieties, but the LAI was small and leaves were distributed mainly in the lower part of the crop canopies. Then, the relative light intensity in Bg750 was generally high, namely, the value on the ground surface was about 20%, and that became markedly large in proportion to the height from ground surface. Plant height of the other varieties was about 80 cm and it was shorter than those of the two varieties mentioned above. Among the four varieties, the amount of LAI in Bg300 was not so large, but the increase of the relative light intensity with rising up its height from ground surface was relatively small and the relative light intensity in the space 0f 30-40cm from ground surface was maintained under reduced condition. On the other hand, the amount of LAI in the other three varieties was large, but the space of only 10-20 cm from ground surface and, the relative light intensity was kept in reduced condition, because leaves of these varieties were distributed mainly in the lower part of crop canopies. The relative light intensity was markedly increased at higher part of the canopies.

It was proved that the formula concerning the process of absorption of solar radiation by plant leaves is as (Monji and Saeki, 1953) follows:

$$I/Io = \exp\text{-}KF \dashrightarrow \log(I/Io) = -KF$$

Where
- I : Light intensity at a certain height in crop canopies
- Io : Light intensity at upper part of crop canopies
- K : Extinction coefficient
- F : Accumulated LAI from upper part at a certain height in crop canopies

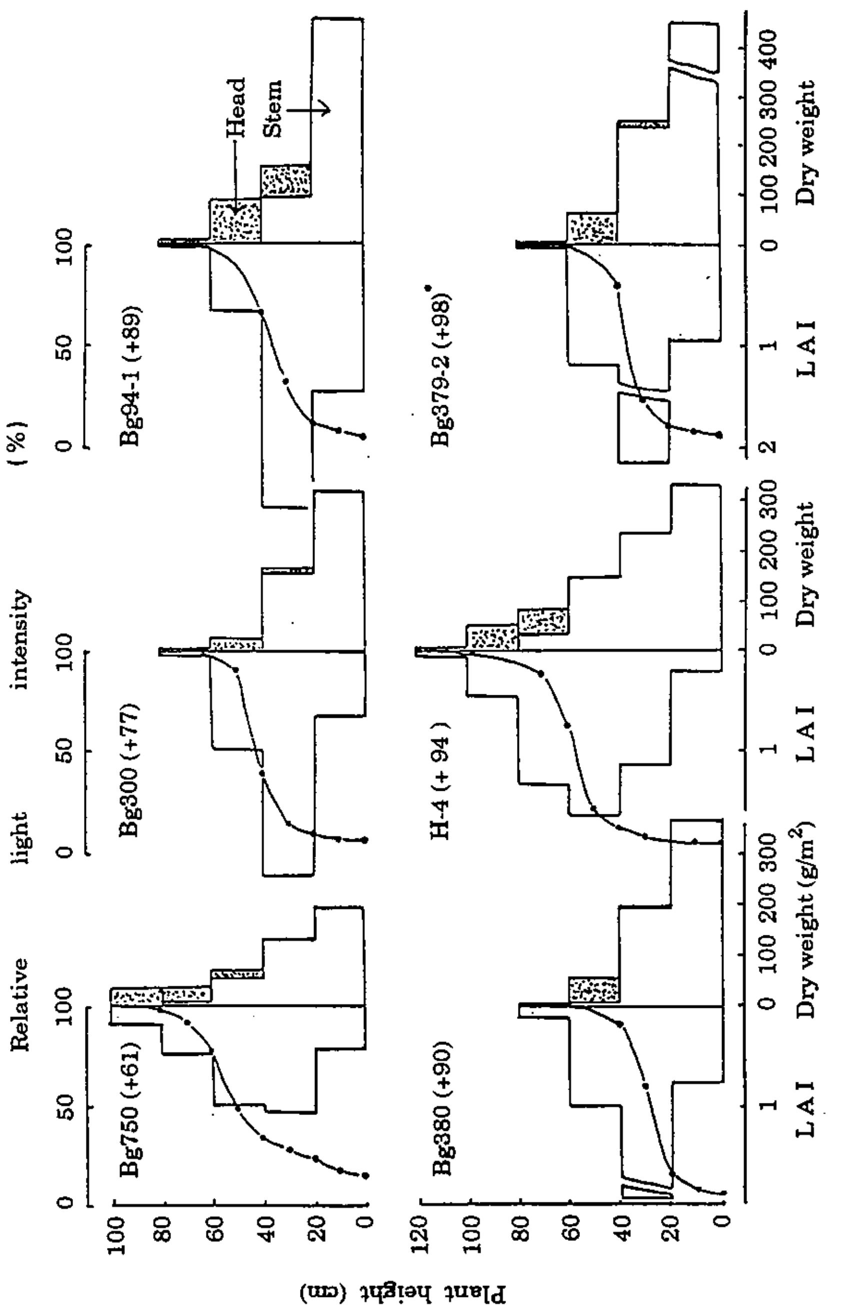

Figure 3. Productive structure at heading stage.

Note : * Days after seeding, —•— Relative light intensity

The value of K varies were arrangement, shape, size, angle, etc. of leaves. Generally the K value in gramineous plant is smaller than that of brodleaf plant. Results of this experiment are shown in Fig. 4. Higher K value were observed in H-4, i.e., 0.774 and in Bg300, i.e., 0.717. Bg379-2 showed the smallest K value among varieties. The K values of Bg750 and Bg94-1 were medium. Now, data of Bg380 was excepted by large variation.

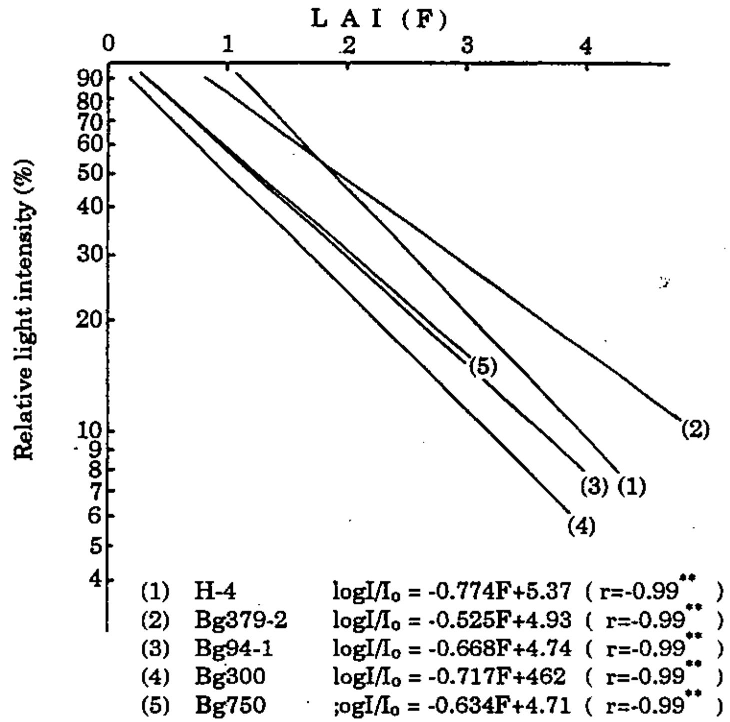

Figure 4. Relationship between LAI and relative light intensity.

It was found that leaves of H-4 and Bg300 were distributed horizontally compared to the other varieties. On the other hand, leaves of Bg379-2 were erect. Therefore, the former varieties could keep relatively high space from ground surface at reduced relative light intensity condition, but the latter could not. These facts support the results of Fig. 3.

From those results, it has been made clear that there are different weed competing abilities among paddy rice varieties. H-4 has a desirable plant character, such as fast stretch at its early stage, highest growth expectancy, and comparatively large LAI. The leaves are distributed among the upper part of crop canopies in horizontal direction. Thus, the higher part can be kept with the relative light intensity under reduced condition. Accordingly, it was found that H-4 had the most effective growth characteristics for competing with weeds among the varieties used in this experiment. In case of Bg750, the early growth is remarkable, the plant height is high, although the LAI is small. It means tgat its shading ability is not sufficient against weeds. Therefore, its weed competing ability is somewhat inferior to H-4. Growth characteristics of Bg300 showed the relatively strong weed competing ability among the new improved varieties of 3-4 1/2 months varieties owing to its early growth, plant length and shading ability. The weed competing abilities of Bg379-2, Bg380 and Bg94-1 were inferior to the above mentioned varieties.

The new improved varieties in Sri Lanka have the general characteristics of short culm and erect leaves. These characteristics are very convenient to utilize solar radiation and to apply fertilizer for high paddy yield. On the other hand, these varieties require precise management including weed control. De Datta (1979) also pointed out the same circumstances of paddy fields in tropical Asia. Under the present condition in Sri Lanka, it will be necessary to look again at the characteristic of H-4 having relatively strong weed competing ability. In the future, varieties with the following growth characteristics are convenient to use for high yield and those weed competition: (1) leaves of those varieties are distributed horizontally in early growth stage for covering the crop rows rapidly; (2) the arrangement of leaves changed and distributed vertically in the third or fourth leaf before flag leaf for utilizing solar radiation effectively; (3) that those varieties have adequate leaf area and plant length.

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WEED CONTROL STUDIES IN RICE WITH ANILOFOS IN INDIA

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ABSTRACT

Anilofos, a new herbicide, selective to rice and effective on most annual grasses and sedges was studied for 5-6 years at different locations in India to establish its rates, timing of application, weed control spectrum and weed control efficacy in different rice cultures. Application of anilofos at 0.3 kg ai/ha 6 days after seeding in rice nurseries and at 0.4 kg ai/ha from three to ten days after rice transplanting provided effective weed control with a high degree of selectivity. Trials in direct seeded rice (puddled/non-puddled) have shown promising results and detailed studies are in progress. *Ischaemum rugosum*, an annual grassy weed (and tolerant to butachlor) for rice seed growers in northern parts of India, was controlled effectively by anilofos. Anilofos in combination with 2,4-D was compatible for the control of grassy and non-grassy weeds.

INTRODUCTION

In India a major constraint encountered in the cultivation of rice is weed control. The yield potential of high yielding cultivars can be fully harvested only when all other crop production technology harmonize with the weed management practices. Reduction in the grain yields of rice may range from 5% to total failure of the crop (IRRI, 1967; Bhan *et al.*, 1980; Singh *et al.*, 1983). The degree and nature of competition between weeds and rice, growing in association with the crop, their habit, and the growth rate and density of both rice and weeds. The types of weeds associated with rice are strongly affected by the type of rice culture adopted.

The main rice cultures practised in our country are transplanting, direct seeding under puddled conditions and direct seeding under non-puddled conditions (upland rice). Rice seedlings are raised in nurseries for transplanting and this is another critical stage where weeds require attention of the farmers. Weed species and their intensity in puddled fields differ distinctly from that of unpuddled conditions.

In the major rice growing areas of India, butachlor has been used for the control of annual grasses in transplanted rice for more than one and a half decades. At present there is no herbicide available that can be used effectively and economically in direct seeded rice either under puddled or unpuddled conditions. The use of a single herbicide in rice that is mainly effective against

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a particular weed spectrum may result in an ecological shift of weed species, and butachlor which was imported in the country till recently, making it costly and therefore a major problem for use by the farmers.

Anilofos [S-(N-(4-chlorophenyl-)-N-isopropyl-)-O,O-dimethyl-dithiophosphate] a new herbicide which has been developed and manufactured indigenously in India by M/s. Gharda Chemicals Limited, and is a major step in solving the import problem and availability of herbicides to farmers. Anilofos is formulated as Aniloguard 30 EC (30% ai). Several field experiments were conducted to evaluate the efficacy of anilofos in various rice culture under different agro-ecological conditions of India. The findings of these multilocation trials are summarized in this paper.

WEED ASSOCIATION IN RICE CULTURES

Several weed species emerge simultaneously with rice seedlings in upland direct seeded rice. Weed population is dominated by annual grasses such as *Echinochloa colonum* (L.) Link, *Digitaria sanguinalis* (L.) Scop., *Eleusine indica* (L.) Gaertn., and *Dactyloctenium aegyptium* (L.) Beauv. and by non-grassy weeds like *Celosia argentea* L., *Commelina benghalensis* L., *Physalis minima* L., *Trianthema monogyna* L. and *Portulaca quadrifida* L. Among sedges, *Cyperus rotundus* L. is the major problem. In puddled fields (direct seeded or transplanted), *Echinochloa colonum*, *E. crus-galli* (L.) Beauv., *Ischaemum rugosum* Salisb., *Cyperus iria* L., *Cyperus difformis* L., *Scirpus grossus* L.f. and *Fimbristylis miliacea* (L.) Vahl, *Commelina benghalensis*, *Caesulia axillaris* Roxb., *Eclipta prostrata* (L.) L., *Rotala densiflora* (Roth) Koehne and *Marsilea minuta* L. are the most dominating weeds. The majority of transplanted rice fields in northern India face the problem of annual grasses and sedges, whereas in southern parts of the country transplanted rice fields get infested with annual grasses, sedges and non-grasses.

Rice seedlings for transplanting are generally raised in wet nurseries where sprouted rice seeds are broadcast in puddled fields. Four week old seedlings are preferred for transplanting. Weeds in rice seedling nurseries compete with rice seedlings and in some instances, depending upon weed density, may cause complete failure of the nursery. *E. colonum* and *E. crus-galli* are the commonest weeds in rice nurseries. Because of the morphological similarities between these weeds and rice seedlings, they are often transplanted with rice seedlings in the field, where they are very competitive and even a low density may cause reduction in rice yields. Weeds transplanted with rice seedlings are difficult to control as no selective herbicide effective against such weeds is yet available.

EFFECT OF ANILOFOS IN THE RICE NURSERIES

Anilofos at 0.2, 0.3, 0.4 and 0.5 kg ai/ha was applied six and nine days after seeding(DAS) of the sprouted rice seeds in wet beds and evaluated for weed control efficacy and phytotoxicity on rice seedlings in comparison with butachlor and thiobencarb both at 1.5 kg ai/ha six DAS (Table 1). Toxicity of anilofos to rice seedlings increased with increasing the dose of the herbicide from 0.2 to 0.5 kg ai/ha when applied six DAS, but the highest toxicity recorded was eight (0-100 scale) at 0.5 kg ai/ha which was of very low magnitude. Toxicity to the crop was of very low magnitude (two) irrespective of application dose when application was delayed to 9 DAS. Weed control efficacy was low at 0.2 kg ai/ha as compared to higher doses irrespective of application time, and was almost the same at 0.3, 0.4 and 0.5 kg ai/ha when applied 6 DAS. Keeping in view of the dose, crop toxicity and weed control efficacy, application of anilofos at 0.3 kg ai/ha at 6 DAS was most cost effective and safest for use in rice nurseries. This is comparable with that of thiobencarb and much superior to butachlor each at 1.5 kg ai/ha applied 6 DAS.

Table 1. Phytotoxicity and weed control efficacy of anilofos in rice seedling nurseries *)

Treatment	Dose (kg ai/ha)	Application (DAS)	No. of trials	Phytotoxicity on rice (0-100 scale)	Weed control efficacy (%)
Anilofos	0.2	6	2	3	70.8
Anilofos	0.3	6	3	4	97.0
Anilofos	0.4	6	4	6	98.0
Anilofos	0.5	6	1	8	98.0
Anilofos	0.2	9	2	2	65.0
Anilofos	0.3	9	3	2	88.0
Anilofos	0.4	9	4	2	92.0
Anilofos	0.5	9	1	2	98.0
Thiobencarb	1.5	6	2	1	98.0
Butachlor	1.5	6	1	1	64.0

DAS = Days after rice seeding
0-100 Scale: 0, no toxicity and 100, complete kill of the crop.
*) Mean values of the data from the trials at Pantnagar, Ludhiana and Madurai (1989-91).

EFFECT IN DIRECT SEEDED NON-PUDDLED RICE (UPLAND RICE)

Anilofos at 0.2, 0.3 and 0.4 kg ai/ha pre-emergence was evaluated for weed control and crop tolerance in upland rice at several locations. The crop was tolerant to the herbicide at all the rates but the weed control efficacy was poor. The annual grasses were controlled but the non-grasses were uncontrolled and sedges dominated at later stages and the initial effect of herbicide was nullified (Babu, 1984). The experiments are still in progress to evaluate its efficacy in combination with other herbicides and cultural methods.

EFFECT IN DIRECT SEEDED PUDDLED RICE

Anilofos at 0.5 and 0.6 kg ai/ha was compared with butachlor and thiobencarb each at 1.5 kg ai/ha in direct seeded puddled rice (Table 2). The reduction in rice grain yields due to weedy condition was 38% when compared with two weedings. Anilofos at both rates produced grain yields at par with that of two weedings, butachlor and thiobencarb. This study was conducted at two locations only and further detailed studies are in progress.

Table 2. Effect of anilofos in direct seeded puddled rice (Directorate of Rice Research, Hyderabad, 1987-88)

Treatment	Dose (kg ai/ha)	Rice grain yield (t/ha) Site I	Site II	Mean
Anilofos	0.5	3.2	5.4	4.3
Anilofos	0.6	3.2	5.4	4.3
Butachlor	1.5	4.0	5.5	4.8
Thiobencarb	1.5	3.9	5.5	4.7
Two weedings	-	4.0	5.6	4.8
Weedy	-	2.8	3.2	3.0
	LSD (P=0.05)	0.8	0.3	-

EFFECT IN TRANSPLANTED RICE

Effect of Dosages

Three rates of anilofos were tested in field trials in comparison to butachlor at 1.5 kg ai/ha and the common practice of two manual weedings. Weed control efficacy (WCE) of anilofos increased from 53.7% at 0.3 kg ai/ha to 95% at 0.6 kg ai/ha (Table 3). The WCE achieved with butachlor and two weedings was 68.0 and 72.5% respectively. Grain yield of rice also increased from 3.7 t/ha to 5.4 and 5.6 t/ha when the rate of anilofos was increased from 0.3 to 0.4 and 0.6 kg ai/ha respectively. The increase in the WCE due to anilofos at 0.6 kg ai/ha in comparison to that at 0.4 kg ai/ha was much higher then the increase in the grain yield. Grain yields obtained due to butachlor at 1.5 kg ai/ha and two weedings performed at 15 and 30 days after transplanting (DAT) were comparable to that of anilofos at 0.4 and 0.5 kg ai/ha. The increase in grain yield of rice due to anilofos at 0.4 kg ai/ha over weedy check was more than 74%. Thus application of anilofos at 0.4 kg ai/ha is considered an optimum, effective and economic dose.

Table 3. Effect of different rates of anilofos on transplanted rice *)

Treatment	Dose (kg ai/ha)	No. of trials	Weed control efficacy (%)	Rice grain yield (t/ha)
Anilofos	0.3	3	53.7	3.7
Anilofos	0.4	8	78.2	5.4
Anilofos	0.6	2	95.0	5.6
Butachlor	1.5	6	68.0	5.3
Handweeding (Twice)	-	8	72.5	5.3
Weedy	-	8	0.0	3.1

*) Source : Annual research reports from Pantnagar, Ludhiana, Kalyani, Coimbatore, Madurai, Hyderabad, Navsari and Directorate of Rice Research, Hyderabad.

Effect of Time of Application

Application of anilofos at 0.4 and 0.8 kg ai/ha 3, 7 and 10 DAT of rice was evaluated to find out the best timing of application. An average loss of 57% in the grain yield of rice was recorded due to uncontrolled weeds when compared with weed-free condition (Table 4). Grain yield as well as, WCE were almost similar at both dosages of anilofos applied 3, 7 and 10 DAT and were comparable to that of butachlor and thiobencarb each at 1.5 kg ai/ha applied 2 DAT. All herbicides irrespective of time and rate of application yielded similar to weed-free condition. Application of anilofos can be delayed up to 10 DAT without losing WCE, an advantage which could not be achieved with either butachlor or thiobencarb.

Table 4. Effect of time of application of anilofos in transplanted rice (Pantnagar, 1986 and 1987)

Treatment	Dose (kg ai/ha)	Time of application (DAT)	Weed control efficacy (%)	Rice grain yield (t/ha)
Anilofos	0.4	3	97.5	6.5
Anilofos	0.4	7	98.1	6.5
Anilofos	0.4	10	97.8	6.5
Anilofos	0.6	3	97.5	6.5
Anilofos	0.6	7	98.1	6.4
Anilofos	0.6	10	97.7	6.5
Butachlor	1.5	2	97.9	6.4
Thiobencarb	1.5	2	97.5	6.5
Weed-free	-	-	100.0	6.5
Weedy	-	-	0.0	2.8

Effect on Major Weeds

Echinochloa colonum, *E. crus-galli* and *Ischaemum rugosum* are the major weeds in transplanted rice throughout India, whilst in southern parts domination also occurs by non-grassy weeds such as *Cyperus* spp., *Marsilea minuta, Rotala densiflora* and *Eclipta prostrata*. Experiments were conducted in the northern and southern parts of the country to test the effect of anilofos on individual weed species. Anilofos alone at 0.4, 0.5 and 0.6 kg ai/ha applied 3, 6 and 9 DAT provided very good control of *E. colonum*, *E. crus-galli*, and *I. rugosum* (Table 5), and good control of *C. iria* and *C. difformis* (Table 6).

Table 5. Effect of rates and timings of application of anilofos on major weeds in rice (Pantnagar, 1990)

Treatments	Dose (kg ai/ha)	Time of application (DAT)	*Echinochloa colonum* plants/m^2	*Echinochloa crus-galli* pants/m^2	*Ischaemum rugosum* plants/m^2	Rice grain yield (t/ha)
Anilofos	0.4	3	3	1	3	6.5
Anilofos	0.5	3	2	2	0	6.4
Anilofos	0.6	3	0	1	1	6.4
Anilofos	0.4	6	4	0	2	6.4
Anilofos	0.5	6	2	0	1	6.6
Anilofos	0.6	6	1	0	0	6.2
Anilofos	0.4	9	0	2	3	6.4
Anilofos	0.5	9	4	3	1	6.5
Anilofos	0.6	9	2	0	2	6.4
Butachlor	1.5	3	2	3	26	5.9
Weed-free	-	-	0	0	0	6.5
Weedy	-	-	232	46	31	2.7

DAT = Days after transplanting

The control of anilofos and butachlor on *Echinochloa* spp. was similar but butachlor did not control *I. rugosum*. *I. rugosum* is considered to be a serious weed in transplanted rice in the northern parts of India, particularly for seed production as the seeds of this weed are separated easily during seed processing operations. Anilofos would prove an ideal herbicide for these situations.

Tank mixed applications of anilofos with 2,4-D(EE) at various rates were tested to evaluate their effects on non-grassy and grassy weeds. Tank mixed application of less than 0.3 kg anilofos ai/ha plus 0.40 kg 2,4-D g ai/ha did not provide satisfactory control of both non-grassy and grassy weeds (Table 6). Combination of anilofos at 0.30 kg and 2,4-D at 0.40 kg ai/ha provided more than 60% control of non-grassy weeds like *M. minuta*, *E. prostrata* and *R. densiflora* without affecting WCE on grassy weeds. This combination would prove more economical than application of anilofos alone at 0.4 kg ai/ha.

Table 6. Weed control efficacy (per cent) of anilofos + 2,4-D on different weed species in rice (Madurai, 1989 and 1990).

Treatment	Dose (kg ai/ha)	Weed E.c	C.s	species M.m	E.p	R.d	Rice Grain Yield (t/ha)
Anilofos	0.4	64.1	60.2	56.2	58.0	63.0	6.2
2,4-D(EE)	0.8	60.0	64.5	71.9	78.0	73.0	6.0
Anilofos + 2,4-D(EE)	0.3 + 0.15	41.5	28.9	38.3	74.0	66.0	5.9
Anilofos + 2,4-D(EE)	0.25 + 0.25	41.5	26.4	40.6	70.0	61.0	5.7
Anilofos + 2,4-D(EE)	0.20 + 0.35	39.0	26.4	49.2	57.0	63.0	5.5
Anilofos + 2,4-D(EE)	0.15 + 0.45	35.1	22.3	50.6	78.0	64.0	5.3
Anilofos + 2,4-D(EE)	0.30 + 0.45	61.0	60.2	61.0	78.0	79.0	6.6
Butachlor + one weeding 30 DAT	1.25	62.9	43.6	50.4	66.0	50.0	6.2
Two weedings 15 & 30 DAT	-	69.7	76.6	72.6	78.0	59.0	6.9
Weedy	-	0.0	0.0	0.0	0.0	0.0	5.1

E.c = *Echinochloa colonum*
C.s = *Cyperus* spp.
M.m = *Marsilea minuta*
E.p = *Eclipta prostrata*
R.d = *Rotala densiflora*
DAT = Days after transplanting
EE = Ethyl ester

VARIETAL TOLERANCE

The trials conducted during the last 5-6 years at various research institutes in the country revealed that the commercially cultivated rice varieties did not show any visual phytotoxic symptoms with anilofos at recommended rates and timings of application.

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EFFECT OF WEED COMPETITION AND WEED POPULATIONS ON LOWLAND RICE

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ABSTRACT

A mixed population of weeds were allowed to compete with broadcast sawn 90 day (Bg 34-8) and 105 day (At 16) maturity rice cultivars for 0, 10, 20, 30, 40, 50, 60, days and compared with a unweeded control, during dry (yala) season 1984 and wet (maha) season 1983/84 respectively. During dry (yala) season 1985 *Echinochloa crus-galli* (L.) Beauv. were allowed to compete with an irrigated transplanted rice of 90 day maturity (Bg 34-8) at weed densities of 0, 1, 3, 5, 10, 15, 20, and 25 plants/m^2.

Result indicated that extending weed competition duration more than 20 days by a mixed weed population decreased yield significantly and extended weed competition duration decreased yield components, panicle length, percent filled grain and panicle number.

Threshold weed density of *Echinochloa crus-galli* under transplanted conditions at season long competition with rice was found to be 5 weeds/m^2. The sensitive yield components of rice were panicle number and spikelet number per panicle. Projecting data for broadcast sown conditions, the threshold level of *Echinoclhoa crus-galli* density was 6% of the total density.

INTRODUCTION

Weed competition duration and population density are two major aspects of weed competition. Early season weed competition reduces yields more than late season weed competition (Mercado 1979). Population density of a perticular weed species is also important since different weed species have different interspecific weed competitive abilities. Chang (1978) indicated that *Echinochloa crus-galli* (L.) Beauv. at densities of 100-200 plants/m^2 reduced the grain yield by 86-91% in lowland rice competition.

This paper reports on experiments to determine the allowable duration of competition by a mixed population of weeds on broadcast lowland rice and the threshold population density of *Echinochloa crus-galli* (L.) Beauv. on transplanted lowland rice.

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MATERIALS AND METHOD

Dry (yala) Season 1985

The experiment was conducted at the Regional Research Station Angunukolapalessa, Sri Lanka during dry (yala) season 1985, under rainfed conditions with supplementary irrigation. During experimentation, 150 cms of irrigation water was usedand 36.5 cms of rainfall was recorded with an average of 6.85 sunshine hours per day. An randomised block design was used with three replications, the plots were 6 m x 3 m.

Ninety day maturity rice cultivar Bg. 34-8 was used. The eight treatments were 0, 1, 3, 5, 10, 15, 20 and 25 *E. crus-galli* plants/m^2. Wet bed nurseries of both rice and *E. crus-galli* were raised and was transplanted at the age of 21 days at a spacing of 20 cm x 20 cm with three plants per hill. The required density of *E. crus-galli* was transplanted with the rice and was evenly spaced in the plot. Fertilizer application and pest and disease control were carried out as recommended by the Department of Agriculture (1983).

Plant height and flag leaf length were measured at harvest from 10 plants selected at random. Tiller count/m^2 was taken at 30 days after transplanting and at harvest. The yield components, i.e. panicle number/m^2, 1000 seed weight, percent filled grain, spikelets per panicle and panicle length from 10 panicles selected at random were also measured at harvest. Paddy was harvested and *E. crus-galli* straw was separated from paddy straw before threshing and weighed. After threshing and winnowing, grain yield and paddy straw weight were recorded.

Wet (Maha) Season 1983/1984 and Dry (Yala) Season 1985

The experiments were conducted at the Regional Research Station, Angunukolapalessa, Sri Lanka, during the wet (maha) season commencing in December 1983 and the dry (yala) season commencing in May 1984.

The 105 day maturity rice cultivar At 16 was used during the maha seaosn 1983/84 and the 90 day maturity cultivar Bg 34-8 during the yala season 1984. Treatments consisted of weed free periods ranging from 0, 10, 20, 30, 40, 50, and 60 days after seeding (DAS). Both experiments were conducted in 3 m x 4 m plots in a randomised complete block design replicated three times.

Pre-germinated seeds were broadcast sown and fertilization was as recommended by the Department of Agriculture (1983). Manual weeding was carried our according to the pre-determined weed competition duration in each treatment. The dry weight of weeds was determined by taking a random sample of weeds at each weeding which was oven-dried at 90°C to a constant weight and weighed. Rice plants were sampled at 10 day intervals from weeded and unweeded controls and biomass production was determined. Flag leaf length, panicle length, tiller number, 1000 grain weight and percent filled grain were determined at harvest. The yala experiment was irrigated whereas the maha experiment was provided with supplementary irrigation due to late rains.

RESULTS AND DISCUSSION

Weed Competition Duration

The natural weed flora in the experimental site was dominated by sedges in both seasons. Broadleaf weeds and grasses were present in small populations (Table 1). Among the grasses *Echinochloa crus-galli* was dominant and its population was higher in the maha season 1983/84 than in the yala 1984 season.

Table 1. Different weed species observed in the natural weed flora at the experimental site.

Sedges	*Cyperus iria* *Cyperus rotundus* *Cyperus dehiscens* *Fimbristylis miliacea*
Grasses	*Echinochloa crus-galli* *Echinochloa colona* *Ischaemum rugosum* *Panicum repens*
Broad leaved	*Aeschynomene indica* *Eichhornia crussipes* *Oxalis corniculata*

Tiller number, flag leaf length and panicle length were apparently reduced by even 10 days duration on weed competition in cultivar At 16 even though the differences were not significant (Table 2). A similar drop in these three parameters was observed in crops weeded only 60 DAS treatment, which coincide with the booting stage of At 16. With rice cultivar Bg 34-8 in the yala season significant differences were observed between treatments (Table 3) and a significant drop in tiller number and panicle length was observed in plants only weeded 40 DAS. However, the flag leaf length was not sensitive to weed competition in Bg 34-8 indicating that cultivar Bg 34-8 which has a greater growth rate because of short age is more tolerant to weed competition than At 16. Yamagishi *et al.* (1976) reported that two periods of rice growth were vulnerable to competition by the perennial weed *Cyperus zerotinum* Rottb.

Table 2. Yield components and grain yield of rice cultivar cv At 16 in the maha season 1983/84.

Treatment	Tiller number per plant at harvest	Flag leaf length (cm)	Panicle length (cm)	Grain yield (mt/ha)
Weed free from sowing	2.38 ns	21.43 ns	19.00 ns	4.34 a [*)]
Weed free from 10 DAS	2.05	19.48	17.67	3.95 b
Weed free from 20 DAS	1.94	19.80	17.87	3.79 b
Weed free from 30 DAS	2.27	20.86	17.73	3.33 c
Weed free from 40 DAS	1.99	20.16	17.73	3.08 c
Weed free from 50 DAS	2.05	20.15	17.16	3.03 c
Weed free from 60 DAS	1.76	17.53	14.31	2.65 d

*) In any column means followed by the same letter are not statistically significant at P = 0.05.

Table 3. Yield components and grain yield of rice cultivar Bg 34-8 in the yala season 1984.

Treatments	Tiller number per plant PI stage	Flag leaf length (cm)	Panicle length (cm)	Tiller number per plant at harvest	Percent filled grains	Grain yield (mt/ha)
Weed free from sowing	3.5 bc [*)]	18.42 abcd [*)]	15.22 abc [*)]	2.9 bc [*)]	82.72 [NS]	3.82 [NS]
Weed free from 10 DAS	4.3 ab	17.07 d	15.18 abcd	3.5 ab	85.46	4.2
Weed free from 20 DAS	4.6 a	19.55 ab	15.94 a	3.1 ab	79.20	4.31
Weed free from 30 DAS	3.3 c	19.49 abc	15.85 ab	3.1 ab	78.72	3.77
Weed free from 40 DAS	2.6 c	19.83 a	12.99 c	2.7 c	79.07	3.74
Weed free from 50 DAS	3.1 c	18.20 abcd	14.72 abcd	2.6 c	79.00	3.66
Weed free from 60 DAS	2.9 c	16.01 c	15.32 abc	2.7 c	77.43	3.55
Unweeded control	2.5 c	18.44 abcd	13.88 abcd	2.4 c	88.76	3.54

*) In any column means followed by the same letter are not statistically significant at 5% level.

The first period was around 14 days after transplanting, at which stage panicle number will be determined whislt the second was the booting stage when the number of spikelets were determined. Senanayake (1990) studied the apical development stages of 90 day (Jirasar 280) and 105 day (IR50) rice and observed that the maximum spikelet number of a 90 day variety was determined around 40 DAS (Fig. 1) and that of 105 day variety was around 60 DAS (Fig. 2). Reduction in tiller number by weed competition for 40 and 60 DAS of Bg 34-8 and At 16 respectively could be attributed to the tillers becoming non effective due to weed competition. Weed competition up to the booting stage of At 16 reduced tiller number, panicle length and flag leaf length by 26%, 26%, and 18% respectively.

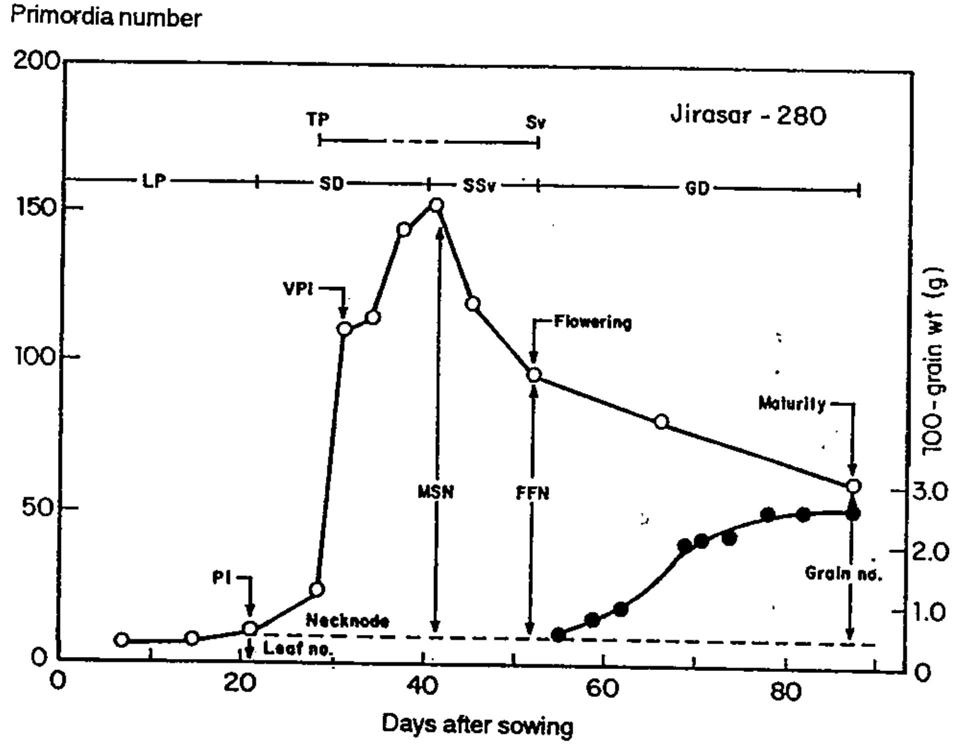

Figure 1. Primordia production at different stages of main culm of Jirasar -280. (TP = tiller production, SV = survival, LP = leaf production, SD = spikelet development, SSV = spikelet survival, GD = grain development, MSN = maximum spikelet primordia number, FFN = fertile floret number, PI = panicle initiation, VPI = visual panicle initiation) (Senanayake 1990).

Grain yield decreased with increasing duration of weed competition significantly in At 16 but was not significant in Bg 34-8, indicating that Bg 34-8 has better weed competition ability. Rice cultivar At 16 showed three steps of significant yield reduction: the first 10 DAS, the second 30 DAS which coincides with tillering, and the third 60 DAS which coincides with booting. Datta (1981) and Yamagishi *et al.* (1976) also indicated that the latter two stages are critical in obtaining high yields. The grain yield reduction due to weed competition duration up to panicle initiation and booting stages was 28% and 27% respectively (Table 2).

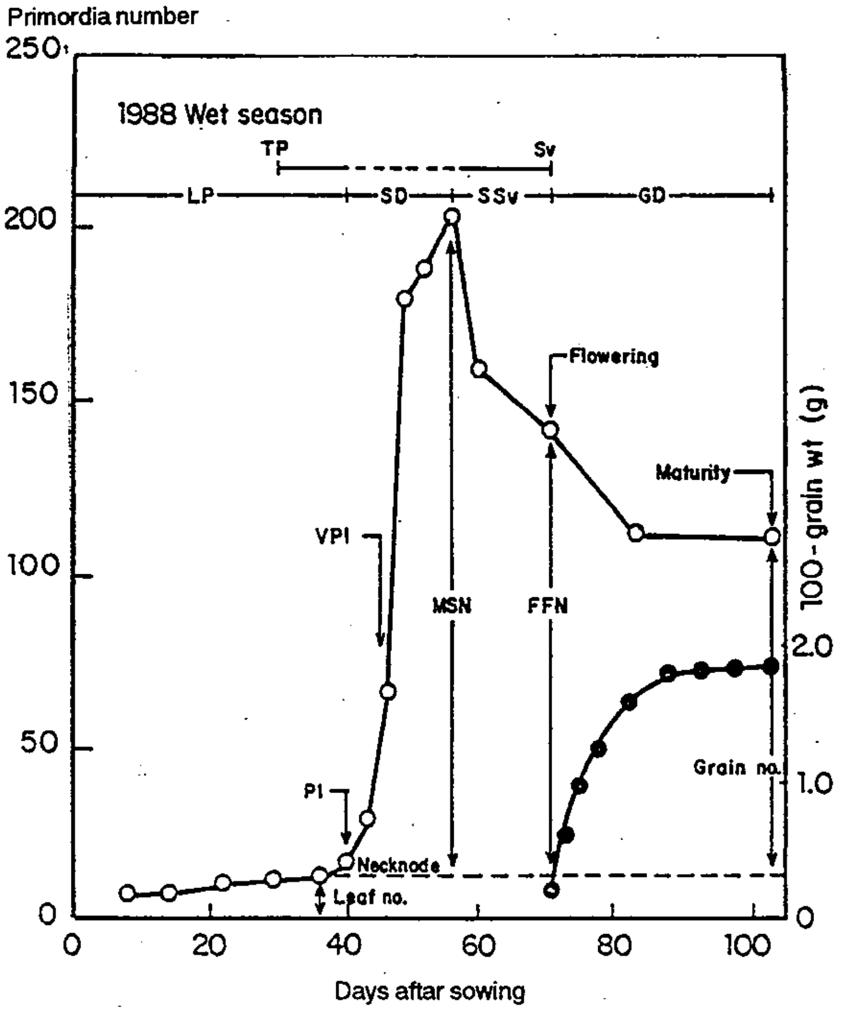

Figure 2. Primordia production at different stages of main culm of IR50. (TP = tiller production, SV = survival, LP = leaf production, SD = spikelet development, MSN = maximum spikelet primordia number, FFN = fertile floret number, PI = panicle initiation, VPI = visual panicle initiation) (Senanayake 1990).

Weed dry weight at each weeding increased up to 40 DAS and decreased thereafter (Table 4), possibly due to death of sedges after completion of their life cycle. Rice biomass production was drastically reduced by weed competition, with competition up to 60 DAS reducing rice biomass by 42%.

Table 4. Weed dry weight and plant dry weight of rice cultivar Bg 34-8 in the yala season 1984

Treatment	Weed Wt. at weeding (g/plot)	Plant dry weight: Weed control (g/plant)	Plant dry weight: Unweedcontrol (g/plant)
Weed from 10 DAS	5.36	0.44	0.43
Weed from 20 DAS	116.05	2.92	1.90
Weed from 30 DAS	344.34	5.65	4.26
Weed from 40 DAS	1978.5	8.15	5.72
Weed from 50 DAS	1526.3	13.15	8.33
Weed from 60 DAS	1270.9	17.65	10.25

Results indicate that weed competition up to 40 DAS and 60 DAS of Bg 34-8 and At 16 respectively, which coincided with the maximum spikelet number stage, reduced the effective tiller number and the panicle length contributing to reduction in grain yields. Cultivar differences in weed competitive ability was also shown.

Threshold Weed Population

Table 5 summarises the data on tiller density 35 DAT, panicle density and on spikelets per panicle at harvest of Bg 34-8. Table 6 shows the grain yield, rice straw and weed dry weights and % yield loss. The data shows that weed competition has a significant effect on tillering up to 20 *E. crus-galli* plants/m^2. However, panicles/m^2 were significantly reduced when the *E. crus-galli* population exceeded 10 plants/m^2, decreasing further with further increase in weed population. This indicate that increasing weed density renders a greater number of tillers ineffective. Further, the number of spikelets per panicle was highly sensitive to interspecific competition by *E. crus-galli* and was significantly reduced even at a density of 1 weed plant/m^2. Further significant decrease was not observed even if the weed population increased up to 25 plants/m^2. Noda (1975) also indicated that *E. crus-galli* competition during maximum tillering reduce the panicle number while during early ripening it reduced grain yield and quality.

Rice grain yield with season long interspecific weed competition decreased with the increase in *E. crus-galli* density (Table 6) and was significant when it exceeded 5 plants/m^2. At this threshold level the decrease in grain yield over no weed competition was 8.33%. The threshold level as a percentage of total density (75 rice plants to 5 *E. crus-galli* plants) was 6.2%. Thus if we were to project this data to other stand establishment methods one could expect a significant drop in grain yield if *E. crus-galli* density exceeds 6%. Further increase in the *E. crus-galli* density to 25 plants/m^2 gave a 38.5% decrease in grain yield; at this density all the planting hills were shared by three plants and a single weed. Smith (1968) also indicated that season long competition between 3 rice plants and 25 *E. crus-galli* plants/ft^2 and 31 rice plants and 25 *E. crus-galli* plants/ft^2 resulted in 79 and 95% rice yield reduction respectively. However, Lubigan and Vega (1971) surmised that *E. crus-galli* density of 20 plants/m^2 reduce grain yield by 20%.

Table 5. Tiller density 35 DAT, panicle density and spikelets per panicle at harvest of rice cultivar Bg 34-8 in the yala season

Treatments	Tillers/m^2 35 DAT	Panicles/m^2 at harvest	Spikelets per panicle at harvest
Control	297.5 a *)	247.5 a *)	225.4 a *)
1 weed/m^2	307.3 a	227.5 ab	196.6 b
3 weed/m^2	295.0 a	237.5 ab	187.9 b
5 weed/m^2	315.0 a	210.0 ab	187.5 b
10 weed/m^2	292.5 a	225.0 ab	197.1 b
15 weed/m^2	277.5 a	192.5 b	174.8 b
20 weed/m^2	265.0 a	197.5 b	178.8 b
25 weed/m^2	197.5 b	165.0 c	185.9 b

*) Any two means followed by the same letter is not significantly different at 5% probability level.

Table 6. Grain yield, straw and weed weight at different densities of *Echinocloa crusgalli* in the yala season.

Treatments	Grain yield (mt/ha)	Straw weight (mt/ha)	Weed dry weight (mt/ha)	% yield loss over control
Control	4.68 a *)	4.50 a *)	- *)	-
1 weed/m^2	4.20 ab	3.84 abc	0.57 d	10.25
3 weed/m^2	4.37 a	3.92 ab	1.43 c	6.62
5 weed/m^2	4.29 ab	2.91 cd	1.01 d	8.33
10 wee/m^2	3.41 b	2.78 d	3.18 b	27.13
15 weed/m^2	3.43 b	2.85 c	2.94 c	26.70
20 weed/m^2	3.04 c	2.47 d	4.24 b	35.04
25 weed/m^2	1.94 d	1.51 e	5.65 a	58.54
Correlation coefficient				
Weed weight	- 0.97	- 0.91		

*) In any column two means followed by the same letter is not significantly different at 5% probability level.

The data indicate that interspecific competition by *E. crus-galli* is very severe. The highest weed density level (25 plants/m^2) competing whereas the control (3 rice plants per hill) with only intraspecific competition produced 4.5 mt/ha dry matter. This could be attributed to the physiological superiority of *E. crus-galli* since it follows a C_4 photosynthetic pathway whereas the rice plants follows C_3 pathway.

Correlation analysis showed a very highly significant negative correlation between weed dry weight and rice grain yield. Significant negative correlation between weed dry weight and rice straw indicates an increase in weed dry matter with increasing weed density and a corresponding decrease in rice straw weight due to increase in intensity of interspecific weed competition.

Matsunaka (1970) also indicated that a linear relationship existed between weed density and yield loss at *E. crus-galli* densities normally encountered in the field. At threshold population levels decrease in rice straw weight due to interspecific competition was 35.3% even though the decrease in grain yield was only 8.3%.

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COMBINATION OF HERBICIDES FOR WEED CONTROL IN COTTON

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ABSTRACT

Trifluralin at a rate 1.2 kg ai/ha was used pre-plant incorporated, alone or in combination with diuron or prometryn. Trifluralin reduced yield in both year of the experiment. A combined application of trifluralin pre-sowing and diuron or prometryn pre-emergence to the crop gave the most control of weeds with no injury to the crop. Tank-mix application of trifluralin and prometryn or diuron was also efficient against weeds. Trifluralin at a rate of 0.96 kg ai/ha followed by one hand weeding was as effective as two hand weedings. Fluazifop-p, haloxyfop methyl and sethoxydium sodium were equally effective against grasses.

INTRODUCTION

Cotton is an important crop next to wheat and rice in Iran and is planted over 220,000 ha. The climate of the most parts of the country is suitable for growing cotton, but the high costs of cotton production including time and labor consuming conventional weed control practices make it unprofitable and consequently difficult to expand the area planted to cotton. Therefore it is imperative to introduce integrated weed control practices for cotton production in order to save labor and reduce production cost. The major weed control means in cotton in Iran is mechanical or hand weeding. Also many farmers apply preplanting herbicides such as trifluralin, ethalfluralin or dinitramin. These herbicides control only part of weeds and usually it is essential to weed their fields by other means to overcome the problem.

Many investigations have been carried out to determine the efficacy of different herbicides in Iran and compared to diuron (Mazaheri, 1961), prometryn, trifluralin, dinitramin and ethalfluralin (Mirkamali and Maddah, 1975), prometryn and fluometuron (Hosseiny and Waezzade, 1976) have been reported the most effective ones. Because application of each of those herbicides is not sufficient for weed control in cotton, during 1989 and 1990, trials were conducted for the evaluation of combination of herbicides.

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MATERIALS AND METHODS

Experiments were laid out at the agricultural research station fields in Varamin. The soil at the field was a silty clay loam with 52% silt, 32% clay and 16% sand, having a pH of 8 and 0.5% organic matter. Before seeding, fertilizer was broadcast at a rate of 100 kg/ha N and 60 kg/ha phosphorus. Planting dates were May 5, 1989 and May 18, 1990.

Treatments consisted of an untreated control, a hand weeded control, trifluralin (Treflan 480 g/l EC) at 1.2 kg ai/ha ppi, diuron (Karmex 80% WP) or prometryn (Gesagard 80% WP) both at a rate of 1.6 kg ai/ha pre-emergence to the crop, trifluralin 1.2 kg ai/ha ppi plus diuron or prometryn 1.6 kg ai/ha pre-emergence, tank-mix of trifluralin and diuron or prometryn both at (1.2 + 1.6) kg ai/ha, trifluralin at rate of 0.96 kg ai/ha followed by one hand weeding, tank mix of diuron and paraquat (Gramoxon 200 g/l SL) 3 weeks after emergence.

Herbicides were applied by a knapsack sprayer with three fan type nozzles delivering 400 l/ha.

Crop tolerance was rated visually weekly till 3 weeks after application of herbicides. Weeds were counted in two separate square meter area of each plot. In the second year, fresh weights of weeds were determined in a one square meter area in each plot in early August.

Cotton yield was measured by harvesting two rows, 10 meters in length in the centre of each plot.

The experiment was arranged as a randomized block design with four replications. Individual plot size, 4 by 10 meters consisted of the four rows of 10 meters of the crop. In the second year, in a separate experiment three grass killer herbicides, fluazifop (Fusilade 125 g/l EC) at rates of 250 and 375 g ai/ha, haloxyfop- methyl (Galant 125 g/l EC) at rate of 187.5 g ai/ha, sethoxydim-sodium (Nabu-S 125 g/l EC) at rate of 500 g ai/ha were tested to determine their efficacy for control of grasses and their selectivity for cotton. All of the grass killers were sprayed at four to five leaf stage of johnsongrass (*Sorghum halepense* Pers.) which was the dominant grass in the plots. Other specifications were the same as in the first experiment.

RESULTS AND DISCUSSION

Trifluralin controlled about 60% of the broadleaves and 75 to 80% of grasses (Tables 1 and 2). This herbicides at a rate of 1.2 kg ai/ha caused 32% reduction in cotton stand during the first year but in the second year there was no significant reduction recorded. In both years there was an average of 53% yield reduction in the plots treated with trifluralin.

Table 1. List of weeds that occurred in the check plots

Annual broadleaves	Annual grasses
Amaranthus blitoides S. Wats.	*Brachiaria eruciformis* Griseb.
Amaranthus retroflexus L.	*Echinochloa crus-galli* L. P.B.
Chenopodium album L.	*Setaria viridis* (L.) Beauv.
Cichorium intybus L.	*Setaria verticillata* L. Beauv.
Chrozophora tinctoria L. Juss.	
Heliotropium europaeum L.	**Perennials:**
Portulaca oleracea L.	*Centaurea picris* Pallas ex Willed.
Salsola kali L.	*Cyperus rotundus* L.
Solanum nigrum L.	*Cyperus rotundus* L.
Tribulus terrestris L.	*Sorghum halepense* (L.) Pers.

Trifluralin, preplant incorporated into the soil followed by diuron or prometryn after sowing and pre-emergence to the crop gave up to 97.5% control of broadleaves and up to 93% of grasses (Table 2).

Tank-mix of trifluralin and prometryn (In the first year) or trifluralin and diuron (in the second year) applied ppi resulted in severe phytotoxicity that reduced the crop by 51 and 53% and the yield by 64 and 70% in the first and second year respectively (Table 3). Reduction in crop stand and consequently the lack of competition allowed the weeds to grow vigorously, therefore the fresh weight of weeds was the highest among the treatments (Table 2). Diuron or prometryn alone did not control enough weeds but were more phytotoxic than when used in combination with trifluralin. This is due to the reduction in the absorbed amount of herbicide due to the reduction of lateral roots of cotton under the influence of trifluralin (Berman *et al.*, 1982).

Table 2. Effects of herbicide combinations on weeds in cotton

Treatments	Annual broadleaves				Annual grasses				Perennials		Fresh weight of weeds
	1st yr		2nd yr		1st yr		2nd yr		1st yr	2nd yr	
	weed m^2	cont. %	weed m^2	cont. %	weed m^2	cont. %	weed m^2	cont. %	weed m^2	weed m^2	g/m^2
Trif. 1.2 kg/ha ppi	36	61	16.5	63	11	74	6.7	81	4	18	990
Trif. 0.96 kg/ha ppi+H.W.	-	-	12.7	72	-	-	3.2	91	-	11	280
Trif. ppi fb. diuron pre-em	2.7	97	2.7	92	3	93	5.2	85	9	12.5	1063
Trif. ppi fb. prometryn pre	2.6	97	7.	85	7.5	82	4.7	87	12	13	1023
Trif.+diuron (or prom) ppi	6.1	94	18.7	58	10.2	76	5.7	84	7.5	9	3385
Diuron 1.6 kg/ha pre-em	11.4	88	14	69	9.2	78	10	73	9	19	2355
Prometryn 1.6 kg/ha pre-em	10.7	89	15.5	66	17.3	59	11.7	68	10.5	16	1102
Diuron+paraquat (mixed) post	-	-	21	53	-	-	15.7	57	-	20	1483
Hand weeding (twice)	3	97	6	87	4.2	90	9.2	75	6	6	56
Check (no weeding)	92	0	44.5	0	41.5	0	36.5	0	12	18	2512
LSD 0.05	20		13.8		12.6		19.8		NS	NS	

H.W. = hand weeding.
fb. = followed by.

Table 3. Effects of herbicides combinations on cotton yield

Treatment	Cotton stand two rows of 10 m.				Cotton yield kg/ha				Phytotoxicity scale 1-9	
	1st year		2nd year		1st year		2st year		1st	2nd
	No.	%	No.	%	yield	%	yield	%	year	year
Trif. 1.2 kg/ha ppi	59	68	80	89	1428	47	1210	47	1	1
Trif. 0.96 kg/ha ppi+H.W.	-	-	90	98	-	-	2234	87	-	1
Trif. ppi fb diuron pre-em	74	85	81	90	2551	84	1890	73	2	1.5
Trif. ppi fb prom. pre-em	75	86	92	100	2254	74	2000	78	1.5	1.5
Trif.+diur. (or prom.)ppi	38	53	46	51	1098	36	781	30	5	5.5
Diuron 1.6 kg/ha pre-em	83	95	92	100	1470	48	1718	67	2.5	2
Prometrin 1.6 kg/ha pre-em	86	100	91	99	1730	57	1675	71	2	2
Diur.+paraq. (tank-mix) post	-	-	94	100	-	-	2156	84	-	2.5
Hand weeding (twice)	86	100	90	98	3041	100	2562	100	1	1
Check (no weeding)	87	100	92	100	268	9	390	15	-	-
LSD 0.05	18.41		12.77		876		668			

H.W. = hand weeding fb = followed by

The tank-mix of diuron and paraquat was nearly as effective as treatments with a single application. This mixture was applied for two purposes, first, to slow down the fast action of paraquat to improve the efficacy and second, to control the subsequent emerged weeds by residual action of diuron. This combination seems to be a suitables system for weed control in small fields, where the farmers do not have the suitable equipment for incorporation of herbicides. Trifluralin at the rate of 0.96 kg ai/ha plus one hand weeding 1 month after cotton emergence gave 72 and 91% control of broadleaves and grasses respectively. This treatment did not reduce the crop stand and also the yield was as much as the hand weeded plots.

All the grass killer herbicides (fluazifop-butyl, haloxyfop- methyl and sethoxydim-sodium) gave good control of grasses even on the johnsongrass which emerged from rhizom fragments (Table 4). None of the tested grass killers were phytotoxic on cotton seedlings.

Combination of the grass killers with other herbicides can help to solve the problem of grasses in cotton.

Table 4. Effects of grass killer herbicides on grass weeds in cotton

Treatments	Weeds/m^2	Fresh wt. of weeds g/m
Fluazifop 250 g/ha	0.8	120
Fluazifop 375 g/ha	0.5	70
Haloxyfop 187.5 g/ha	0.6	100
Sethoxydim 500 g/ha	0.5	85
Check	14	1650

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WEEDS IN GARLIC FIELDS AND THEIR CHEMICAL CONTROL

SHI XIN[1]

ABSTRACT

Field experiments showed that the application of Chloroluron, Oxadiazon, Cinmethylin and Napropamide could control weeds in garlic fields successfully. The application techniques of Chloroluron in garlic fields has been promoted and the economic benefits has been gained.

INTRODUCTION

Garlic is a very popular kind of vegetables in China. There are nearly 60,000 ha of planting area all over the country. Beside the suburban districts of large cities, garlic is mainly planted in Jiading County of Shanghai, Qidong, Taican of Jiangsu Province, Canshan County of Shandong Province, the suburbs of Zhengzhou of Henan Province, Xinjiang and Gansu Province. The growing period of garlic is relatively long, it takes as long as 240 days in Jiading of Shanghai from sowing to reap. During the growing period, garlic undergoes serious weed encroachment which is the primary factor affecting the production, quality and export grade of garlic. During 1985 - 1988, the author was engaged in systematic experiments and researches on weed flora, distribution and infestation, the determination of loss rate and the chemical control of weeds, etc. The results were relatively identical. Later the method of chemical control has been popularized rapidly and gained distinct economic effect. A systematic research similar to ours has not been reported at home or abroad until now.

MATERIALS AND METHODS

1. Survey of Weed Flora and Infestation in Garlic Fields

From 1987-1988, the five grade visualized rating method of weed infestation had been applied in spring and autumn respectively. Investigations were made on weed infestation in garlic fields in Jiading of Shanghai, Taican of

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Jiangsu, Cixi of Zhejiang and Canshang of Shandong. More than 100 plots were sampled each time.

2. Effect of Time and Frequency of Hand Weeding on the Crop Loss Rate

Ten treatments were set including hand weeding at different times and frequencies as follows: 1) hand weeding, once in early autumn; 2) hand weeding, once in late autumn; 3) hand weeding, twice in spring; 4) hand weeding, twice in autumn; 5) hand weeding, twice, one in early spring and another in early autumn; 6) hand weeding, twice, one in late spring and another in late autumn; 7) hand weeding, once in early autumn plus twice in spring; 8) hand weeding, twice in autumn plus once in early spring; 9) hand weeding, twice in autumn and spring respectively, and 10) the control. The actual time for weed control: early autumn means the third ten-days of October, late autumn means the first ten-days of November, early spring-the second ten-days of April and late spring-the third ten-days of April.

The methods of weed control was as follows: In autumn, weeding was carried out with hoes; when garlic roots have been extended to the surface of the soil, weeds were pulled up in order not to injure the crop. Each treatment was replicated three times. In each sampling, weed flora, number and biomass of each weed species were recorded. The area of each plot was 20 m^2 and the treatments were randomized completely.

3. Experiments of the Efficacy of Herbicides

Eleven herbicides with 19 dosages were used including Chloroluron, Ronstar, Cinmethylin and Napropamide to control autumn-winter weeds and spring weeds respectively. The area of each plot was 33.3 - 66.6 m^2 and all plots were in completely randomized design with three replicates. Systematic samplings were carried out in January, February and March after herbicide application to estimate the control efficacy. The quality and estimated yield of garlic were also measured periodically.

4. Researches on Application Techniques of Chloroluron

Experiments were designed to estimate the effect of dosage and application time on the control efficacy of the herbicide. Dosages were 3 kg/ha, 4.5 kg/ha and 6 kg/ha respectively (commercial product). The herbicide was applied post-sowing, but before emergence and at two-leaf and four-leaf stages respectively.

The multi-factor split design was conducted including the time of application, dosage, variety of garlic and sowing depth. The safety of the herbicide to garlic was observed.

The applcation methods included: mixed with soil, mixed with fertilizer and spraying.

The plots were 33.3 - 66.6 m^2 with three replcates and all in randomized design.

RESULTS AND DISCUSSION

1. Weed Flora and Infestation in Garlic Fields

According to the sampling of 1,460 plots in garlic fields in Jiading of Shanghai, 47 main weed species were found which belong to 18 families. The frequency of weeds in garlic fields was 100%. Among them, 71.64% exceeded the infestation grade II and 29.81% exceeded grade III. The weed infestation index was 39.71 (Fig. 1). The results from Cixi of Zhejiang, Taican of Jiangsu were similar.

The weed infestation in spring and autumn was different in weed population composition and number of weeds. In autumn, the frequency of weeds was 100%. Among them, 46.82% exceeded infestation grade II. The weed infestation index was 34.26. Most of them were *Malachium aquaticum, Galium aparine, Alopecurus aequalis, Mazus japonica, Xanthium sibiricum, Cardamine flexuosa* and *Veronica didyma*. In spring, most of the autumn weeds still existed, and in addition, there were also some spring weeds. The weed infestation was more serious than in autumn. The frequency of weeds was 100%. Among them, 67.18% exceeded grade II. The infestation index was 43.95. Most of them were *Polygonum lapathifolium, Chenopodium serotinum, Amaranthus spinosus, Rorippa montana, Erigeron annuus, E. canadensis, Poa annua* and *V. anagallis* (Table 1).

2. Determination of Crop Loss Caused by Hand Weeding of Different Frequencies and at Different Times

Shortly before garlic was reaped on the third ten-days of May, weed control in different periods and frequencies and their relationship with the emergence of weeds were evaluated. The results indicated that twice hand weeding, in autumn and spring respectively had the best control efficacy. The period of weed infestation was shorter than the other treatments. But four times hand weeding, consumed a lot of manpower. Comparatively, hand weeding in late autumn and late spring was more economical and reasonable. Not only the period of weed infestation was shorter but the control efficacy was relatively higher (Table 2).

The results indicated that the highest yield and export rate could be achieved if more than three times of hand weeding were applied. The second highest yield and export rate were achieved when two times of hand weeding

Table 1. Weed species infesting garlic fields and damage caused by their infestation (Jiading County)

Weed species	Survey in autumn (560 plots)							Survey in Spring (470 plots)						
	Frequency (%)	Proportion of different damage grades (%)					Proportion of damage grade over "1" (%)	Frequency (%)	Proportion of different damage grades (%)					Proportion of damage grade over "1" (%)
		1	2	3	4	5			1	2	3	4	5	
Humulus scandens								3.4	93.8	0	6.2	0	0	6.2
Polygonum aviculare								29.8	96.4	2.1	1.5	0	0	3.6
Polygonum salicifolium								59.8	72.2	19.2	5.0	2.5	1.1	27.6
Polygonum lapathifolium								70.2	70.0	12.7	6.1	0.9	0.3	20
Rumex japonicus	8.4	100	0	0	0	0	0	12.5	100	0	0	0	0	0
Chenopodium serotinum	7.3	92.7	7.3	0	0	0	7.3	67.2	77.8	16.5	5.4	0.3	0	22.2
Chenopodium album	5.5	96.8	3.2	0	0	0	3.2	7.0	97.0	0	3.0	0	0	3.0
Amaranthus spinosus	2.9	100	0	0	0	0	0	1.5	71.4	28.6	0	0	0	28.6
Amaranthus adsendens	3.2	100	0	0	0	0	0							
Malachium aquaticum	70.4	69.3	22.3	5.8	2.3	0.3	30.7	75.7	77.2	19.7	2.2	0.6	0.3	24.5
Cerastium viscosum	32.7	96.7	3.3	0	0	0	3.3	22.1	90.4	8.7	0.9	0	0	9.6
Ranunculus acris	5.7	100	0	0	0	0	0	15.3	95.5	4.2	0	0	0	4.2
Ranunculus muricicatus	9.3	94.2	5.8	0	0	0	5.8	13.4	85.7	11.1	3.2	0	0	14.3
Cardamine flexuosa	25.9	99.3	0.7	0	0	0	0.7	6.4	96.7	3.3	0	0	0	3.3
Rorippa montana	27.8	98.1	1.9	0	0	0	1.9	58.9	92.4	6.9	0.7	0	0	7.6
Rorippa palustris	6.6	100	0	0	0	0	0	9.6	88.9	11.1	0	0	0	11.1
Acalypha australis								3.8	100	0	0	0	0	0
Euphorbia helioscapia	2.7	100	0	0	0	0	0	2.8	100	0	0	0	0	0
Cnidum monnieri								13.4	96.8	3.2	0	0	0	3.2
Metaplexis japonica								0.6	100	0	0	0	0	0
Convolvulus arvensis	1.1	100	0	0	0	0	0	7.0	100	0	0	0	0	0
Bothriospermum chinense	8.2	100	0	0	0	0	0	3.6	100	0	0	0	0	0
Salvia plebeia	5.4	100	0	0	0	0	0	5.3	100	0	0	0	0	0
Mazus japonica	21.8	99.3	0.7	0	0	0	0.7	33.6	93.7	4.4	0.6	1.3	0	6.3
Veronica anagallis	6.8	92.1	7.9	0	0	0	7.9	34.7	98.8	0.6	0.6	0	0	1.2
Veronica agrestis	23.6	96.2	3.8	0	0	0	3.8	20.9	98.0	2.0	0	0	0	2.0
Veronica peregrine	3.0	100	0	0	0	0	0	26.4	79.8	16.1	2.4	1.7	0	20.2
Plantago major	2.3	100	0	0	0	0	0	10.9	98.0	2.0	0	0	0	2.0
Galium aparine	48.4	73.4	23.2	2.2	1.1	0	26.6	49.6	81.5	13.7	4.8	0	0	18.5
Cephalanoplos segetom	3.9	100	0	0	0	0	0	12.8	100	0	0	0	0	0
Helmistepla carthamoides	11.1	100	0	0	0	0	0	5.3	100	0	0	0	0	0
Gnaphalium multiceps	5.4	100	0	0	0	0	0	16.2	100	0	0	0	0	0
Erigeron annuus	25.1	100	0	0	0	0	0	45.1	94.3	4.7	1.0	0	0	5.7
Conyza canadensis	25.0	99.3	0.7	0	0	0	0.7	36.8	98.3	1.2	0	0.5	0	1.7
Erigeron bonariensis								7.2	100	0	0	0	0	0
Bidens pilosa								3.8	88.9	5.5	5.6	0	0	11.1
Asteromaea indica	0.9	100	0	0	0	0	0	3.4	100	0	0	0	0	0
Sonchus oleraceus														
Ixeris denticutata	7.5	100	0	0	0	0	0	3.4	100	0	0	0	0	0
Sonchus arvense	4.3	100	0	0	0	0	0	2.8	100	0	0	0	0	0
Aster subulatus								1.3	100	0	0	0	0	0
Beckmania cruciformis								0.2	100	0	0	0	0	0
Sclerochloa kengiana								28.9	91.0	8.8	0.7	0.7	0	10.3
Poa annua	5.7	100	0	0	0	0	0	53.6	90.9	7.9	1.2	0	0	9.1
Alopecurus aequalis	64.5	91.1	7.5	1.1	0.3	0	8.9	46.0	87.0	10.6	1.9	0.5	0	13.0
Polypogon frugax	5.2	86.2	13.8	0	0	0	13.8	1.3	66.7	33.3	0	0	0	33.0
Echinochloa hispidula								2.8	100	0	0	0	0	0

Table 2. Occourrence of weeds after diverse weeding treatments with herbicides applied at different periods and frequencies (surveying date the second ten days of May)

Treatment	*Alopecurus aequalis*		*Malachium aquaticum*		*Rorippa montana*		*Polygonum hydropiper*		*Mazus japonica*		Fresh weight (g)	Inhibition rate (%)	Investation period (days)
	a	b	a	b	a	b	a	b	a	b			
One application in early autumn	17	0	20		7	82.5			0	100	1086	57.36	210
One application in late spring	0	100	19		6	85			3	62.5	8	99.7	190
Two applications in spring	4	76.5	5	66.7	25	37.5			4	50	506	80.1	180
Two applications in autumn	3	82.4	14	6.7	23	42.5			0	100	872	65.8	150
Two applications, one early spring, the other in early autumn	4	76.5	36		16	60			6	25	268	89.5	210
Two applications, one in late spring, the other in late autumn	4	76.5	17		3	92.5	2		0	100	8.5	99.7	130
One application in early autumn plus two applications in spring	5	70.6	26		28	30	11		0	100	198	92.2	160
Two applications in autumn plus one application in early spring	2	88.2	11	26.7	16	60	11		1	87.5	94	96.3	140
Two applications in autumn and spring respectively	1	94.1	10	33.3	18	55	6		3	62.5	84	96.7	110
No application (control)	17		15		40				8		2547		230

were applied; the lowest yield and export rate were achieved when hand weeding was applied only once. On the condition that in the same frequency of hand weeding taken in different periods, the effects on yield and export rate were not alike. For instance, on the condition that hand weeding was applied twice in autumn, the extent of yield increase was greater.

3. Chemical Weed Control in Garlic Fields

Weeds in garlic fields were mainly those germinating in October and November and those germinating in May of the next spring. Those germinating in autum were the principal weeds. So the object of chemical weed control was the weeds appearing in autumn and also in winter.

a. Herbicides for weed control in autumn and winter

In dealing with the weeds germinating in autumn and winter such as *A. aequalis, M. aquaticum, C. flexuosa, G. aparine* and *R. montana*, Chloroluron, Napropamide, Fluometuron, Prometryn, Nitrophen, Ronstar and Cinmethylin etc. for soil treatment and MCPA, Bentazon, Ronstar, Starane for shoot spraying to control *G. aparine* were applied. The results were as follows :

(1) Applying 25% Chloroluron 1,500 g/ha, the control efficacy of controlling *M. aquaticum, A. aequalis* was about 90% and was also good in controlling *C. flexuosa* and *R. montana*. As to *G. aparine*, the control efficacy was poor (Table 3).

Table 3. Effects of diverse treatments with herbicides applied at diffferent periods on the head number, yield and product value of garlic

Treatment	Garlic sprout		Garlic head		Export rate*		
	Yield (jin/mu)	Increase over CK (%)	Yield (jin/mu)	Increase over CK (%)	(%) Export rate	Increase over CK (%)	Product value (yuan/mu)
One application in early autumn	596.8	25.6	902.2	19.0	28.3	39.4	460.76
One application in late spring	528.1	11.1	857.1	13.1	21	3.4	410.55
Two applications in spring	531.7	11.9	968.8	27.8	33.3	64	468.03
Two applications in autumn	647.5	36.2	1017.1	34.2	29.3	44.3	503.91
Two applications, one early spring, the other in early autumn	588.2	23.8	979.5	29.2	43.7	115.3	521.82
Two applications, one in late spring, the other in late autumn	602.7	26.8	966	27.4	26.7	31.5	465.62
One application in early autumn plus two applications in spring	592	24.6	1341.1	76.9	44.0	116.7	616.31
Two applications in autumn plus one application in early spring	688.6	44.9	1162	53.3	63.3	211.8	670.72
Two applications in autumn and spring respectively	661.9	39.3	992.4	30.9	56.3	177.3	579.64
No application (CK)	475.3			758.1			20.3

(2) Applying 12% Ronstar EC 2,250 ml/ha, the weed infestation in garlic fields could be controlled effectively. The experiments in Huating Farm showed that the control efficacy was 95.0% in controlling *A. aequalis* and 99.7% in controlling the weeds of Cruciferae. It was specially good in controlling *G. aparine*, the control efficacy was about 97% and it was safe to garlic. Yield increase was remarkable by such application.

(3) Applying 750-2250 ml/ha 82% Cinmethylin EC, the control efficacy of controlling *A. aequalis* came to 100% even at the two-leaf or three-leaf stage of the weed. As to weeds of Cruciferae, the control efficacy came to 91.4, 99.8 and 99.9% respectively.

(4) Applying 50% Devrinol WP 1,500 g/ha, the control efficacy on *M. aquaticum* and *A. aequalis* was above 85%. As to *C. flexuosa, R. montana* etc. of Cruciferae, the control efficacy was poor.

(5) Applying 48% Bentazon EC 3,000 ml/ha, the control efficacy on *G. aparine* was remarkable (over 99%) but the yield and export rate of the crop was reduced (Table 4).

Table 4. Efficiency of controlling autumn and spring weeds by the application of diverse herbicides (1985, in Jiaxi)

Herbicide	Dosage g (ml)/mu	*M. aquaticum*		*A. acqualis*		*G. aparine*		*C. flexuosa*		*R. montana*		Total		Safety scale*
		a	b	a	b	a	b	a	b	a	b	a	b	
25% Chloroluron WP	300	0a	100	5a	92.4	12	0	10	90.1	18ab	64.0	46a	82.2	2
50% Prometryn WP	100	2a	89.4	22ab	66.7	5	37.5	30ab	70.5	14ab	72.0	75ab	70.9	2
80% Fluometuron WP	100	0a	100	0a	100	12	0	0a	100	3a	94.0	18a	93.0	2
50% Devrinol WP	100	1a	94.7	9a	86.3	6	25.0	45 ab	55.8	7a	86.0	72ab	72.1	1
48% Treflan EC	100	9b	52.6	42b	36.3	3	62.5	51b	50	13ab	74.0	118b	54.3	1
CK		19c	/	66c	/	8	/	102c	/	50c	/	258c	/	

a: Number of plants, b: Control efficacy
* Safety scale, 1: Safe, 2: Applicable only in opportune conditions, 3: Non applicable

(6) Applying 20% Starane 750 ml/ha, the control efficacy on *G. aparine* at mature stage was excellent and the herbicide was comparatively safe to garlic (Table 5).

Table 5. Efficiency of controlling *Galium aparine* by applicatio of diverse herbicides and influence of treatments on the economic characters of garlic (Huating Farm, 1987)

Herbicide	Dosage (ml/mu)	Stem number (plants/m²)	30 days after application					Weight of garlic heads		Diameter of garlic heads		Export rate	
			Plants/m	Decrease rate (%)	Adjusted rate (%)	Fresh weight (g/m^2)	%	kg/mu	Increase or decrease rate over CK (%)	cm	Increase or decrease rate over CK (%)	%	Increase or decrease rate over CK (%)
12% Ronstar EC	150	199	5	97.5	97.5	0.7	99.5	0.356	64.6	4.12	7.6	83.3	19.0
48% Bentazon EC	200	188	1	99.1	98.9	0.2	99.8	0.198	-8.5	3.55	7.3	46.7	-33.3
20% Starane EC	50	200	10	96.5	95.9	1.9	98.6	0.243	12.3	3.88	1.3	76.7	9.6
CK		218	188	13.2	/	144.0	/	0.216	/	3.83	/	70.0	/

The application of Fluometuron, Prometryn, Nitrophen, Trifluralin and MCPA had poor control efficacies or might be harmful to garlic.

b. Herbicides for weed control in spring

In dealing with the weeds germinating in spring and those surviving autumn and winter, nine herbicides were applied including Prometryn, Nitrophen, Saturn, Machete, Trifluralin, Devrinol, Fluometuron, Ronstar and Cinmethylin. The results showed that all of these herbicides had fairly good efficacies. In a comprehensive consideration, Devrinol, Ronstar and Cinmethylin were good options, which gave good control efficacies and great yield increase of the crop (Table 6).

Table 6. Efficiency of controlling surviving autumn weeds and spring weeds by application of diverse herbicides and influence of treatments on the yield of garlic (Xuhang, 1988).

Herbicide	Dosage	Surviving autumn weeds				Spring weeds				Diameter of garlic head		Diameter		Fresh weight of 100 heads	
		plants/m²	%	g/m²	%	plants/m²	%	g/m²	%	cm	%	%	%	g	+ %
Ronstar	150	51	58.1	126	73.0	0	100	0	100	4.81	9.5	93	17	5160	24.3
Devrinol	100	11	90.0	3.4	93.2	0	100	0	100	4.77	8.6	90	14	4900	
Cinmethylin	100	6	95.0	9.4	97.9	0	100	0	100	4.82	9.7	96	20	5000	
CK		122	/	468.3	/	10	/	10	/	4.39	/	76	/	4100	/

Note: Surviving autum weeds include mainly *Malachium aquaticum*, then *Rorippa montana, Alopecurus aequalis* and *Galtum aparine*; spring weeds include *Chenopodtum seroticum*, *Polygonum aviculare* and spring polygonum.

4. The Applied Techniques of Chloroluron

a. Dosage and application time

Applying Chloroluron 3.0, 4.5 and 6.0 kg/ha after sowing and before germination, the weed control efficacies reached 82.8, 88.3 and 95.4% respectively. Applying the dosages mentioned above in four-leaf stage, the control efficacy reached 68.9, 81.4 and 94.3%. T-test indicated that in whatever garlic growing periods, 3,000 g/ha Chloroluron was distinctly different from 4,500 or 6,000 g/ha, the former was not so good. The test also indicated that applying after sowing and before germination did not harm the crop. More green leaves, thick stems and heavy sprouts and heads appeared. In condition, the diameter of garlic head and export rate were distinctly high (Table 7).

Table 7. Efficiency of controlling weeds in garlic fields by chlorooluron applied at different times and the influence of treatments on the growth of garlic

Herbicide	Application time	Dosage (g/mu)	Height of plant		Green leaf number		Stem girth		Weight of garlic sprout		Weight of garlic head		Diameter of garlic head		Export rate	
			cm	%		%	cm	%	kg	%	kg	%	cm	%	%	%
25% Chloroluron WP	Between seeding and emergence	300	51.33 a	-3.7	5.88 a	6.9	1.5 a	8.7	0.88 r	8.6	4.84 a	30.81	1.0 ab	8.6	60.1 ab	22.0
25% Chloroluron WP		400	50.9 ab	-4.6	5.87 a	6.7	1.48 a	7.2	0.84 ab	3.7	4.78 a	29.2	1.02 a	9.2	80.4 ab	23.3
25% Chloroluron WP	Two-leaf stage	300	48.77 bc	-8.6	5.79 ab	5.3	1.46 a	5.8	0.80 ab	-1.2	4.14 bc	11.9	3.79 bc	3.0	75.6 ab	16.0
25% Chloroluron WP	Two-leaf stage	400	46.61 c	-16.72	5.66 b	3.6	1.35 bc	-2.2	0.73 bc	-9.8	3.93 c	6.2	3.58 c	-2.7	59.1 a	-9.4
25% Chloroluron WP	Four-leaf stage	300	48.17 bc	-9.7	5.43 c	-2.9	1.36 bc	-1.4	0.66 c	-18.5	3.41 d	-7.83	3.47 cd	-5.7	19.2 cd	-24.5
25% Chloroluron WP	Four-leaf stage	400	43.64 d	-18/2	5.34 c	-3.3	1.28 c	-7.2	0.51 d	-37.0	2.85 d	-23.03	3.28 d	10.9	46.6 d	-28.5
CK			53.33 a	/	5.5 a	/	1.38 a	/	0.81 ab	/	3.7 cd	/	3.68 c	/	65.2 bc	/

b. Conditions for application

Factors in the experiments included application period such as after sowing and before germination, two-leaf stage and four-leaf stage, dosage (4,500 and 6,00 g/ha), garlic variety (Baishuang No. 1, Baishuang No. 2 and Tienshuang) and sowing depth (shallow, medium and deep). Multi-factor split design was conducted to test the herbicide safety to the crop. It was observed that the application at two-leaf or four-leaf stage was harmful to garlic. Garlic variety and sowing depth did not affect the herbicide safety.

c. Methods of application

Garlic is usually interplanted with cotton. It is inconvenient to apply the herbicide at the presowing or post-sowing and pre-emergence stage and is advisable to apply soil toxication (mixed with soil) or fertilizer toxication (mixed with fertilizer). T-test showed no difference among the three application methods.

WEED ECOLOGY, POPULATION DYNAMICS, VEGETATION SUCCESSION, COMPETITION AND PROBLEMS

REPRODUCTIVE STRATEGY OF TROPICAL ANNUAL WEEDS

S. S. SASTROUTOMO[1]

ABSTRACT

Seed germination, seedling growth, allocation of biomass and reproductive efforts of *Mimosa invisa, Leucas lavandulaefolia, Bidens pilosa, Borreria alata, Synedrella nodiflora, Porophyllum ruderale* and *Euphorbia prunifolia* were investigated under glasshouse conditions in petridish or pot experiment.

In petridishes, *B. pilosa, P. ruderale* and *M. invisa* had germination more than 50%; with soil as medium, *B. alata, S. nodiflora* and *L. lavandulaefolia* had higher germination rates compared to the results in petridishes.

The seedling growth was highest for *B. pilosa* with 200 mg DW/plant, however the highest maximum RGR for seedlings was found in *P. ruderale*.

Allocation of biomass to roots in the mature stage was highest for *L. lavandulaefolia* than other species, to stems for *P. ruderale* and *E. prunifolia*, and to leaves for *B. alata* and *S. nodiflora*. *L. lavandulaefolia* had the highest maximum RGR than the other species.

Porophyllum ruderale had the highest RE than other species, the order being *P. ruderale* > *B. alata* > *E. prunifolia* > *S. nodiflora*.

INTRODUCTION

Accurate predictions of weed composition and relative aggressiveness of each individual species would greatly enhance weed management. Grime (1974), Grime and Hunt (1975), and Grime (1977) characterize weeds as colonizing species of plant that exhibit physiological, morphological, genetic and ontogenetic traits for rapid growth. A species that grows faster or larger than its neighbours will utilize a disproportionate amount of available resources, therefore, growth rates may reflect relative competitive ability.

Harper (1967), Gadgil and Solbrig (1972) suggest the possibility that colonizing species of plants which usually grow in an unstable environment e.g. farmland, would allocate more energy to reproductive activities at the expense of vegetative activities (r-strategies) and have a shorter life span. Conversely, in a stable environment, plants would allocate more energy to vegetative activities for increased competitive ability at the expense of reproductive activities (K-strategies).

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There is increasing evidence that distribution and abundance of adults in a weed community is often mediated by events that occur during seedling establishment. (Cook, 1979; Gross and Wenner, 1982). Seed and seedling characteristics are likely determinants of both the types of communities in which a species can occur and the types of microsites within a community where seedlings can establish. Large seed size is generally assumed to provide individuals with a competitive advantage, and such an advantage has been demonstrated in some studies (Harper *et al.*, 1970; Gross and Wenner, 1982). However, there are aspects of life history other than seed size e.g. emergence time and seedling growth rate, that may affect seedling emergence and the success of seedling establishment in the field (Grime, 1979).

Very few studies have examined the comparative growth and allocation strategies of annual or perennial weeds of tropical agriculture (Saxena and Ramakrishnan, 1983). The present study concerns the germination, growth and resource allocation strategies during the life-cycle of some important tropical annual weeds in a glasshouse.

MATERIALS AND METHODS

Seeds for in all experiments were collected during fruiting time from the experimental field of SEAMEO-BIOTROP at Tajur, Bogor, Indonesia in 1983. Ripe seeds of *Mimosa invisa, Bidens pilosa, Leucas lavandulaefolia, Borreria alata, Synedrella nodiflora, Porophyllum ruderale* and *Euphorbia prunifolia* were collected from wild populations.

Germination tests were conducted in a glasshouse with temperature ranging from 28-32°C and using natural light. In the first experiment, seeds were placed on filter paper in glass petridishes at full water holding capacity, and in the second, seeds were placed on plastic trays covered with 1 cm sterilized soil. Tests with five replicate dishes or trays of 50 seeds lasted for 18 days. Based on these parameters, the percent germination was calculated.

Sixty germinated seeds each from *M. invisa, L. lavandulaefolia, B. pilosa, S. nodiflora* and *P. ruderale* were used for seedling growth study. Each set of the 60 germinated seeds were planted in a small pot filled with sterilized soil. The pot measured 5 cm in diameter and 12.5 cm in height. Ten seedlings of each species were harvested randomly at weekly intervals for dry weight determination and the experiment was terminated after a six week period. Seedlings were dried for 48 hrs at 85°C and weighed to the nearest microgram.

Another sixty germinated seeds each from *S. nodiflora, M. invisa, B. alata, L. lavandulaefolia, P. ruderale* and *E. prunifolia* were individually planted in medium-sized pots (10 cm diameter and 20 cm height) filled with sterilized soil. In addition to this, another set of experiment with an additional fertilizer (NPK at 50 kg/ha) was conducted for *P. ruderale* and *E. prunifolia*.

Ten plants of each species were harvested at random every 2-3 weeks after four weeks of planting. Roots, stems, leaves, and reproductive structures (i.e. seeds, fruits, flowers, pedicels and peduncles) were separated, dried at 85°C for 72 hrs, and weighed.

Another experiment with different types and combinations of fertilizers was also conducted on *P. ruderale, E. prunifolia* and *L. lavandulaefolia*. Eight different fertilizer treatments were arranged in a series of pots with sterilized soils as below :

a. without fertilizer (control)
b. with N-fertilizer (50 kg/ha)
c. with P-fertilizer (50 kg/ha)
d. with K-fertilizer (50 kg/ha)
e. with N+P fertilizers (50+50 kg/ha)
f. with N+K fertilizers (50+50 kg/ha)
g. with P+K fertilizers (50+50 kg/ha)
h. with N+P+K fertilizers (50+50+50 kg/ha)

Each plot was planted with germinated seeds and each treatment had five replicates. The plants were harvested after 12 weeks of planting. Roots, stems, leaves and reproductive structures were separated, dried at 85°C for 72 hrs, and weighed.

The relative growth rate (maximum and average) was calculated as:

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

where W_1 is biomass at t_1 and W_2 is biomass at t_2. The ratio of the total dry weight of sexual reproductive tissue and the total dry weight of plant (reproductive effort = RE) of each species were also calculated and compared.

RESULTS

Seed Germination

The results of the germination experiment are shown in Figures 1 and 2. In petridishes, *P. ruderale* and *M. invisa* germinated faster (after three days) than other species. After 18 days, only three species had germination of more than 50%, i.e. *B. pilosa* (98%), *P. ruderale* (90%) and *M. invisa* (58%). *B. alata* and *S. nodiflora* had the lowest germination rate with only about 20%.

With soil as the medium, *B. pilosa, P. ruderale*, and *M. invisa* had the same high germination results as in the petridishes. Three species, i.e. *B. alata, S. nodiflora* and *L. lavandulaefolia* had higher germination rates compared to the results in petridishes.

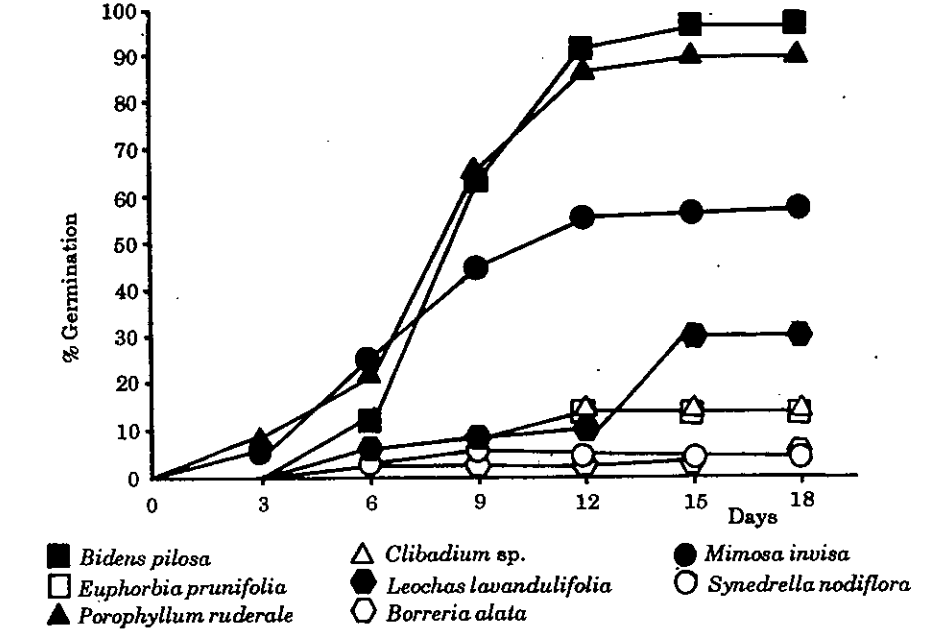

Figure 1. Germination of 8 species of weeds in petridishes.

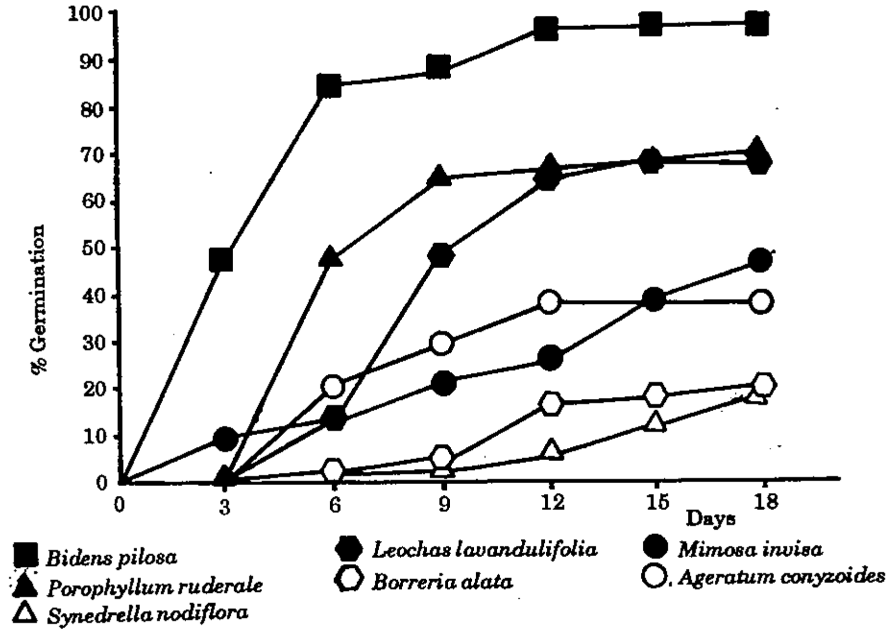

Figure 2. Germination of 7 species of annual weeds in the soil.

Seedling Growth

Figure 3 shows seedling growth of five annual weeds as measured in average dry weight per plant. Until two weeks *S. nodiflora* had the fastest growth followed by *B. pilosa* and *M. invisa*. However, after six weeks, the weight of *B. pilosa* per plant was the highest with 200 mg followed by *S. nodiflora* (150 mg) and *M. invisa* (110 mg).

L. lavandulaefolia and *P. ruderale* had the slowest seedling growth with 40 mg and 35 mg weight respectively after six weeks of germination.

Table 1 shows the estimated average and maximum dry matter prodution in the seedling stage of annual weeds. *P. ruderale* had the highest maximum RGR than the other four species, however, the highest average RGR was by *B. pilosa*, while *S. nodiflora* had the lowest maximum as well as average RGR.

Table 1. Estimates of the rates of dry matter production in the seedling phase

Species	Seed weight (mg)	RGR max (g/g/week)	RGR mean (g/g/week)
Porophyllum ruderale	0.98	1.11	0.47
Bidens pilosa	1.99	0.88	0.50
Mimosa invisa	6.79	0.79	0.46
Leucas lavandulaefolia	0.96	0.78	0.30
Synedrella nodiflora	1.64	0.65	0.26

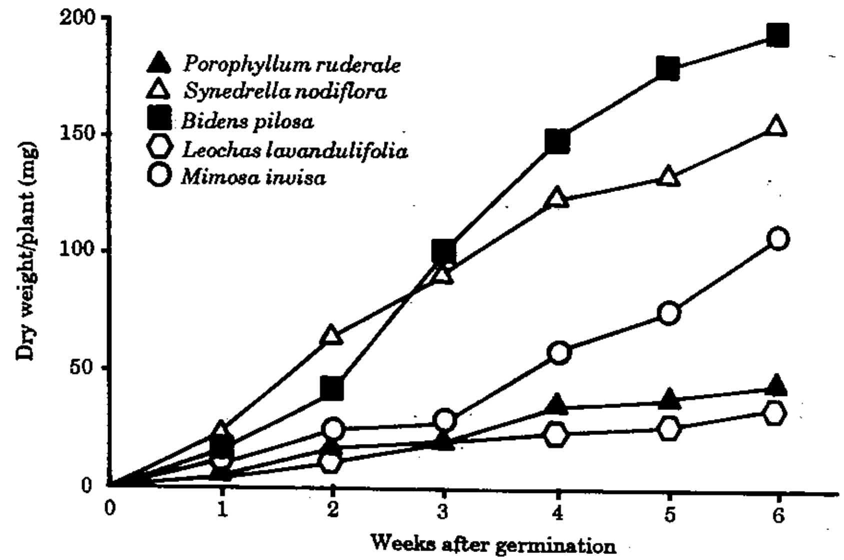

Figure 3. Seedling growth of 5 annual weeds expressed in mg dry weight/plant.

Allocation of Biomass

Figs. 4-10 show the mean dry matter production of six annual weeds at different harvest times and with/without fertilizer application. The biomass of *M. invisa*, *B. alata* and *S. nodiflora* increased tremendously from time to time until the end of the experiment (14 weeks), however, the biomass of *L. lavandulaefolia* and *E. prunifolia* reached their maximum after 10-11 weeks. Allocation of biomass to roots was highest for *L. lavandulaefolia* than other species, to stems for *P. ruderale* and *E. prunifolia*, and to leaves for *B. alata* and *S. nodiflora*.

The estimated average and maximum dry matter production and the ratio of above-ground to under ground biomass in the mature stage of six annual species is given in Table 2. *P. ruderale* had the highest ratio of aboveground compared to underground biomass (9.0-10.0), followed by *E. prunifolia* (4.5-5.0), *M. invisa* (2.96) and *B. alata* (1.98), and *L. lavandulaefolia* had the lowest ratio with only 0.67. The ratios for *P. ruderale* and *E. prunifolia* in the experiment with additional fertilizer were lower than in the experiment without fertilizer.

Table 2. Estimates of the rates of dry matter production in the mature stage

Species	Seed Weight (mg)	S/R	RGR max (g/g/week)	RGR mean (g/g/week)
Mimosa invisa	6.79	2.96	0.72	0.50
Leucas lavandulaefolia	0.96	0.67	1.08	0.72
Borreria alata	2.55	3.61	0.97	0.51
Synedrella nodiflora	1.64	1.98	0.43	0.32
Porophyllum ruderale	0.98	10.57	0.65	0.42
- with fertilizer		9.03	0.95	0.46
Euphorbia prunifolia	4.00	5.50	0.65	0.48
- with fertilizer		4.00	0.85	0.62

L. lavandulaefolia had the highest maximum RGR than the other species, the order being *L. lavandulaefolia* > *B. alata* > *M. invisa* > *P. ruderale* and *E. prunifolia* > *S. nodiflora*. With the application of NPK fertilizers, the maximum RGR of *P. ruderale* and *E. prunifolia* was higher as compared to the maximum RGR without fertilizers.

The average dry weight per plant of *L. lavandulaefolia*, *E. prunifolia* and *P. ruderale* in different types and combinations of fertilizers is given in Figs. 11-13. In general, *L. lavandulaefolia* had the highest dry weight per plant as compared to the other species, however, the highest ratio of above ground biomass to under ground biomass was found in *P. ruderale* (6.7-10.3).

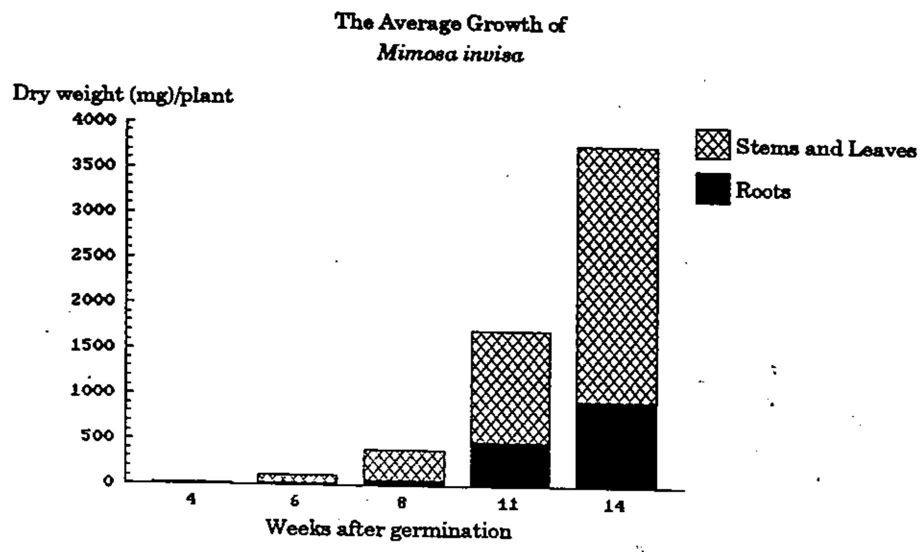

Figure 4. Average growth of *Mimosa invisa* in different times after germination.

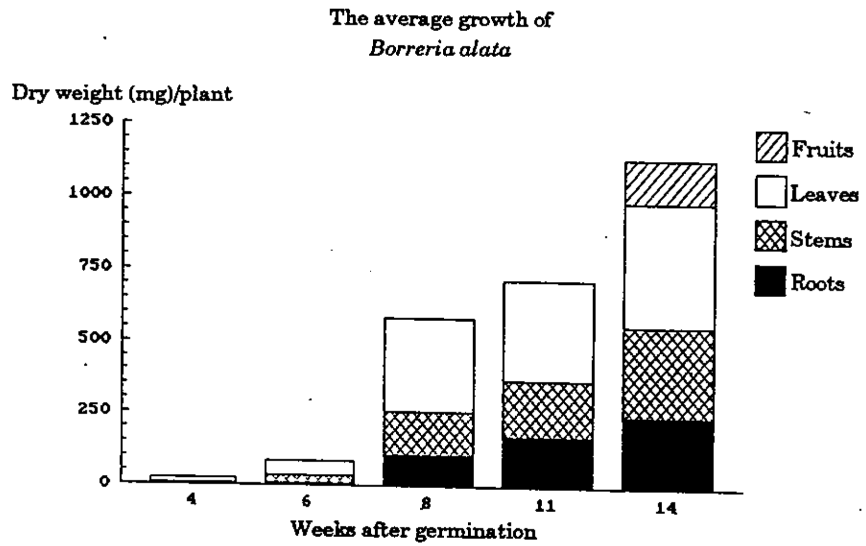

Figure 5. Average growth of *Borreria alata* in different times after germination.

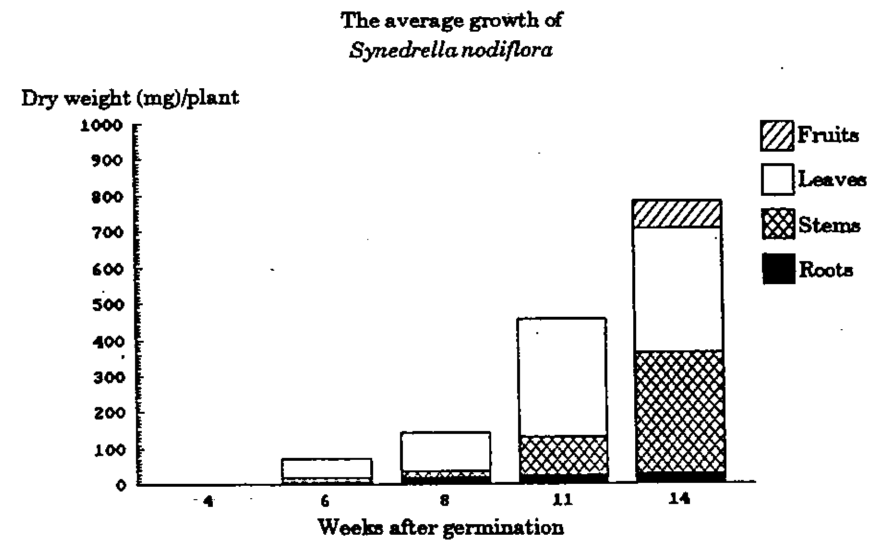

Figure 6. Average growth of *Synedrella nodiflora* in different times after germination.

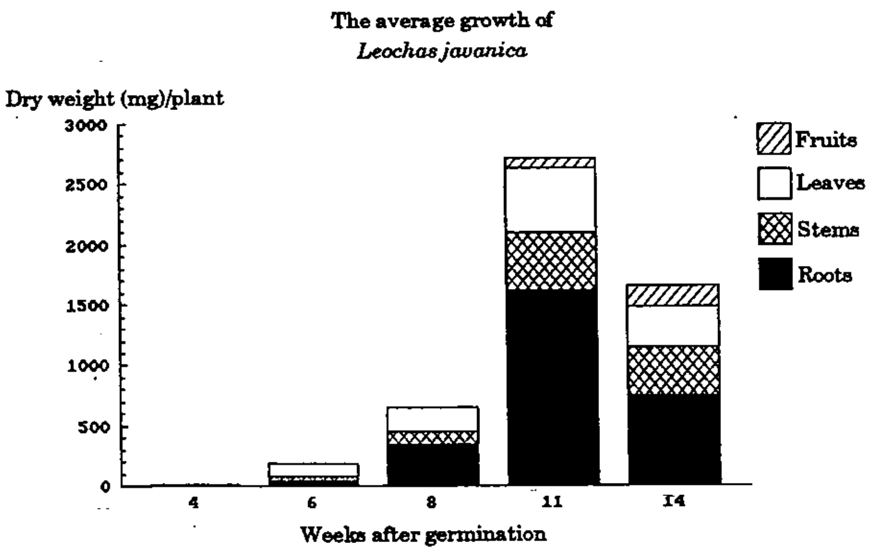

Figure 7. Average growth of *Leucas lavandulaefolia* in different times after germination.

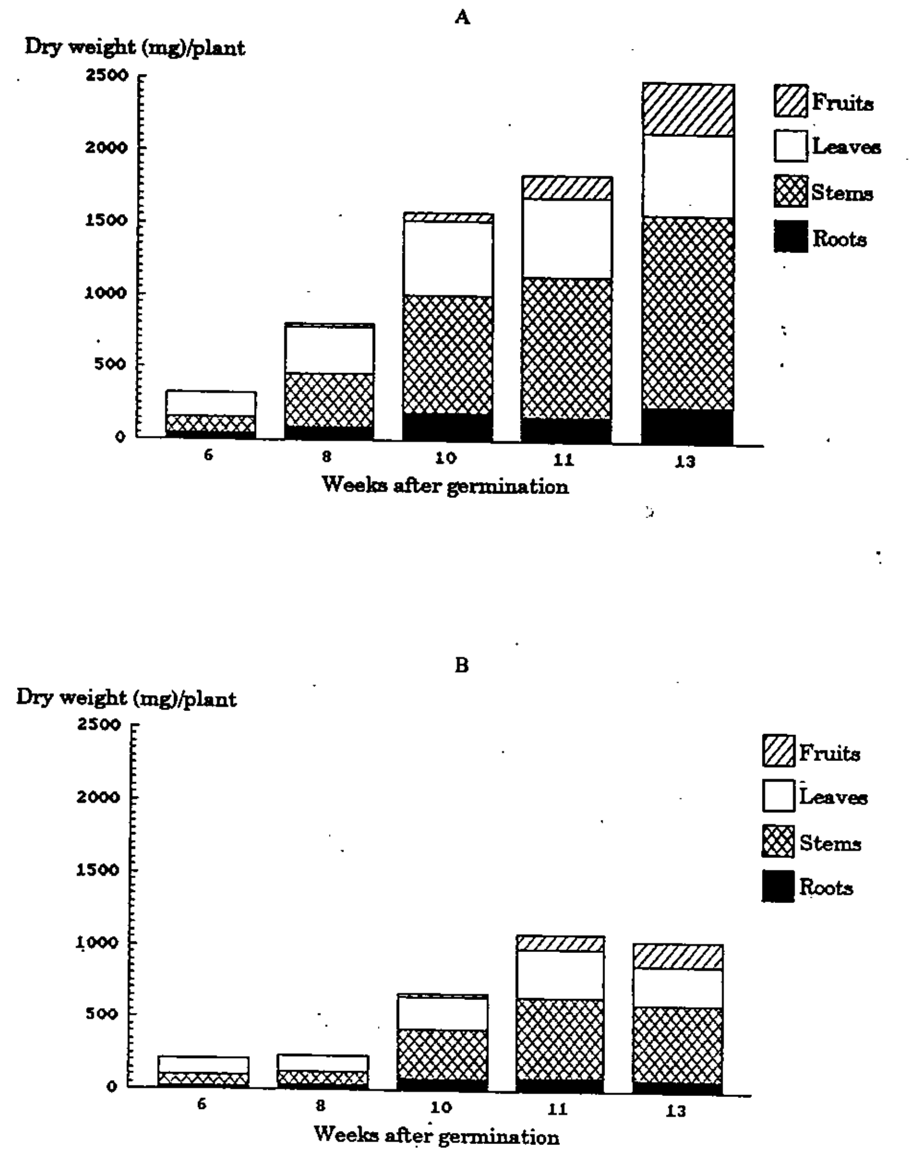

Figure 8. Average growth of *Porophyllum ruderale* in different times after germination. A: with fertilizerB: without fertillzer.

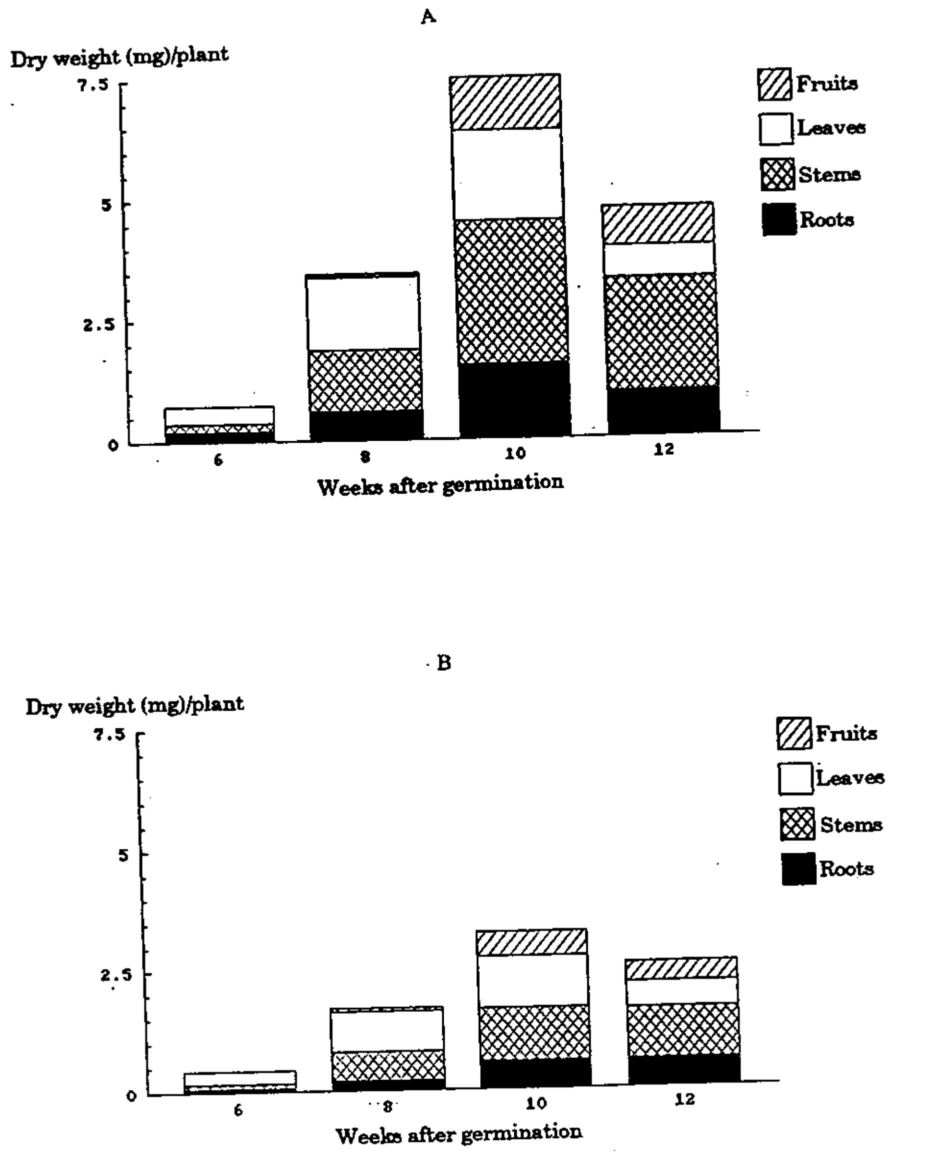

Figure 9. Average growth of *Euphorbia prunifolia* in different times after germination.
A: with fertilizer B : without fertilizer.

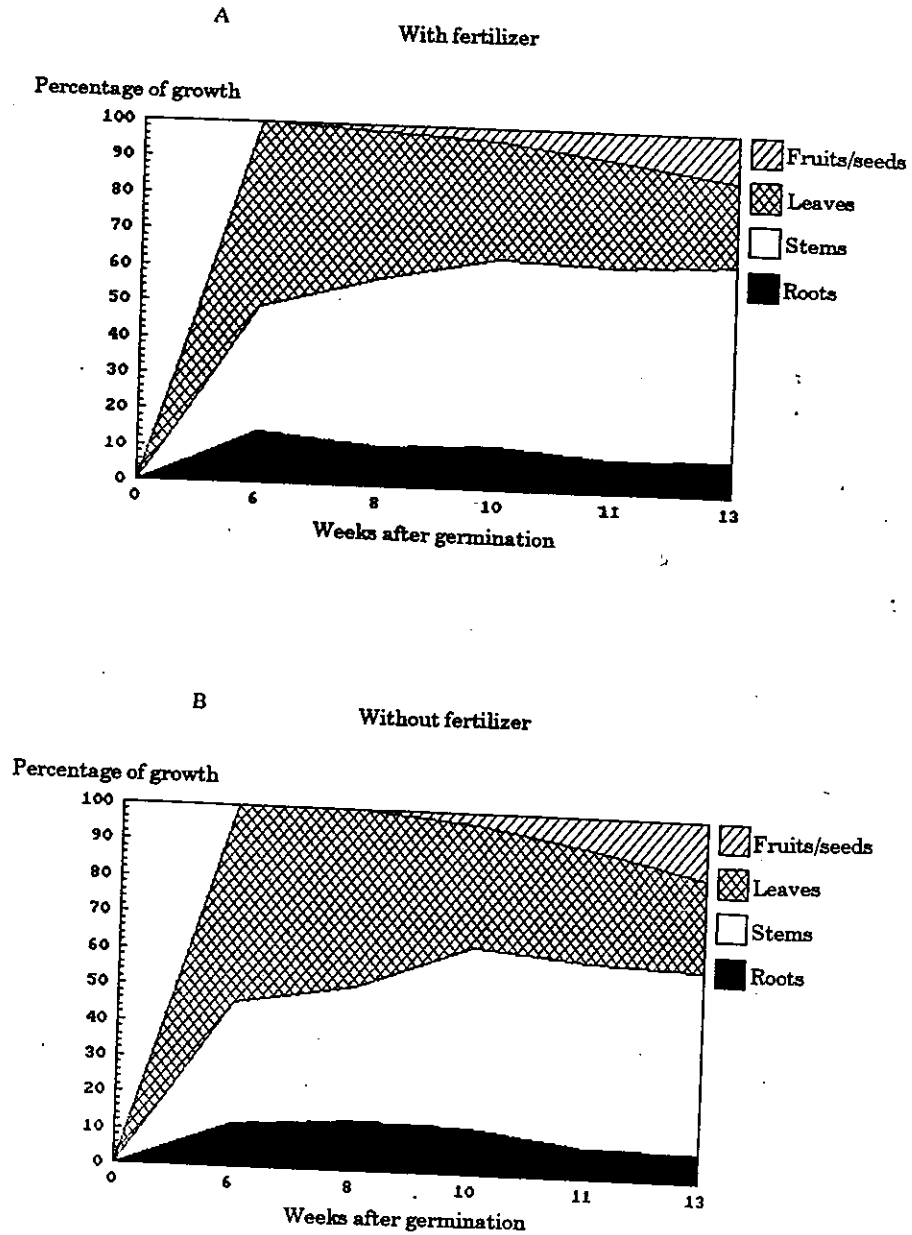

Figure 10. Biomass allocation (%) of *P. ruderale*. A : with fertilizer B : without fertilizer.

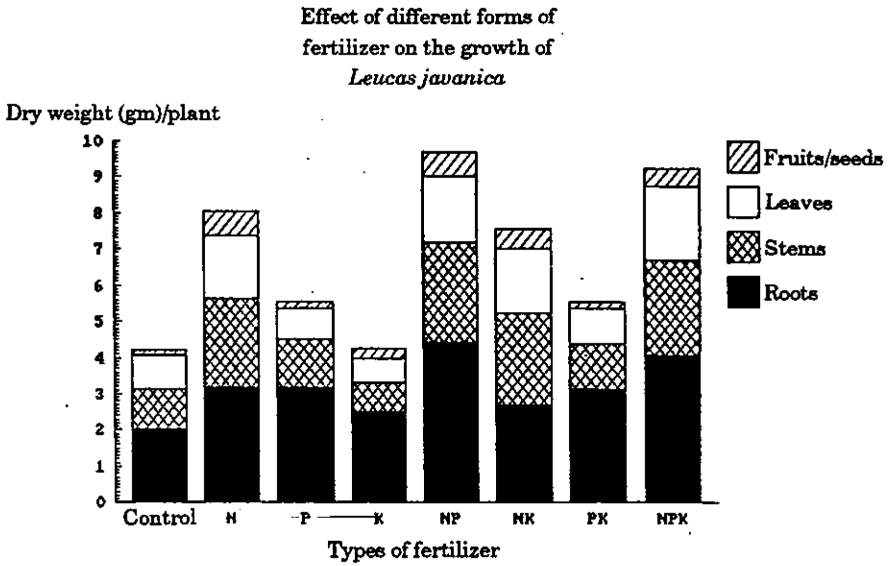

Figure 11. Average dry weight/plant of *L. lavandulaefolia* in different types and combination of fertilizers.

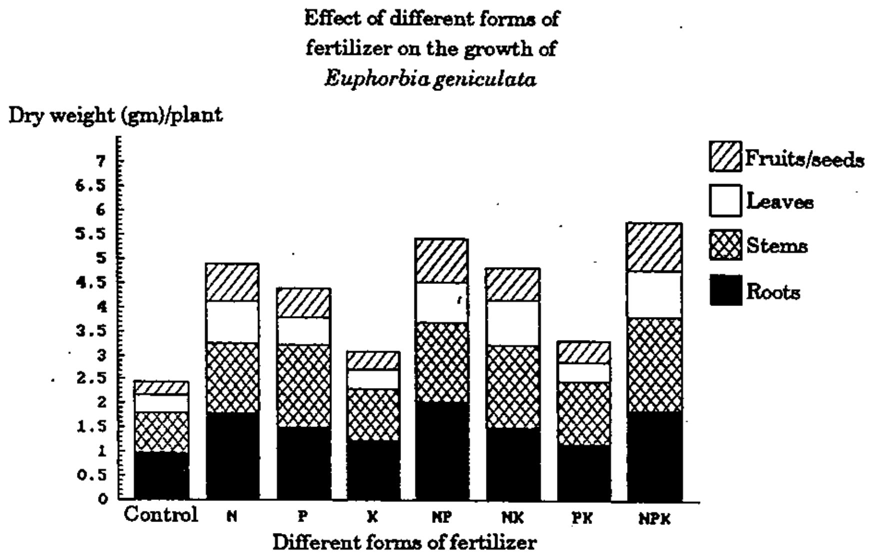

Figure 12. Average dry weight/plant of *E. prunifolia* in different types and combination of fertilizer.

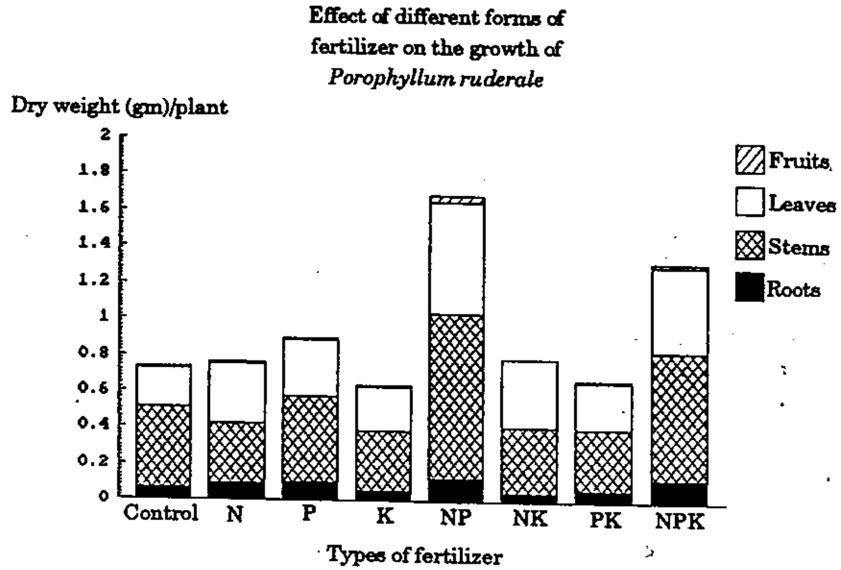

Figure 13. Average dry weight/plant of *P. ruderale* in different types and combination of fertilizers.

In the single application of the fertilizer, nitrogen gave a highly significant increase in dry weight/plant for *E. prunifolia* and *L. lavandulaefolia* compared with phosphorus and potassium fertilizers. All fertilizer combinations with nitrogen (NP, NK, and NPK) gave a highly significant increase of the dry weight/plant in all the three species, however, with PK fertilizers, the increase in dry weight was not significantly different from the control. Application of NP fertilizers gave the highest dry weight/plant in *L. lavandulaefolia* and *P. ruderale*, however, in *E. prunifolia*, the highest dry weight was obtained with NPK fertilizers.

In *L. lavandulaefolia*, the ratio of aboveground to underground biomass was less than 1.0 with the application of NPK and PK fertilizers, however, with other treatments including control, the ratios were above 1.0. The highest ratio was found with the application of NK fertilizers (1.79), followed by of N (1.53) and NPK (1.26). In *E. prunifolia*, all fertilizer applications including control gave ratios of more than 1.0 with the highest using NP fertilizer (2.28) followed by NPK (1.96) and P (1.93). The lowest ratio was found in the control (1.51). In *P. ruderale*, the ratios for all the fertilizer applications and combinations were higher than the ratios for *L. lavandulaefolia* or *E. prunifolia* with an average of 8.92. The highest ratio was found with the application of P (10.4) followed by NP (9.7) and K (9.27).

Reproductive Efforts

From Table 3, it is evident that *P. ruderale* had the highest reproductive effort than other species; the order being *P. ruderale* > *B. alata* > *E. prunifolia* > *L. lavandulaefolia* > *S. nodiflora.*

Table 3. Reproductive efforts (RE) of some important annual weeds under glasshouse conditions.

Species	RE (%)
Leucas lavandulaefolia	11.71
Borreria alata	15.49
Synedrella nodiflora	8.29
Porophyllum ruderale	19.3
Eupborbia prunifolia	15.0

The effect of fertilizer application on the number of fruits/seeds in *E. prunifolia* and *P. ruderale* is given in Table 4. Fertilizer application gave a significant increase in the number of mature fruits and seeds in *E. prunifolia* and *P. ruderale*, however, the RE of both species was reduced significantly by application of fertilizers.

Table 4. The effect of NPK fertilizer on the RE and seed production of *P. ruderale* and *E. prunifolia.*

Species	No. of fruits		No. of seeds		RE	
	+NPK	-NPK	+NPK	-NPK	+NPK	-NPK
Porophyllum ruderale	7	3	261	115	15.2	19.3
Euphorbia prunifolia	14	6	48	20	11.6	15.8

DISCUSSION

Among the six annual species studied, there was significant difference in their abilities to germinate, emerge and grow. *B. pilosa, P. ruderale* and *M. invisa* had higher germination rates than the other species, however, in seedling emergence, *B. pilosa, S. nodiflora* and *L. lavandulaefolia* had slow seedling growth with only 40, 40 and 35 mg/plant, respectively after six weeks.

M. invisa, which had the largest seed among the species, had a lower maximum RGR than *P. ruderale* and *L. lavandulaefolia*, both in the seedling and mature stages, respectively. However, the average RGR of *M. invisa* was not significantly different from that of *P. ruderale* and slightly higher than *L. lavandulaefolia.* In the mature stage, the highest maximum and average RGR was found in *L. lavandulaefolia* followed by *B. alata*, and the lowest was found in *S. nodiflora.* Six weeks after germination, no significant relationship was observed between seed size and seedling growth in all the species.

Gross (1984) reported that positive correlation was found between seed size and final seedling weight in six monocarpic perennial plants and concluded that large seed size increased seedling competitive ability. Large seed size is generally assumed to provide seedlings with a competitive advantage than other seedling (Black, 1958; Harper *et al.*, 1970; Baker, 1972 and Fenner, 1978).

The maximum and average RGR in the seedling and mature stages of all the species were lower than most annual competitive- ruderals reported by Grime and Hunt (1975), except for *Zea mays* and *Helianthus annus*, and lower than *Ambrosia trifida* (Bazzaz and Carlson, 1979). The average RGR values for all the species were higher than tropical perennial weeds e.g. *Imperata cylindrica, Chromolaena odorata, Grewia elastica* and *Thysanolaena maxima* (Saxena and Ramakrishnan, 1983). Species with broadleaves, generally have higher values of maximum RGR than species with narrow leaves (Grime and Hunt, 1975).

The range of values for reproductive efforts obtained in this study was in close agreement with those obtained for a number of annual composites (Harper and Ogden, 1970) and three species of *Helianthus* (Gaines *et al.*, 1974), but lower than *Polygonum cascadense* (Hickman, 1975) and herbaceous plants of one year old field (Newell and Tramer, 1978), and higher than *Senecio sylvaticus* (Van Andel and Vera, 1977). No data is available on the reproductive efforts of other tropical annual weeds.

By comparing the germination rates, *B. pilosa* can be characterized as an early growing species. From comparisons of the RGR in the seedling phase, ratio of shoots to roots and reproductive strategies, *P. ruderale, B. alata* and *E. prunifolia* can be characterized as annual competitive ruderals with an r-strategy. The characteristics of this group are that they always occur in habitats of high productivity and soil fertility, e.g. abandoned arable fields; and are adapted to circumstances in which there is a low impact of stress; and competition is restricted to a moderate intensity by disturbance (Grime, 1979). Further studies, examining the seed size and other life history characteristics such as germination requirements, emergence time, RGR and RE, and the establishment pattern of tropical annual weeds in the fields, are still needed.

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COMMUNITY ECOLOGY AND BIOMASS PRODUCTION OF WEEDS AND CROPS UNDER TRADITIONAL AGRICULTURE IN RIPARIAN CORRIDORS OF THE GANGA AND GOMATI RIVERS

R.S. AMBASHT, ANIL K. TIWARI AND M.P. SINGH[1]

ABSTRACT

Riparian corridors are specialized habitats which by nature are fragile and delicately balanced, 'stressed' (Shannon index H ranging from 1.2310 to 1.4293) ecosystems. Cultivation of wheat, mustard and vegetables (*Brassica oleracea* and *Lycopersicon esculentum*) is commonly practised in the post-flood winter season. Two such sites were studied, one at Jaunpur on the bank of River Gomati and another at Varanasi on River Ganga. The species composition, Importance Value Index, Diversity index, Similarity index, biomass structure and production were studied for self grown weeds in summer fallow period and both crops and weeds in the winter season. In summer the dominant species at both sites was *Cynodon dactylon* with IVI 122.17 and 160.31 at Jaunpur and Varanasi respectively. In winter *C. dactylon* was the dominant weed at Jaunpur (IVI 91.70), in all three zones throughout the crop cycle. While at Varanasi *Cyperus rotundus* was the most dominant weed (IVI 63.70). The Shannon diversity index (H) was on the lower side in both sites and seasons. Similarity index between the stands was also on the lower side (0.5333 in summer and 0.5747 in winter between Jaunpur and Varanasi).

The highest biomass attained was in wheat (1015.05 g/m^2 at Jaunpur and 1210.51 g/m^2 in the middle zone at Varanasi) followed by vegetable crops (1057.69 g/m^2) in the upper zone at Varanasi and mustard (801.68 g/m^2) at Jaunpur. Among weeds at Jaunpur, the highest biomass attained was in *C. dactylon* (192.12 g/m^2) followed by *C. rotundus* (31.58 g/m^2). In contrast, at Varanasi, peak values were attained by *C. rotundus* (81.28 g/m^2) followed by *C. dactylon* (43.18 g/m^2). Zonewize highest biomass was in the lower, followed by the middle and the upper zone at Jaunpur. While at Varanasi highest biomass was in the middle zone. At Jaunpur productivity of crops was highest at 105 days (wheat 23.4 g/m^2/day and mustard 23.17 g/m^2/day). In contrast, peak weed productivity was at 90 days (*C. dactylon* 2.60 g/m^2/day and *C. rotundus* 0.75 g/m^2/day). Zonewise, seed productivity decreased from the lower to the upper zone for both crops. The peak grain yield for both wheat and mustard was highest in the lower zone (2.95 ton/ha/season and 1.95 ton/ha/season, respectively).

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INTRODUCTION

This paper evaluates crop-weed interactions in two bio-edaphic areas of neglected riparian wetlands in the mid-Gangetic Plains of North India. The riparian agroecosystems consist of narrow strips of seasonally flooded sandy-clay soils along the banks of major rivers. They are 50 to 500 m wide and are extremely fragile and delicately balanced due to a constant flux of the edaphic environment through frequent flooding, silting, erosion and biotic stresses including grazing, scraping, bathing and sewage disposal. The riparian zone has a long edge to area ratio and is wet in the inner lower zone, semi-moist in the middle and dry and sandy on the upper zone. Stream flow adds to the seed bank with inputs from the upper reaches of the river and its watersheds. Nutrient renewal of the habitat is achieved through silting, keeping the soil in a pedogenetically young condition (Etherington, 1975).

In the river bank ecosystems cultivation of crops in the rainy season (July-October) is not possible due to flooding, whilst the extremely dry conditions of summer (March to June) do not permit cropping except on exposed islands. Crop production in the post- flood nutrient enriched habitat in winter (November to February) is common, mostly with wheat (*Triticum aestivum* L.), mustard (*Brassica campestris* L.), cabbages (*Brassica oleracea* L.) and tomatoes (*Lycopersicon esculentum* Mill.). Very little work has been done on riparian agroecosystems.

This study outlines the weed-crop community ecology of river banks during the summer fallow and the traditionally farmed winter season on the Ganga River at Varansi and its tributary the Gomati River at Jaunpur (80 km from Varanasi). It describes the species composition, ecological importance of component species, Shannon's diversity index, similarity index, and biomass of crop and weeds of the upper, middle and lower zones in winter and of weeds in summer.

MATERIALS AND METHODS

The study sites were the riparian agroecosystem located at Jaunpur (25°45′ N and 82°43′ E) on the convex right side of the River Gomati and at Varanasi (25°18′ N and 83°1′ E) on the somewhat convex left bank of the River Ganga. The transects were 125 m and 200 m wide and were divided into distinct upper, middle and lower ecological zones. Wheat and mustard are grown at Jaunpur and wheat in the lower and middle zones and vegetables in the upper zone at Varanasi using traditional ploughing with very little input of manures, fertilizers or irrigation.

The Importance Value Index (IVI) was obtained as a summation of the Relative Frequency, Relative Density and Relative Dominance (out of 300) and

taken as the overall dominance of weed species (Mueller-Dombois and Ellenberg, 1974). The diversity index (Shannon and Weaver, 1963) and similarity index (Sórensen, 1948) were calculated using the formulae:

$$\text{(i) Shannon index } (\overline{H}) = -\sum \frac{n_i}{N} \log_e \frac{n_i}{N}$$

(Multiplied by 2.303 to convert $\log_{10}$)

where n_i is importance value of each component, N is importance value of all components together, and

$$\text{(ii) Similarity index (S)} = \frac{2C}{A+B}$$

where C is the number of species common to both stands and A and B, the number of species in stands A and B, respectively.

Standing crop biomass was estimated by the short term harvest method of Odum (1960) whilst the core technique (Dahlman and Kucera, 1965) was used to sample root and shoot biomass. Sampling was done by excavating monoliths to a depth of 30 cm (Golley, 1965). Harvested plant material was gently washed in a wire cage with water, roots and rhizomes were separated as the underground fraction, and the samples were oven-dried at 80°C for 48 hours. Productivity was estimated by summation of positive biomass difference values of successive samplings. Economic yield of crops was calculated in terms of seeds and fruits. Soil moisture content was determined by sampling at 0-10, 10-20, and 20-30 cm and drying at 105°C for 48 hours and calculated as percentage soil weight.

Analysis of variance and correlation coefficients between crop and weed productivity were calculated (Campbell, 1974) for the Jaunpur site.

RESULTS AND DISCUSSION

In the riparian corridor in summer, 37 species of weeds were recorded at Jaunpur and 23 species at Varanasi (Table 1). *Cynodon dactylon* (L.) Pers. was dominant at both sites with IVI values of 122.17 and 160.31 at Jaunpur and Varanasi respectively. *Croton bonplandianum* Baill. (IVI 67.08) was co-dominant at Jaunpur, and *Saccharum munja* Roxb. (IVI 26.87) at Varanasi. A clear-cut stratification of species was observed. In the lower zone the characteristic species were *Polygonum plebejum* R. Br. and *Ranunculus sceleratus* L. The middle zone was characterized by *Saccharum munja*, *Cynodon dactylon* and *Cyperus rotundus* L. and the upper zone by *Xanthium* *strumarium* L., *Cynodon dactylon*, *Chrozophora rottleri* Juss. and *Argemone mexicana* L.

Table 1. Importance Value Index of weeds in summer fallow at Jaunpur and Varanasi

Name of species	IVI	
	Jaunpur	Varanasi
Ammania senegalensis Lam.	1.0	2.24
Argemone mexicana L.	2.59	5.75
Chenopodium album L.	2.45	-
Chrozophora rottleri (Neck.) Juss	6.30	7.84
Croton bonplandianum Baill.	67.08	-
Cynodon dactylon Pers.	122.17	160.31
Cyperus rotundus L.	18.25	19.56
Desmostachyta bipinnata Stapf.	8.36	-
Digitaria adscendens Hall.	2.46	-
Eclipta prostrata L.	3.57	7.88
Eragrostis tenella (Beauv.) R. & S.	1.85	-
Eragrostis uniloides (Beauv.) Nees	1.19	-
Euphorbia thymifolia L.	2.4	-
Fimbristylis bisumbellata (Vahl) Bub.	6.43	-
Launaea asplenifolia (Cass.) Hk. f.	11.4	5.21
Phyla nodiflora Mich.	9.2	18.07
Portulaca oleracea L.	1.35	-
Salvia plebeia R. Br.	9.8	-
Scirpus tuberosus L.	1.35	-
Scoparia dulcis L.	1.13	-
Solanum nigrum L.	1.01	-
Solanum surattense Mill.	8.7	1.83
Verbascum chinensis L.	1.77	-
Xanthium strumarium L.	1.0	3.81
Amaranthus spinosus L.	-	1.72
Euphorbia spp.	-	4.73
Glinus oppositifolius L.	-	2.83
Heliotropium indicum L.	-	2.81
Lantana indica Roxb.	-	3.32
Melilotus alba (Juss.) Desv.	-	1.52
Nicotiana plumbaginifolia L.	-	3.39
Polygonum plebejum R. Br.	-	9.7
Ranunculus sceleratus L.	-	4.89
Rumeex nigricans HK. f.	-	3.35
Saccharum munja Roxb.	-	26.87
	13 others species at Jaunpur with IVI < 1	2 other species at Varanasi IVI < 1

Forty-nine weed species were recorded in the riparian agroecosystem in winter at Jaunpur and 33 species at Varanasi (Table 2). Some were present

throughout the crop cycle, some had shorter life cycles, and some were very short lived. Weed appearance is largely controlled by seed and underground perennating bud dormancy, germination requirements (Branchley and Warington, 1933) and soil moisture (Roberts and Marget, 1980).

Table 2. Species composition and IVI of winter crop fields at Jaunpur and Varanasi

Name of species	IVI	
	Jaunpur	Varanasi
Alternanthera sessilis (Forsk.) R. Br.	1.53	-
Anagallis arvensis (Tourn.) L.	1.45	2.81
Argemone mexicana L.	5.98	4.61
Asphodelus tenuifolius Cav.	1.86	-
Brassica campestris L.	26.8	-
Chenopodium album L.	10.88	9.12
Croton bonplandianum Baill.	1.1	-
Cynodon dactylon Pers.	91.70	57.31
Cyperus rotundus L.	15.76	63.70
Eclipta prostrata L.	1.18	1.07
Fimbristylis bisumbellata (Vahl) Bub.	1.36	-
Grangea maderaspatana (Forsk.) Poir	1.01	-
Lathyrus aphaca L.	2.16	-
Launaea asplenifolia (Cass.) HK. f.	1.54	1.61
Melilotus indica (Juss.) All.	7.03	-
Phalaris minor Retz.	1.85	-
Phyla nodiflora Mich.	3.85	2.01
Triticum aestivum L.	105.29	89.67
Xanthium strumarium L.	1.69	1.72
Amaranthus spinosus L.	-	2.12
Bacopa monieri L.	-	1.26
Brassica oleracea L.	-	7.41
Cassia tora L.	-	1.8
Euphorbia hirta L.	-	1.13
Lantana indica Roxb.	-	1.3
Linum usitatissimum L.	-	1.08
Lycopersicon esculentum Mill.	-	32.12
Melilotus alba (Juss) Desv.	-	1.12
Polygonum plebejum R. Br.	-	3.29
Ranunculus sceleratus L.	-	2.19
Rumex nigricans HK. f.	-	1.67
Saccharum munja Roxb.	-	1.86
	32 others species at Jaunpur with IVI < 1	13 other species at Varanasi with IVI < 1

At Jaunpur a maximum weed density of 235.5 individuals/m^2 was observed at the crop flowering stage in February. The most prominant weeds at both sites were *Cynodon dactylon* and *Cyperus rotundus*, with *Cynodon dactylon* (IVI 91.70) dominant throughout the cropping season in all three zones at Jaunpur. *Cyperus rotundus* was densely distributed in the moist lower zone due to its preference for high soil moisture. At Varanasi, *Cyperus rotundus* (IVI 63.70) was the most dominant weed in all three zones, probably due to higher moisture availability than at Jaunpur.

Diversity index ($\overline{H}$) was on the lower side (Table 3) in both sites and seasons conforming the fragility and stressed condition of the riparian slopes. In summer, the vegetation is sparse and open and the main stresses operating are the extremely dry conditions and biotic stresses including scraping and grazing. In winter the stress is created by ploughing for crops.

The similarity index (S) between Jaunpur and Varanasi in summer and winter was 0.533 and 0.574 respectively (Table 3). These values are in the lower range and may be due to the 80 km distance between the sites and distinct differences in the bio-edaphic conditions.

Table 3. Shannon index ($\overline{H}$) and Similarity index (S)

Type and location	Summer	Winter
(a) Shannon index ($\overline{H}$)		
1. Jaunpur site	1.385	1.429
2. Varanasi site	1.231	1.339
(b) Similarity index (S) between Jaunpur and Varanasi	0.533	0.574

Maximum biomass of crops occurred at 120 days after sowing and of weeds 105 days after sowing at Jaunpur. The highest biomass was contributed by wheat (1015.05 g/m^2) at Jaunpur, while at Varanasi it was 1210.51 g/m^2 in the middle zone followed by vegetables (1057.69 g/m^2) in the upper zone. The biomass of mustard at Jaunpur was 801.68 g/m^2. Among weeds, the peak values at Jaunpur were 192.12 g/m^2 for *Cynodon dactylon* and 31.58 g/m^2 for *Cyperus rotundus*, with the other weeds contributing 39.20 g/m^2. At Varanasi the peak values were 81.28 g/m^2 for *Cyperus rotundus*, 43.18 g/m^2 for *Cynodon dactylon*, and 26.89 g/m^2 for the other weeds. At Jaunpur the highest crop biomass occurred in the lower zone and the least in the upper zone. The wheat biomass was 1015.05 g/m^2 in the lower, 909.06 g/m^2 in the middle and 857.75 g/m^2 in the upper zone, whilst for mustard the corresponding values were 801.68 g/m^2, 410.72 g/m^2 and 229.02 g/m^2 respectively. *C. dactylon* had its highest biomass in the middle zone while the other weeds had theirs in the upper zone, probably because of less competition due to poorer growth of crop plants. *C. rotundus* had its highest biomass in the moist lower zone. At Varanasi, the crops had their highest biomass in the middle zone and their least in the lower zone; the wheat biomass was 1210.51 g/m^2 in the middle zone and 955.3 g/m^2 in the lower zone. Vegetable crops produced 1057.69 g/m^2 in the upper zone where the sandy soil was well tolerated by tomatoes and cabbages. *C. rotundus* had a high biomass in all three zones during the crop cycle in Varanasi.

Analysis of variance was obtained for standing total biomass where monoliths were the source of variation (variance ratio was significant at $P<0.05$ in the middle and the lower zones) and for plant ages (significant at $P<0.001$ in all three zones). There was significant interaction between plant ages and zones. At Jaunpur weeds showed increasing contribution to the total biomass with increasing age and a similar trend was visible at Varanasi.

At Jaunpur the productivity of crops was highest at 105 days (wheat 23.5 g/m^2/day, mustard 23.17 g/m^2/day and total crops 46.67 g/m^2/day), and this compares favourably with reports for non-riparian upland agroecosystems by Ambasht and Chakhiyar (1979) for pure mustard at 19.77 g/m^2/day and Marwah (1972) for wheat crop at 21.48 g/m^2/day. In contrast, weed production was highest at 90 days (*C. dactylon* 2.60 g/m^2/day, other weeds 0.82 g/m^2/day, *C. rotundus* 0.75 g/m^2/day and total weeds 4.17 g/m^2/day). Zonewise, productivity was highest in the lower zone followed by the middle and the upper zones at Jaunpur due to higher moisture availability and less sandy texture of the soil. At Varanasi, the lower zone was not so productive due to strong anthropogenic interference on large tracts of the zone by bathers, boatmen, fishermen and religious congregations.

At Jaunpur there was a significant positive correlation ($P < 0.05$) between weed and crop productivity in the upper zone due to less competition. Seed yield started at 60 days in wheat and 75 days in mustard and increased with age. Grain productivity decreased from the lower to the upper zones for both crops. The peak grain yield for both wheat and mustard was highest in the lower zone at 2.95 ton/ha/120 days and 1.95 ton/ha/120 days in Jaunpur. Further, the total net production (g/m^2 per four months) (see Table 4) at Jaunpur was highest for the lower zone (2047.26 g/m^2/four months), followed by the middle and the upper zones. All these indications clearly show that the lower zone at Jaunpur is most productive due to better soil texture, nutrient inputs, moisture availability and lower level of biotic disturbance. In contrast, a low production value of 992.80 g/m^2/four moths in the lower zone at Varanasi is due to heavy anthropogenic interference despite its inherently high productive potential.

The results show that riparian wastelands can be profitably brought under cultivation in winter to boost food production, whilst summer cropping would also be possible with some input of irrigation by pumping river water. Weed species on riparian slopes should not be visualized only as competitors of crop plants, since they also have a beneficial role in conserving the soil and nutrients of these slopes (especially in summer) and increasing the nutrient level and fertility of soil by their faster turnover rate.

Table 4. Total net production (g/m^2 per four months) during the winter crop period and total net production (g/m^2 per eight months) during the fallow period at both sites in the three zones

Zones	Jaunpur		Varanasi	
	Fallow	Crop	Fallow	Crop
Upper	297.37	1266.99	562.18	1182.10
Middle	329.32	1552.61	412.10	1328.89
Lower	185.63	2047.26	132.98	992.80

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THE PEST STATUS AND CHEMICAL CONTROL OF *JATROPHA GOSSYPIFOLIA* L. IN THE NORTHERN TERRITORY, AUSTRALIA

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ABSTRACT

Bellyache bush (*Jatropha gossypifolia* L.) is a noxious weed with a wide distribution in the Northern Territory of Australia. This study presents results from a series of herbicide efficacy trials. Seedling numbers were significantly reduced for up to 2 years and residual control of mature bellyache bush was also achieved with 10 and 15 kg a.i./ha hexazinone liquid or 1.5 and 2 kg a.i./ha tebuthiuron pellets. Aerially applied glyphosate+simazine and metsulfuron methyl did not provide adequate control of mature bellyache bush. A third trial compares ground based foliar applied glyphosate, fluroxypyr, and metsulfuron methyl+modified polydimethylsiloxane. Results indicate that 30 g a.i./ha metsulfuron methyl with the addition of 2 ml/l modified polydimethylsiloxane will be successful in controlling mature bellyache bush.

INTRODUCTION

Bellyache bush or cotton-leaf physic nut (*Jatropha gossypifolia* L.) is an erect, woody, perennial shrub native to tropical America. It is a member of the family Euphorbiaceae. Bellyache bush has thick sappy stems, deeply five-lobed leaves and small red and yellow flowers. It grows to a height of about 2.5 m, but in shaded areas it can exceed 3 m. The leaves of some plants have a purple colouration, while others are glossy green. Petioles and leaf margins are covered with coarse gland-tipped, sticky, brown hairs. The fruit capsules are round to oblong, 1- 1.5 cm in diameter and contain three toxic seeds (Everist, 1974).

The plant is used for medicinal purposes in Africa (Irvine, 1961), Thailand and Tropical America and is cultivated as an ornamental in Florida (Dehgan, 1982). The active constituents in bellyache bush are antileukemic, tumour inhibiting, molluscicidal and irritant, and have traditionally been used as a purgative and an emetic (Ponglux *et al.*, 1987).

Jatropha spp. can survive with low nutrition (Dehgan, 1982), so the genus is well adapted to degraded land. Bellyache bush is a weed in India, Australia, Brazil, Jamaica, Trinidad, Africa and Papua New Guinea, and it also occurs in the flora of Indonesia, Puerto Rico and Florida (Irvine, 1961; Chadhokar, 1978; Holm *et al*, 1979; Dehgan, 1982). Other *Jatropha* species

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were introduced to the Darwin Botanic Gardens last century (Anon. 1888) and bellyache bush was probably deliberately introduced to northern Australia for medicinal or ornamental purposes.

In the Northern Territory bellyache bush is declared as a Class B noxious weed (spread to be controlled), under the Noxious Weeds Act, 1978. Originally declared noxious because of its toxic seeds, it has also shown aggressive tendencies, spreading into pastoral land, forming dense thickets and rendering land unsuitable for grazing (Miller, 1982). It is unpalatable to livestock, competes with and displaces native vegetation, obscures fence lines and interferes with mustering (Pitt *et al.*, 1990). The current distribution of bellyache bush in the Northern Territory is shown in Figure 1.

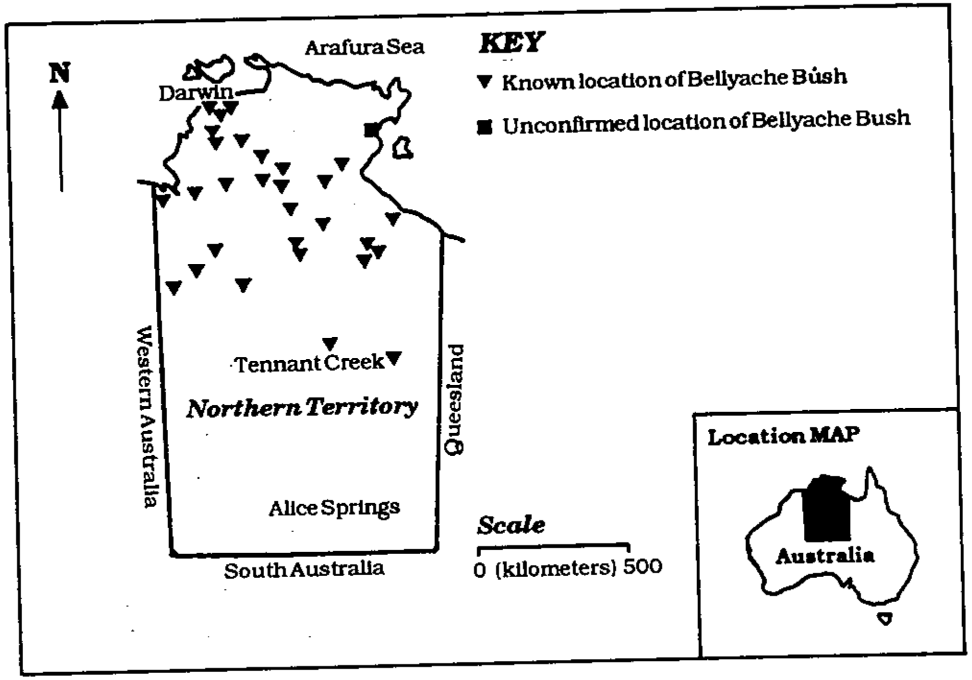

Figure 1. The distribution of bellyache bush in the Northern Territory of Australia.

The largest infestation of bellyache bush in the Northern Territory occurs at Willeroo Station, 125 km south west of Katherine. This infestation occupies over 700 ha of the Aroona Creek system and plant numbers are increasing at 145% per year (Pitt *et al.*, 1990).

Bellyache bush can spread through the movement of seed or vegetative material. Cut stumps will regrow rapidly in the wet season if herbicide or diesel fuel are not applied to the stump immediately after cutting. Pods burst open

when mature, dispersing the seed up to about 2 m. Green pods float on water and will release viable seed when mature. Viable seed are able to survive in soil for some time before germinating (D. Hansen *pers comm*). The root system is relatively small, allowing seedlings and small mature plants to be removed by hand.

Previous work with herbicides on bellyache bush in the Northern Territory (I.L. Miller unpublished results), showed that a cut stump application of 5% picloram + 2,4,5-T (Tordon 105, 5+20% a.i.) in water and basal bark applications of 2% picloram+2,4,5-T (Tordon 1040, 10+40% a.i.) in diesel gave complete kills of bellyache bush. Concentrated hexazinone (Velpar L, 25% a.i.) injected into the soil at a rate of 4 ml/plant was also effective. Glyphosate (Roundup, 36% a.i.) as 0.67% and 1% foliar sprays and triclopyr (Garlon 480, 48% a.i.) as 0.5% and 1% foliar sprays gave good initial defoliation but regrowth occurred within 12 weeks.

This paper reports on further chemical control trials conducted on bellyache bush in the Northern Territory.

MATERIALS AND METHODS

The following trials were conducted at Willeroo Station (15°17'S, 131°17'E), which has a semi-arid tropical climate. The average annual rainfall is 733 mm, with about 94% of this falling in the November to March period.

Trial 1. A comparison of soil applied hexazinone and tebuthiuron for control of bellyache bush

On February 7, 1989, hexazinone liquid (Velpar L, 25% a.i.) at 5, 10 and 15 kg a.i./ha and tebuthiuron pellets (Graslan, 20% a.i.) at 1, 1.5 and 2 kg a.i./ha were soil applied to a dense, mature stand of bellyache bush. Approximately 300 mm of rain fell in the two months following herbicide application.

The experiment was conducted on self mulching cracking clay soil with a slope of less than 1%. The experimental design was a randomised block with three replications. Plot size was 12 m x 4 m with a 3 m buffer between plots. Hexazinone was applied using a spotgun calibrated to deliver 2 ml of concentrate. Doses of 2, 4 or 6 ml were applied to bare soil on a 1 m^2 grid throughout the designated plots. Preweighed tebuthiuron pellets were applied by hand evenly over the plots.

Visual assessments of percentage defoliation and regrowth were conducted at 2 and 4 months after treatment (MAT) and total plant counts at 6, 12 and 24 MAT. Bellyache bush greater than 50 cm were regarded as mature for the purpose of the experiment, and those less than 50 cm as seedlings. The results were analysed by a one-way analysis of variance.

Trial 2. A comparison of aerially applied glyphosate + simazine and metsulfuron methyl for control of bellyache bush

On February 13, 1989, glyphosate (Roundup CT, 45% a.i.)+ simazine (Simazine, 50% a.i.) at 1.5+2.0, 1.5+4.0 and 3.0+4.0 kg a.i./ha and metsulfuron methyl (Brushoff, 60% a.i.) at 50, 75 and 100 g a.i./ha were aerially applied to dense, mature bellyache bush. Total spray volume equivalent to 60 l/ha was applied and included the addition of non-ionic organic surfactant (Agral 60, 60% a.i.) at 2 ml/l. Climatic conditions remained favourable throughout the application and rainfall did not occur until eight hours after application.

A Hiller UH12E agricultural helicopter was used for the herbicide application. It was fitted with an 11.6 metre boom carrying 28 D8/45 nozzles pressurised to 210 kPa. This produced droplets with a theoretical volume median diameter of 410 microns and a swath width of 13 m. The experimental design was a randomised block with two replications. Plot size was 0.5 ha with a 26 m buffer between plots. Visual assessments were conducted at 1, 2 and 3 MAT, and quadrat counts at 6 and 12 MAT. A one-way analysis of variance was conducted on results obtained at 12 MAT.

Trial 3. A preliminary evaluation of foliar applied fluroxypyr, glyphosate and metsulfuron methyl for control of bellyache bush

On March 8, 1991, glyphosate (Glyphosate 450, 45% a.i.) at 0.45, 0.90 and 1.35 kg a.i./ha+2 ml/l non-ionic organic surfactant, fluroxypyr (Starane, 30% a.i.) at 0.3, 0.6 and 0.9 kg a.i./ha+2 ml/l non-ionic organic surfactant, and metsulfuron methyl (Brushoff, 60% a.i.) at 30, 60 and 90 g a.i./ha+2 ml/l modified polydimethylsiloxane (Pulse, 100% a.i.) were foliar applied to dense, mature bellyache bush. A total spray volume equivalent to 1000 l/ha was applied using a compression sprayer pressurised to 400 kPa, with a hollow centrebody nozzle.

The experimental design was a randomised block with three replications. Plots were 5 x 2 m with a 2 m buffer. Visual assessments and total counts were conducted at 1, 2, and 3 MAT.

RESULTS

Trial 1

Plants were showing symptoms of herbicide uptake by 2 MAT, with the severity of symptoms increasing with herbicide rate. These symptoms included

leaf chlorosis, leaf necrosis and some defoliation. By 4 MAT, the defoliation of mature bellyache bush treated with hexazinone at 10 and 15 kg a.i./ha was well advanced. The effect of tebuthiuron at 1.5 and 2 kg a.i./ha was also noticeable, although defoliation was slower.

Counts of live mature bellyache bush and seedlings were conducted at 6, 12 and 24 MAT. The results are shown in Table 1.

Table 1. Mean numbers of live bellyache bush 6, 12 and 24 months after the soil application of three rates of hexazinone and tebuthiuron

Treatment	6 MAT		12 MAT		24 MAT	
	Seedlings	Mature	Seedlings	Mature	Seedlings	Mature
Hexazinone 5.0 kg a.i./ha	109.0^{abc}	7.7^{a}	119.7^{ab}	22.0^{ab}	107.3^{a}	73.3^{bc}
Hexazinone 10.0 kg a.i./ha	23.0^{ab}	0.7^{a}	70.7^{a}	8.0^{a}	33.3^{a}	17.7^{ab}
Hexazinone 15.0 kg a.i./ha	11.0^{a}	0.3^{a}	53.3^{a}	6.0^{a}	28.7^{a}	9.7^{a}
Tebuthiuron 1.0 kg a.i./ha	204.7^{cd}	80.7^{b}	179.0^{ab}	61.7^{b}	209.7^{a}	73.7^{bc}
Tebuthiuron 1.5 kg a.i./ha	137.3^{bc}	53.7^{ab}	84.7^{a}	16.7^{ab}	36.7^{a}	29.0^{ab}
Tebuthiuron 2.0 kg a.i./ha	109.3^{abc}	66.0^{b}	43.3^{a}	2.3^{a}	17.7^{a}	17.0^{ab}
Control	313.3^{d}	42.0^{ab}	250.0^{b}	62.0^{b}	496.7^{b}	90.3^{c}
LSD (5%)	126.3	54.47	155.9	46.55	241.2	59.67

Note : Means within columns followed by the same letter are not significantly different at the 5% level using a one-way analysis of variance.

Hexazinone treatments produced the most rapid response, particularly for control of mature bellyache bush. At 6 MAT, numbers of seedlings were significantly reduced in all hexazinone treatments, and with tebuthiuron at 1.5 and 2.0 kg a.i./ha. At 12 MAT there were significant reductions in the numbers of seedlings and mature plants treated with hexazinone at 10 and 15 kg a.i./ha and tebuthiuron at 1.5 and 2 kg a.i./ha. There were no significant differences between these herbicide treatments.

Seedling numbers at 24 MAT were significantly lower in all herbicide treatments, but there were no significant differences between these treatments. Efficacy was greatest with the highest rates, with a gradual decrease in plant numbers from lowest to highest. Mature plant numbers were least in the 15 kg a.i./ha hexazinone, but this treatment was not statistically different from hexazinone at 10 kg a.i./ha or tebuthiuron at 1.5 and 2 kg a.i./ha.

Trial 2

Poor control was obtained with the aerial application of glyphosate+simazine and metsulfuron methyl. At 1 MAT, some chlorosis, necrosis and defoliation had occurred in all herbicide treatments. Metsulfuron methyl at 75 and 100 g a.i./ha and glyphosate+simazine at 1.5+4 and 3+4 kg a.i./ha gave best results. Regrowth from original stems occurred in all treated plots.

By 2 MAT, defoliation was greatest in the metsulfuron methyl plots. Regrowth was abundant and herbicide effects were barely visible in the glyphosate+simazine plots. Effects from the herbicide application were less noticeable at 3 MAT, and refoliation was almost complete in all treatments. Quadrat counts of live mature bellyache bush at 6 and 12 MAT, failed to detect any significant difference in plant numbers between treatments and control plots.

Trial 3

Initial observations of foliar applied herbicides indicated a very rapid response to metsulfuron methyl plus modified polydimethylsiloxane, at all rates of application. Approximately 90% of bellyache bush foliage was necrotic in these plots by 1 MAT. In contrast, only a slight response to all rates of glyphosate and fluroxypyr was initially observed and diminished with time. These observations were confirmed by total counts of live mature bellyache bush at monthly intervals. Means and percentage change of these total counts are shown in Table 2.

The greatest reduction in numbers of live mature plants was observed in the metsulfuron methyl treatments. Preliminary results indicate that the best control may be achieved with 30 g a.i./ha metsulfuron methyl+2 ml/l modified polydimethylsiloxane. Further assessments are planned for 6 and 12 MAT.

DISCUSSION

Soil Application

Bellyache bush seedling numbers can be significantly reduced for up to 2 years through the soil application of hexazinone liquid or tebuthiuron pellets. Residual control of mature plants was also achieved with hexazinone at 10 and 15 kg a.i./ha and tebuthiuron at 1.5 and 2 kg a.i./ha.

One hundred percent mortality of mature bellyache bush and seedlings was not achieved with any of the treatments applied. The relatively small root system of bellyache bush may reduce exposure and therefore susceptibility to soil applied herbicides.

A reduction in off-target species was evident in plots treated with hexazinone at 10 and 15 kg a.i./ha. All rates of tebuthiuron appeared to have a lesser effect on competitive grass species at 24 MAT, demonstrating the selective nature of this chemical at moderate and low rates of application. This characteristic is desirable where the treatment of large infestations of bellyache bush could otherwise result in extensive soil erosion.

Table 2. Mean numbers of live mature bellyache bush after foliar application of 3 rates of fluroxypyr, glyphosate and metsulfuron methyl (plus modified polydimethylsiloxane)

Treatment	1 Mat	2 Mat	3 Mat	% Mean Change 1-3 Mat
Fluroxypyr 0.3 kg a.i./ha (+ 2.0 ml/l non-ionic organic surfactant)	24.0	24.0	23.3	-2.9%
Fluroxypyr 0.6 kg a.i./ha (+ 2.0 ml/l non-ionic organic surfactant)	23.7	23.7	21.3	-10.1%
Fluroxypyr 0.9 kg a.i./ha (+ 2.0 ml/l non-ionic organic surfactant)	26.3	26.3	25.7	-2.3%
Glyphosate 0.45 kg a.i./ha (+ 2.0 ml/l non-ionic organic surfactant)	31.3	31.3	31.0	-1.0%
Glyphosate 0.9 kg a.i./ha (+ 2.0 ml/l non-ionic organic surfactant)	27.0	28.7	26.7	-1.1%
Glyphosate 1.35 kg a.i./ha (+ 2.0 ml/l non-ionic organic surfactant)	17.3	17.3	16.7	-3.5%
Metsulfuron methyl 30.0 g a.i./ha (+ 2.0 ml/l modified polydimethylsiloxane)	12.3	0.7	0.3	-97.6%
Metsulfuron methyl 60.0 g a.i./ha (+ 2.0 ml/l modified polydimethylsiloxane)	17.7	4.7	4.3	-75.7%
Metsulfuron methyl 90.0 g a.i./ha (+ 2.0 ml/l modified polydimethylsiloxane)	23.7	9.3	2.7	-88.6%
Control	17.0	17.5	17.5	+2.3%

Foliar Application

All aerially applied treatments gave inadequate control of mature bellyache bush. In contrast, up to 100% mortality was achieved with ground based foliar application of glyphosate+simazine at 3+4 kg a.i./ha plus 20 g/l ammonium sulphate and 2 ml/l non-ionic surfactant, and with metsulfuron methyl at 30 g a.i./ha plus 2 ml/l modified polydimethylsiloxane (J. Vitelli *pers., comm.*). Initial results from the ground-based foliar applied trial confirm that 30 g a.i./ha metsulfuron methyl plus 2 ml/l modified polydimethylsiloxane will achieve control of mature bellyache bush. The response to glyphosate and fluroxypyr was poor.

The discrepancy in results between aerial and ground based foliar application may have resulted from a reduction in the overall volume of carrier applied. Best results were achieved with high volume application. The addition of modified polydimethylsiloxane appears to enhance the efficacy of metsulfuron methyl for control of bellyache bush.

Further work is required to refine rates and methods of herbicide application.

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THE INSTABILITY OF THE BOTANICAL NAMES OF IMPORTANT WEEDS, A NUISANCE TO WEED SCIENTISTS

P.W. MICHAEL[1]

ABSTRACT

As end-users of the published work of plant taxonomists, we, weed scientists concerned with the biology, ecology or control of weeds are continually aware of the problems of keeping up-to-date with name changes. In this age of data-bases, we long for stability. Arguments for and against conservation of names are presented.

Changes may sometimes be simply nomenclatural, involving small alterations in spelling or in authorities, e.g. *Pennisetum polystachion* for *P. polystachyon; Imperata cylindrica* (L.) Rauesch. for *I. cylindrica* (L.) Beauv. Sometimes plants well-known under a particular genus are transferred to another, e.g. *Eupatorium odoratum* to *Chromolaena odorata; Gnaphalium pennsylvanicum* to *Gamochaeta pennsylvanica;* many *Polygonum* spp. to *Persicaria* spp. Many times there is disagreement concerning the placing of particular species, e.g. should *Borreria* spp. be transferred to the earlier described genus *Spermacoce* or should these genera be kept separate? Is it wise to follow some authors, who, on genomic grounds, transfer the common weeds, known in Australia as barley grass, from *Hordeum* to the little-known genus *Critesion*? Are some species of *Cyperus* better included in *Kyllinga*? Answers to these questions are attempted.

The recognition of taxa (taxonomic entities), hidden under broad names like *Echinochloa crus-galli* or *Rubus fruticosus* is defended on morphological and ecological grounds.

Attention is given to names used in error e.g. *Melastoma malabathricum* for *M. affine* and to names of plants often confused e.g. *Brachiaria distachya* and *B. subquadripara (B. miliiformis)*.

Proper typification of important weeds is stressed, referring especially to recent work where R.C. Barneby has found that *Mimosa pigra* L. is restricted to a small area in South America. He has given convincing reasons for choosing the name *Mimosa pellita* H. & B. ex Willd. for the common weed known throughout the tropics as *M. pigra*.

INTRODUCTION

A report (Hattersley, 1991) on a meeting "Improving the Stability of Names: Needs and Options" held at the Royal Botanic Gardens, Kew, in February 1991 and organized under the auspices of IUBS (International Union of Biological Sciences), in association with IAPT (International Association of Plant Taxonomists) and the Systematics Association, has prompted the writing of this paper.

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As end-users of the published work of plant taxonomists, we, weed scientists concerned with the biology, ecology or control of weeds are continually aware of the problems of keeping up to date with name changes. As far as I know, weed scientists were not represented at the meeting, but like the conservationists, geneticists, horticulturalists, mycologists, palaeobotanists, seed technologists and teachers who were, like ourselves, we can hardly call satisfied customers. In this age of data-bases, we long for stability in the names of weeds, especially of those we consider most important.

The scientific naming of the plants we call weeds is subject to the International Code of Botanical Nomenclature, accepted by taxonomists throughout the world, though interpretation of the rules may differ. I do not believe that it is necessarily the Code that we are to blame for the instability of names. A much more valid reason is the great lack of taxonomists who are or have been seriously engaged in the study of weedy genera. The typification of widely used weed names has been much neglected and too often, taxonomists have been able to examine only an inadequate number of specimens of plants belonging to particular weedy groups, not at all representative of the areas in which they occur as weeds.

Some greatly favour the development of a list of names in current use which could be conserved especially against names that might later be unearthed from the literature and promulgated on the grounds of priority. If taxonomic problems were only nomenclatural this might be satisfactory or agreeable but unfortunately, and especially with weeds, problems of identity of the weed in question with other plants given the same name in other regions must first be resolved and, moreover, typification of names is vital to prevent the development of still greater difficulties in the course of further studies.

I shall now proceed to discuss some concrete examples in order to elucidate and amplify the difficulties experienced.

NAME CHANGES

Changes may sometimes be simply nomenclatural involving small alterations in spelling or in authorities. *Pennisetum polystachion* is the correct spelling for the plant sometimes spelt *P. polystachyon*, following Linnaeus's original spelling of the epithet in *Panicum polystachion* published in his Systema Naturae in 1759. *Panicum* is an example of a Linnaean genus which has long since been much divided. *Imperata cylindrica* (L.) Beauv. has become *I. cylindrica* (L.) Rauesch. because it was discovered that Raueschel had made the combination for Linnaeus's *Lagurus cylindricus* under *Imperata* before Palisot de Beauvois had. According to the Rules the prior authority for the combination should be used.

There are many example of name changes due to the discovery of earlier names applied to the same species. These are true synonyms and they will be found in good recent floras. The application of some earlier names can sometimes be questioned if there has not been a proper attempt at typification. In some cases there is, indeed disagreement in the literature. As an example, the common fern which may behave as a weed in plantation crops, *Nephrolepis biserrata* has recently been fitted to *N. auriculata* by Holttum at Kew (Andrews, 1990). In Flora of Taiwan, Vol. I, however, both these species are held to be distinct. On close examination, however, it appears that in Flora of Taiwan, *N. auriculata* has been taken as the name of the tuber-bearing fern generally known elsewhere as *N. cordifolia.*

Melastoma affine, a common weed in South-East Asia and elsewhere has often been confused with *M. malabathricum* much better-known as an ornamental.

Clayton and Renvoize (1982) have given the opinion that *Brachiaria distachya* and *B. subquadripara* (syn. *B. miliiformis*) are distinct species in contrast to A Revised Flora of Malaya Vol. 3 (1971) where they are considered to be synonymous. My investigations suggest that the plants called *B. miliformis (sic)* by Barnes and Chan (1990); *B. distachya* by Moody *et al.* (1984), Häfliger and Scholz (1980) and Pancho and Obien (1983); and *B. subquadripara* in Flora of Java Vol III. are all the same species and if we accept Clayton and Renvoize's distinction in spikelet size none is *B. distachya.*

Sometimes plants well-known under a particular genus are transferred to another. King and Robinson at the Smithsonian Institution in Washington, USA have for many years studied the huge genus *Eupatorium* and it is following their work that we now name four weeds, once described under *Eupatorium*, *Chromolaena odorata, Ageratina adenophora, A. riparia* and *Austroeupatorium inulifolium*. Fortunately only the ending of the specific epithet is changed where necessary.

The breaking up of the genus *Gnaphalium* has been threatening us for some time, at least since Cabrera in South America included many species, most of them weedy in the genus *Gamochaeta*. The weeds, common in the Indian Sub-continent, the highlands of Indonesia and in eastern Australia, now known as *Gnaphalium pennsylvanicum* (formerly in error as *G. indicum*) will, I believe, come to be known as *Gamochaeta pennsylvanica*. At first we sensibly resist such a change, but with more studies in this group the weight of evidence has increased and we have no intelligent alternative.

Resistance to change has also been observed in the genus *Polygonum*. For some time taxonomists in Japan and Australia have, on morphological grounds, transferred or reinstated plants well-known under *Polygonum* to the genus *Persicaria*. Now, it appears that taxonomists in Europe are following the same trend. In The 1991 Weed Science Glossary published by The Weed Science Society of Japan the following changes are listed, among others:

Polygonum hydropiper to *Persicaria hydropiper*,
Polygonum lapathifolium to *Persicaria lapathifolia*,
Polygonum longisetum to *Persicaria longiseta*,
Polygonum nepalense to *Persicaria nepalensis*,
Polygonum persicaria to *Persicaria vulgaris*.

Only the last named demands a different specific epithet. Of longer standing is the change from *Polygonum convolvulus* to *Fallopia convolvulus* for the weed of crop-land in more temperate regions.

Many times there is disagreement among taxonomists as to the placing of particular species into the most appropriate genus. As an example is the difficult family, Rubiaceae, should *Borreria* spp. be transferred to the earlier described genus *Spermacoce* or should these genera be kept separate and, if so, then which species does one put into each genus?

Senaratna (1945) separates the two genera according to whether the capsule has only one carpel which is ventrally dehiscent (*Spermacoce*) or both carpels ventrally dehiscent (*Borreria*). In *Spermacoce* he places *S. hispida* L. and in *Borreria* he places *B. ocymoides*.

Dwyer (1980) in the Flora of Panama distinguishes *Borreria* with fruits with both cells similar and both dehiscent from *Spermacoce* in which the cells are dissimilar with only one opening. In *Borreria* he includes *B. laevis*, *B. latifolia* and *B. ocymoides* and in *Spermacoce* he includes *S. confusa* and *S. tenuior*.

Steyermark (1972) in the Flora of The Guyana Highland treats only *Borreria* including *B. hispida* Spruce ex Schuman (not *Spermacoce hispida* L.), *B. laevis*, *B. ocymoides* (*sic*) and *B. alata* and *B. latifolia*, which he distinguishes from each other, *B. latifolia* being the common weed throughout the tropics. I have noted the confusion in Barnes and Chan (1990 where *B. alata* is given as a synonym of *B. latifolia* and in Soerjani *et al*. (1987) where *B. latifolia* is given as a synonym of *B. alata*.

Verdcourt (1976) in the Flora of Tropical East Africa sees no justification in separating the two genera. Though dehiscence characters of the fruit are useful they are not accompanied by differences in morphology and habit. With Verdcourt I find this lack of association of characters disturbing and would prefer to include all our weedy species in the Asian-Pacific region under *Spermacoce*, for example *Borreria latifolia* becomes *Spermacoce latifolia*, *Borreria articularis* becomes *Spermacoce hispida* L. and *Borreria ocymoides* becomes *Spermacoce ocymoides*. In the Flora of Java the key to *Borreria* conveniently includes the single species of *Spermacoce* recorded in the flora, *S. confusa*.

The common weeds known in Australian as barley grass and included for a long time in the genus *Hordeum* were transferred to the little-known genus *Critesion* by A. Löve, based essentially on genomic characteristics. The change was followed by Simon in A Key to Australian Grasses and by others in Australia. This generic change is, I believe, unacceptable - the morphological differences are flimsy, based on the fragility of the rachis and the presence or absence of stamens in the lateral spikelets of the spikelet clusters, insufficient differences for the barley grasses to be put into a different genus. Why not be content with placing them in a separate section of the genus *Hordeum*, thereby retaining their familiar names. In taxonomy, it is inadvisable to attach too much importance to any single approach fashionable though it may be, be it genomic, cytogenetic, electrophoretic, chemotaxonomic or any other.

On reading the world literature, questions arise as to whether certain cyperaceous species should be treated under the genus *Cyperus* or *Kyllinga*. Widespread species are *Cyperus brevifolius* or *Kyllinga brevifolia* and *Cyperus kyllingia* or *Kyllinga monocephala*. A species of special importance in Fiji, where it is known as Navua sedge, and elsewhere is *Cyperus aromaticus* or *Kyllinga polyphylla*. Kern in Flora Malesiana treats them in a section of *Cyperus*, Koyama from the New York Botanical Garden in the Revised Flora of Ceylon and Häfliger *et al*. (1982) treat them as *Kyllinga*. If we are unable to make a decision, and that will apply to most of us then it is important to choose one name and to acknowledge the other as a synonym.

Some names as traditionally used include a wide range of forms, some of which are, for the most part, distinguishable from other forms on morphological grounds. I consider that the broad species *Echinochloa crus-galli* is best subdivided into two subspecies- namely, ssp. crus-galli of more temperate distribution and spp. *hispidula* of more tropical distribution and that within these there are varieties which may show particular ecological preferences or be confined to particular localities or regions. The differences between subspecies and varieties are generally not so clear as the differences between species.

The thorny weeds known as blackberries (of European origin) in Australia are mostly grouped under the broad name, *Rubus fruticosus*, an aggregate species comprising lots of forms, sometimes called microspecies. The time has come, however, with the appearance of keys in the most recent floras to use other names for the different blackberry taxa, which can certainly be distinguished from each other in the field. Field workers must be trained to fit the names to plants of a particular habit. Dried specimens of these trailing prickly plants are often difficult to identify. In the future, it is to be hoped that names like *Rubus ulmifolius*, *R. discolor* and *R. ulmifolius* hybrids will become more widely used for the common blackberries. There are a number of other species of lesser importance which may fit into particular ecological or historical patterns.

CONCLUSION

Finally I wish to draw attention to the work done on the typification of the tropical lowland weed, now known as *Mimosa pigra* L., by Barneby (1989), a pre-eminent legume taxonomist at the New York Botanical Garden. While engaged on studies on Neotropical *Mimosa* he was surprised to find that *M. pigra* L. had not yet been typified. On close examination of the descriptions and illustrations referred to in Linnaeus's original protologue (1755 and 1759), Barneby concluded that *M. pigra* L. could be properly referred not to the widespread weed but to an uncommon species endemic to the shores of the Paraná river and the Plate estuary in Paraguay and Argentina, and recently described under another name. Barneby found also that another name *M. asperata* L., often quoted as a synonym of *M. pigra*, should be referred to a Mexican species generally known as *M. berlandieri*. What an impasse! Both *M. pigra* and *M. asperata* are no longer appropriate names to use for the widespread tropical lowland weed.

On close examination of a number of competing names, Barneby has chosen *M. pellita* H. & B. ex Willd. This is the name he is currently using for the plant we have been calling *M. pigra*.

I have given this example to show how important typification of species names is, and how such typification is best done by an expert in the particular group in question. Do we follow Barneby now or do we wait until his full treatment of Neotropical *Mimosa* appears and measure the reaction to his study. I think that the more conservative action is better. Meanwhile, we must be made aware of his work, hidden, like many taxonomic studies related to weeds, in out of the way places.

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THE DISCOVERY OF *ECHINOCHLOA ORYZICOLA* (VASING.) VASING. IN INDONESIA

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It has puzzled me for some years that in Indonesia where *Echinochloa crus-galli* (L.) Beauv. ssp. *hispidula* (Retz.) Honda var. *hispidula* is so widespread in rice, that there has been no record of the obligate paddy-field rice mimic, *E. oryzicola* which, on morphological grounds would appear to have been derived from *E. crus-galli* var. *hispidula* through selection and genetic change after long periods of hand-weeding, threshing and cleaning. I have thought that *E. oryzicola* is perhaps best adapted to colder regions and that it had developed in regions of Far East Asia or the Indian Sub-continent where *E. crus-galli* var. *hispidula* is also abundant along with *E. crus-galli* var. *crus-galli* from which I have assumed another rice mimic, *E. oryzoides* (Ard.) Fritsch has been derived.

Now this has all changed. In an examination of *Echinochloa* in BIOTROP Herbarium at Bogor, Indonesia I discovered a specimen of *E. oryzicola* collected in October 1976 by Dekker and Wirjahardja at Cibeureum, altitude 890 m, 10 km towards Bogor from Cianjur, West Java. On visiting Cianjur in October 1991, I collected more of the same species at Cangklek and Legok villages close to Cianjur. From observations made during my visit the species is widespread in the area in rice-fields from Cibeureum to Cianjur. It would not be surprising if it has been hidden for a long time in this traditional rice-growing area where highly prized tall varieties of "indica" rice are still being grown.

I have previously stated (Michael, 1983) that *E. phyllopogon* (Stapf.) Koss. is the correct name for *E. oryzicola*, but since writing that account of the genus I have examined many more specimens of *Echinochloa* and now I believe that *E. phyllopogon* is a synonym of *E. oryzoides*. I mistakenly felt, along with others, that the tufts of hair in the collar region, characteristic of one form of *E. oryzicola* were confined to that species. Now, I believe that this character appears also in *E. oryzoides*.

The plants with such tufts of hair described by Stapf as *Panicum phyllopogon* need no longer be supposed to be part of a mixed collection of *E. oryzoides* and *E. oryzicola*. Accordingly another sheet comprising both inflorescence and appropriate vegetative features should now be taken as the lectotype of *P. phyllopogon*.

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The lesson to be learned from this turnabout is that it is dangerous to attach too much significance to a single character.

I do not agree with those who consider *E. oryzoides* and *E. oryzicola* as synonymous. These two species may be differentiated according to the following criteria.

	E. oryzicola	*E. oryzoides*
Spikelets	Ovate-elliptical Awns present or absent	Broadly ovate to ovate Nearly always with awns
Inflorescence	Nodding more or less horizontal at maturity	More or less erect
Relative length of embryo to length of mature caryopsis	about 0.9	about 0.7
Chromosome number	2n = 36	2n = 54

The more important synonyms for each of the species are:

1. *E. oryzicola* (Vasing.) Vasing.
   (syn. *E. crus-galli* (L.) Beauv. var. *oryzicola* Ohwi)

2. *E. oryzoides* (Ard.) Fritsch.
   (syn. *E. phyllopogon* (Stapf.) Koss.
   E. macrocarpa Vasing.
   E. hostii (Bieb.) Boros ex Holub.
   E. crus-galli (L.) Beauv. ssp. *oryzoides* de Bolos et Mascl.)

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THE PRESENT STATUS AND POTENTIAL OF *POROPHYLLUM RUDERALE* VAR. *RUDERALE* IN INDONESIA

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ABSTRACT

Porophyllum ruderale (Jacq.) Cass. var. *ruderale* belongs to the family Asteraceae/Compositae. The plant is native to Central and South America. *Porophyllum* is a genus of 28 species, with only 1 species represented in Indonesia. Recent work described another form of the species as var. *macrocephalum*.

The Indonesian form has been confirmed as var. *ruderale*. In Indonesia it was found for the first time in Bogor in 1945 and by 1965 it was reported to be rapidly naturalizing and spread. It was also the first record in the Malesian region.

Present distribution in Indonesia is restricted to West, and Central Java and Sumatra. Only a few studies on *P. ruderale* var. *ruderale* have been made in Indonesia despite the report that it occurred abundantly in upland crops in Southern Sumatra.

INTRODUCTION

Porophyllum ruderale (Jacq.) Cass. var. *ruderale* is an introduced species in Indonesia. It was first collected near Bogor, West Java in 1945, and since then it has become naturalized. It is included under the name *P. ruderale* (Syn. *P. ellipticum* Cass.) in the Flora of Java (Backer & Bakhuizen van den Brink, 1965). Only a few studies have been made on this weed despite the report by Eussen and Madenan (1979) that it occurred abundantly in upland crops in Southern Sumatra and was likely to cause substantial reduction in crop yield.

METHODOLOGY

The study is based on the examination of herbarium specimens preserved in the Herbarium Bogoriense (BO) and BIOTROP Herbarium (BIOT), and also fresh specimens from Bogor.

The distribution in Indonesia was recorded from the labels on the herbarium specimens and all other information found on the labels was noted.

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RESULTS AND DISCUSSION

Taxonomy

Porophyllum belongs to the family Asteraceae (Compositae). It has been placed traditionally in the tribe Helenieae, subtribe Tagetininae (Bentham, 1873; Hoffman, 1894). Bentham and Hooker (1873) and Gray (1886) placed the genus in the tribe Tageteae, subtribe Tagetanae, or Tagetinae of Cassini (1829). Cronquist (1955) included this genus, as well as the other Helenieae, in the Heliantheae, stating that the single main criterion used for the separation of the Heliantheae is insufficient (Johnson, 1969).

Porophyllum is a genus of 28 species. In Indonesia it is only represented by one species, *Porophyllum ruderale* var. *ruderale*, which was originally described by Linnaeus (1753) as *Cacalia porophyllum*. The Indonesian form has been confirmed as var. *ruderale* by Keil (personal communication).

Synonyms of *P. ruderale* var. *ruderale* include:

- *Cacalia porophyllum* L., Sp. Pl. 834. 1753
- *Kleinia porophyllum* L. (Willd.) Sp. Pl. 3: 1738-1804
- *Porophyllum ellipticum* Cass., Dict. Sci. Nat. 43: 56. 1826
- *Porophyllum ellipticum* var. *ruderale* (Jacq.) Urb., Symb. Antil. 1: 468. 1900
- *P. ruderale* ssp. *ruderale* Johns., Univ. Kansas Sci. Bull. XLVIII 7: 225-267.

Another form of the species has recently been described as ssp. *macrocephalum* by Johnson (1969) and var. *macrocephalum* by Keil (1975). In Mexico var. *macrocephalum* is well known as a green vegetable and medicinal plant (Johnson, 1969).

Var. *ruderale* can be distinguished from var. *macrocephalum* by its shorter achenes (7-9 mm long, compared with 11-12 mm), its longer leaf blades (2-9 cm compared with 1-2.5 cm) and only slightly inflated peduncles compared with the strongly inflated peduncles in var. *macrocephalum*. Var. *macrocephalum* has a much stronger smell.

Var. *ruderale* has a chromosome number of n= 11, 22 (Johnson, 1969), whilst in var. *macrocephalum* n= 11 (Keil, 1975).

In Indonesia the vernacular name is only found in Sundanese (Soerjani *et al.*, 1987) as "seungit" which means "fragrant" and "mangga ngora" which means "young mango". In Mexico various taxa of the genus *Porophyllum* are called "papaloquelite" (Bretting and Hernandez X, 1982).

Description

Annual herb 30-200 cm tall, erect, much branched above, aromatic, stem green or partly reddish purple. Leaves opposite or alternate, ovate elliptical or obovate, glabrous, laterally bluntly sinuate with a slit shaped gland below each sinus which is easily observed when held against light, yellow colour, gland, 1-7 x 0.5-2.5 cm. Bloom easily rubbed from the stem. Flower head terminal or axillary, solitary or 2 together, bracts with slit-shaped glands, florets 30-60, corolla greenish to purplish 10-13 mm long. Achenes cylindric, black or brownish, with tawny bristles, 7-11 mm long.

Origin

The center of origin is possibly Mexico or Central America (Johnson, 1969).

Habitat

The plant is found in pasture land, humid soil, sunny or slightly shaded locations, preferring fertile soils. It is a lowland ruderal, and grows in upland rice fields (Soerjani *et al.*, 1987).

Johnson (1969) reported that in their native places the plant is common as a weed in low, flat areas, such as fields and vacant lots. It is usually found at elevations below 1,300 m but may occur up to 2,500 m or more a.s.l. In Indonesia it grows from an altitude of 15-1000 m a.s.l. (Table 1).

Distribution in Indonesia

The only previous report on the introduction of *P. ruderale* var. *ruderale* in Indonesia was in 1945 citing as evidence a herbarium specimen collected by Schorel (BO 161124). It was found among tea shrubs, at Bogor in West Java. The plant was then determined as *Porophyllym ellipticum* (L.) Cass var. *genuinum* Urb., and this was the first record for Malesia.

In 1988 Sastroutomo (personal communication) reported that *P. ruderale* var. *ruderale* was found at the oilpalm plantation at Pameungpeuk, West Java. Other specimens from Java were recorded from Purwokerto and Semarang in Central Java. The author also observed *P. ruderale* var. *ruderale* at Bantul, Yogyakarta. There has been no report yet from East Java (Table 1, Figure 1).

The first record from Sumatra was from the transmigration area in South Sumatra, collected by Wirjahardja and Dekker (BIO 2591) in 1978. Other specimens from Sumatra have also been found in Lampung and North Sumatra.

The spread of *P. ruderale* var. *ruderale* from Java to Sumatra might be through the movement of man and vehicles or by contaminated grains. With the construction of the trans Sumatra highway from Aceh to Java crossing the Sunda Strait, movement between Java and Sumatra will become easier.

Table 1. The distribution of *Porophyllum ruderale* var. *ruderale* in Indonesia based on specimens at the Herbarium Bogoriense, BIOTROP Herbarium and other resources.

Island	Province	Location	Alt. (m)
Java	West Java	Bogor	260-300
		Pameungpeuk*	-
	Central Java	Purwokerto	70
		Getasan (Semarang)	1000
	Yogyakarta	Pundong (Bantul)	-
Sumatra	Lampung	Pulungkencana (North Lampung)	100
	South Sumatra	Between Baturaja-Martapura	50
	North Sumatra	Medan	15

* S.S. Sastroutomo,1988.

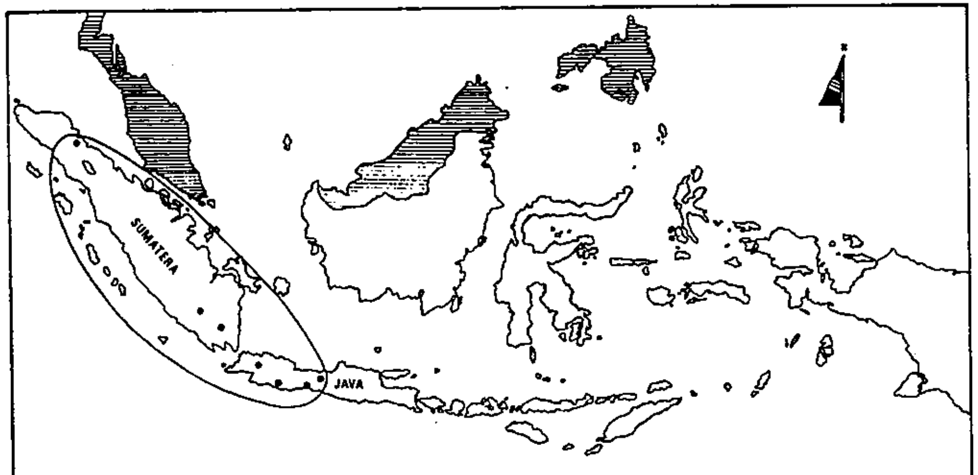

Figure 1. Distribution of *Porophyllum ruderale* in Indonesia

There is no report yet on the occurence of *P. ruderale* var. *ruderale* from other islands in Indonesia, but it has been reported from Singapore.

The potential as an important weed in upland crops

The results of field observations in Bogor showed that *P. ruderale* var. *ruderale* started to flower 60 days after sowing. Each individual produced in average approximately 54 flower heads and each flower head contains in average approximately 49 seeds (achenes). Each plant was calculated to have the capacity of producing approximately 2,650 seeds.

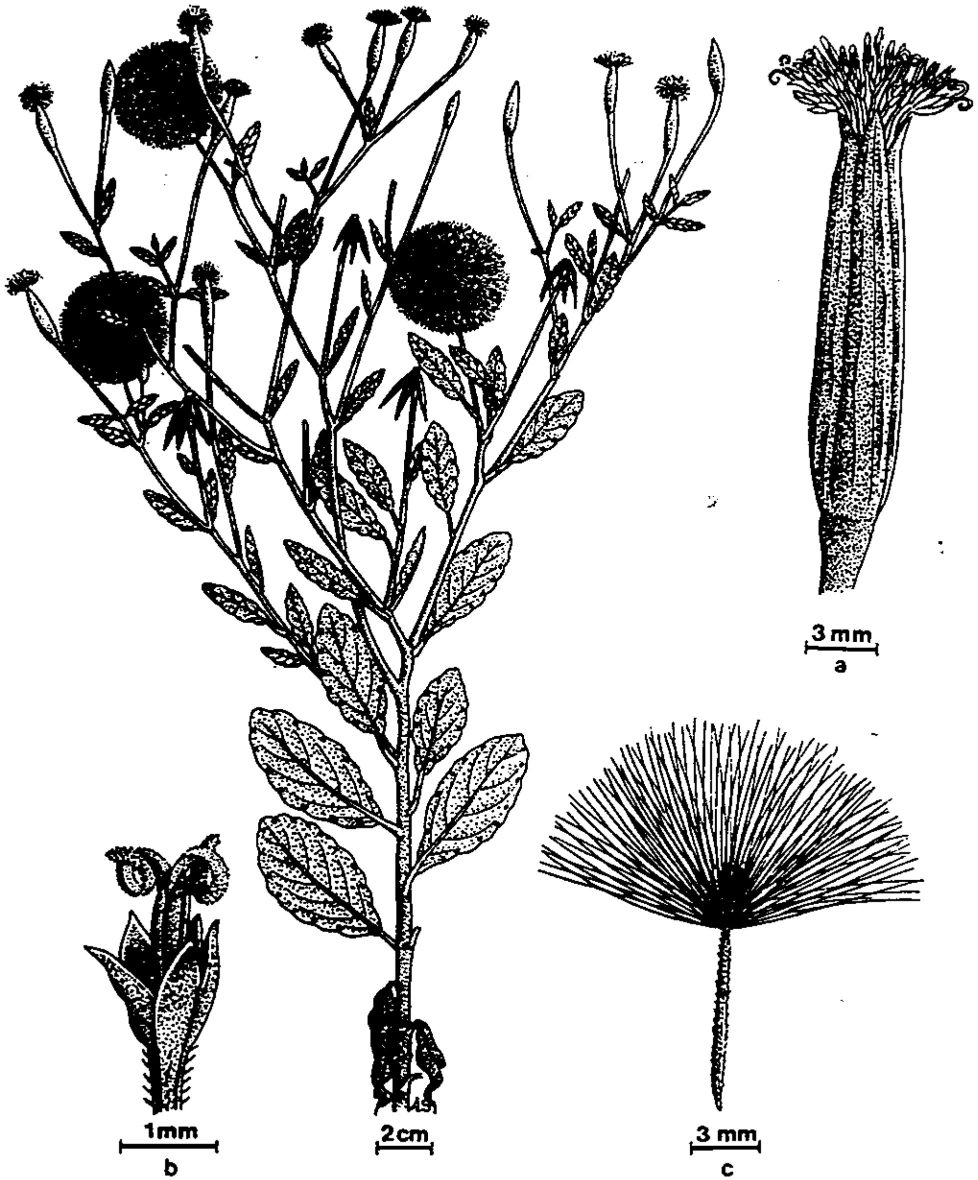

Figure 2. *Porophyllum ruderale* var. *ruderale*; a. flower head, b. flower, c. achene with pappus.

These results are very similar to the work of de Marinis *et al.* (1980) on *P. ruderale* presumably var. *ruderale* in Brazil. They reported that the average number of seeds per flower head was 53, and the number of seeds per individual 2,510. Each plant was capable of producing 2,008 viable seeds based on a germination viability of about 80%.

The plant flowers all year round, and the seeds are very easily distributed by wind soon after being detached from the flower.

Sastroutomo in 1984 reported that on land which was not cultivated at Tajur, Bogor the number of individuals/m^2 was 1,228. Among these 170 individuals were in flower. If each plant produces 54 flowers and each flower produces 49 seeds, within 1 m^2 more than 450,000 seeds will be produced. He also reported that flowering and seed production were more abundant in cultivated plots than in non cultivated plots.

In upland crops *Porophyllum ruderale* var. *ruderale* has the ability to compete with crops. It was shown by the report of Utomo (1981) that in his pot experiment of competition between *Porophyllum ruderale* var. *ruderale* and upland rice, at 60 days after sowing tiller formation of rice was retarded, and there was a 50% reduction in grain yield.

At the higher density of 32 plants/pot the effect appeared at 30 days after sowing and grain yield was reduced by 91% (Eussen and Madenan, 1981).

It was reported by Eussen and Madenan in 1979 that in Southern Sumatra *P. ruderale* var. *ruderale* occurred abundantly in cultivated upland areas, and that it could develop into an important weed species in these areas.

Its potential as an important weed in upland crops can be seen from its high ability to produce seeds in all seasons of the year and its ability to compete with upland crops.

ACKNOWLEDGEMENT

The author wishes to thank Prof.Dr. David J. Keil from California Polytechnic State University, U.S.A. for identifying the specimen of *Porophyllum ruderale* var. *ruderale* and provided some references.

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WEED POPULATION SHIFTS IN WHEAT AND RAPESEED FIELDS AND THEIR CONTROL STRATEGY IN SHANGHAI

TANG HONGYUAN, WANG XUEE, FENG WENXU AND SHEN GUOCHUI[1]

ABSTRACT

According to the authors' survey in 1981, the percentage of weed infestation areas in wheat and rapeseed fields in Shanghai were 68.2 and 75.0% respectively and the percentage of over-medium infestation area were 34.0 and 50% respectively. In 1990, however, the percentage of weed infestation areas reached 91.6 and 94.0% in wheat and rapeseed fields respectively and the percentage of above-medium infestation area were 79.6 and 86.0% respectively. The population composition of the field weed communities have also changed greatly since early 80s. Some major weeds have been controlled successfully while some herbicide tolerant (esp. Chloroluron tolerant) weeds such as *Beckmannia syzigachne, Alopecurus japonicus* and *Polypogon frugax* have increased dramatically. The infestated areas of the three weed populations have increased 34.0, 21.8 and 19.8% respectively during 1981 to 1990.

Factors leading to such changes area discussed. The need for a safe, economical and effective integrated weed management system is proposed by means of appropriate rotation and the mixed use of certain chemical herbicides.

INTRODUCTION

The weed distribution and infestation in Shanghai fields were investigated in 1981 by the authors (Tang *et al.*, 1986). A serious weed infestation and heavy crop loss (50,000 tons) were emphasized which had encouraged the chemical weed control in South China. Until now the percentage of field areas for chemical weed control reached more than 70%. In spite of the unremitting efforts made for chemical weed control, weed infestation has been becoming more and more serious now. To understand such a phenomenon, a careful field weed investigation was carried out in 1990 and a comprehensive analysis was conducted (Tang *et al.*, 1986; Tao *et al.*, 1990; Feng *et al.*, 1990; Tang *et al.*, 1988). In the one hand the success of the chemical weed control was emphasized, and in the other, causes of the increasing weed infestation have been understood and the strategy have been estabilished to deal with such problems.

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RESULTS AND DISCUSSION

According to the investigations in wheat and rapeseed fields in 1981 and 1990, the weed infestation areas in the suburbs of Shanghai have increased 19.0 and 23.6%, the above-medium infestation area have increased 45.6 and 36.0, especially those seriously infested fields (Table 1 & 2). The population composition of weed communities has also changed significantly. Factors leading to such changes and the increasing weed infestation may include:

1. The continuous simple rotation of rice-wheat is one of the key factors. The planting area of cotton and corn has been reduced dramatically since 1985. The continuous rice-wheat rotation gave rise to a high soil moisture thus some hydrophytes and hydrophilous weeds grew up rapidly. In our experiments, the germination percentages of some hydrophilous weed seeds such as *Alopecurus aequalis* and *Beckmannia syzigachne, A. japonicus, Sclerochloa kengiana* and *Polypogon frugax* reached 39.3, 82.0, 3.0, 62.7 and 33.3% respectively in rice-wheat rotation fields, while in cotton-wheat rotation fields the germination percentages were 0.0, 1.7, 0.0, 0.0 and 0.7% respectively.

Table 1. Weed population shifts in wheat fields in Shanghai

Weeds	May, 1991					May, 1990				
	Infestation rate (%)					Infestation rate (%)				
	1	2	3	4	5	1	2	3	4	5
Alopecurus japonica	16.8	4.4	0.3	0.0	0.0	20.5	8.5	4.0	9.0	5.0
Beckmannia syzigachne	45.2	7.6	1.7	0.2	0.0	27.0	17.0	8.5	4.5	3.5
Sclerochloa kengiana	29.4	12.0	5.9	1.7	0.4	23.2	11.6	9.6	4.8	2.4
Polypogon frugax	36.3	6.9	1.3	0.8	0.2	41.5	12.5	7.5	5.0	4.0
Alopecurus aequalis	35.1	19.7	10.1	4.3	1.4	42.5	7.5	4.5	1.5	0.5
Malachium aquaticum	52.9	28.3	6.3	1.2	0.0	71.5	7.5	1.5	0.0	0.0

Table 2. Weed population shifts in rapeseed fields in Shanghai

Weeds	April, 1991					April, 1990				
	Infestation rate (%)					Infestation rate (%)				
	1	2	3	4	5	1	2	3	4	5
Alopecurus japonica	12.0	5.0	5.0	0.0	0.0	27.6	8.8	6.8	5.6	7.6
Beckmannia syzigachne	2.5	7.5	2.5	2.5	0.0	34.0	15.2	14.0	6.4	4.4
Sclerochloa kengiana	5.0	0.0	0.0	0.0	0.0	23.6	14.0	9.2	8.0	2.4
Polypogon frugax	12.0	0.0	0.0	0.0	0.0	46.8	16.8	10.4	1.6	2.0
Alopecurus aequalis	52.0	17.0	22.5	5.0	2.5	19.5	2.0	0.0	0.0	0.0
Malachium aquaticum	50.0	20.0	30.0	0.0	0.0	59.6	12.8	5.2	0.8	0.0

It implies that the soil weed bank of some hydrophyti weeds could be reduced dramatically in non-irrigated fields. The experiments showed that the germination percentage of *A. aequalis* seeds reached 18.5-31.8% in the soil of 15-30% moisture content for 20 days but only reached 6.0-7.5% in the soil of 5-10% moisture content.

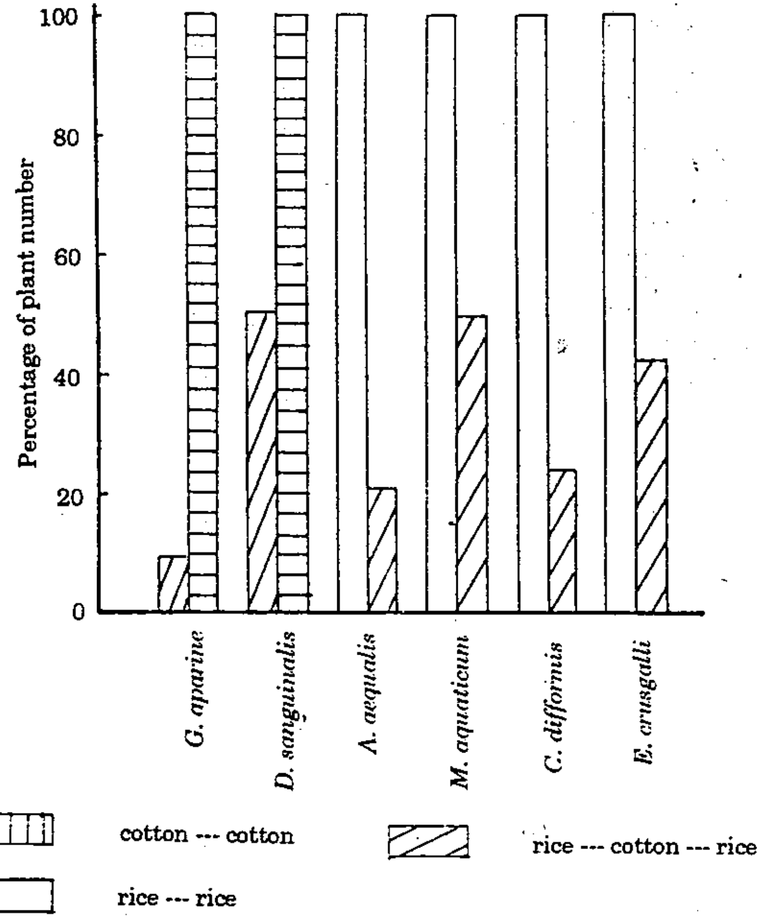
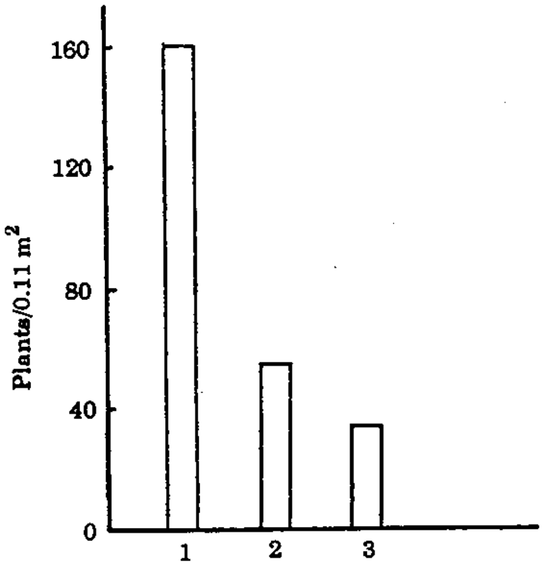


Figure 1. The effect of crop rotation on the composition of weed community.

2. The rapid development of rural enterprises gave rise to a large scale transformation of labour powers from crop production to industry and sideline production. Agricultural process tends to be simplified and extensive. Some traditional agricultural means had been abandoned including the application of river silt in wheat fields, ploughing in wheat fields and

intertilling in rapeseed fields after the promotion of non-tillage cultivation techniques in wheat and rapeseed fields. The seed bank of weeds in non-tillage fields is greater than in traditional tillage fields, hence, more weeds germinate earlier and have a greater competitive ability. The weed infestation was 15.0-20.7% more serious in these fields (Tang *et al.*, 1990).

3. The reduction of green-manure crops and the increasing trend of continuous planting of wheat (rapeseed). There have been an increasing trend of reducing green-manure crops to plant more edible crops. The planting of wheat, rapeseed and green-manure crops took one third of the total planting area in the suburbs of Shanghai just a decade ago, but it almost approaches zero recently.
   In rice-wheat rotation fields, the seeds of *A. aequalis* get mature at the same time with wheat, more than 80% of *A. aequalis* seeds have fallen into soil until harvest. The weed seeds have a higher viability in wet soil thus increases the seed bank of weeds in such fields. In wheat-green manure crops rotated fields, however, green manure crop fields are tilled on 20-30 of April in South China when the seeds of *A. aequalis, A. japonicus* and *B. syzigachne* have not matured to increase seed bank content of weeds, thus leading to a low weed infestation in the following year (Figure 2).



1 (rice) --- wheat --- rice --- wheat
2 (rice) --- wheat --- rice --- rapeseed
3 (rice) --- wheat --- rice --- green manure crops

Figure 2. The effect of crop rotation on the occurrence of *Alopecurus aequalis*.

4. Residues of wheat are rather high after harvesting and wheat straws are returned to the fields, thus a large quantity of weed seeds remains in fields especially. *S. kengiana* and *A. aequalis* which are lower than half of the plant height of wheat. Traditionally organic fertilizer is fermented and then applied into the fields, but now it is applied directly almost without fermentation.

5. The promotion of single type herbicide like Chloroluron had controlled 90% of *A. aequalis* and *M. aquaticum* and 70% of *S. kengiana* at ordinary dosage. The percentages of infestation areas of the two weeds in wheat and rapeseed fields had been reduced from 35.5 and 35.8% to 14 and 9% respectively in the suburbs of Shanghai (the percentages of the above-medium infestation areas were reduced from 15.8 and 7.5% to 6.5 and 1.5 respectively). The infestation of *S. kengiana* maintains the same level as before (7.5% increasing). As for some Chloroluron tolerant weeds like *A. japonicus, B. syzgachne* and *P. frugax*, the controlling efficacy is quite low. The infestation area of the three weeds had increased 34.0, 21.8 and 19.8% respectively and the above-medium infestation area increased 14.6, 14.2 and 17.7% respectively. They have already been dominant weeds in wheat or rapeseed fields in some regions.

Another Chloroluron tolerant weed, *Galium aparine* had once spread soon after the promotion of Chloroluron and had been controlled effectively by the promotion of Bentazon and Mataxon.

A safe, effective and economical weed control can only be reached by integrated weed management. Several suggestions may be given toward such a goal:

1. The planting of dry land crops like cotton, corn and soybean should be somewhat increased and the planting of green manure crops should be recovered which is helpful to control diseases, pests, weeds and ameliorate soil (Figure 1 & 2).

2. Weed population shifts are almost inevitable when single type of herbicide is applied. The mixed use of herbicides is helpful to control a broad spectrum of weed according to different population composition of field weed communities. The antagonism between different herbicides should be noticed. As for those *A. aequalis* and *M. aquaticum* dominated wheat fields, Chloroluron or the mixture of Chloroluron and Glean (Chlorsulfuron) is preferrable; for those grass weeds dominated wheat fields, Illoxan and Puma are preferrable; for those broadleaved weeds dominated fields, Bentazon, Starane or Metaxon can be applied; for those *A. japonicus, B. syzigachne, G. aparine, M. aquaticum* dominated fields, it is advisable to apply Illoxan or Puma for the first time and Bentazon or Chloroluron +

Glean for the second time, for those *S. kengiana* and *G. aparine* dominated fields, Illoxan or Puma can be applied for the first time, later Bentazon is applied or it can be treated by Illoxan + Glean at two-leaf stage (Tang *et al.*, 1990; Yu *et al.*, 1991; Tao *et al.*, 1990).

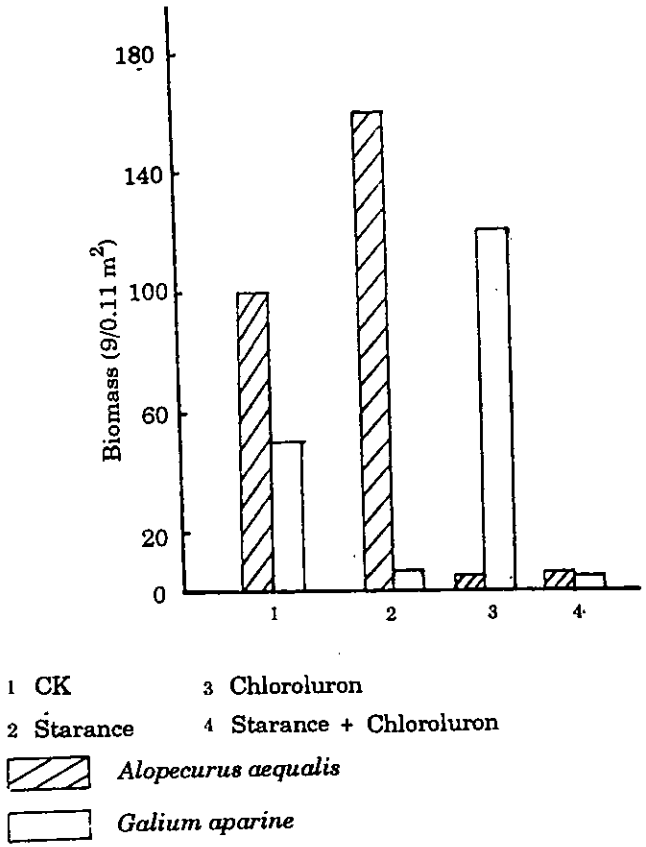


Figure 3. The effect of herbicide treatments on field weed populations.

In rapeseed fields, herbicides available are limited and have not been able to deal with all possible weed population compositions yet. As for those grass weeds dominated fields, Illoxan, Puma, Onecide, Gallant, NC-302 and Sethoxydim can be used; for those both *M. aquaticum* and grass weeds dominated fields, Acetochlor may be preferrable. No effective herbicides are available to control broadleaved weeds in rapeseed fields yet, for those broad-leaved weed dominated fields, it is advisable to apply wheat - green manure crops - rapeseed rotation to reduce soil seed bank of weeds (Figure 2).

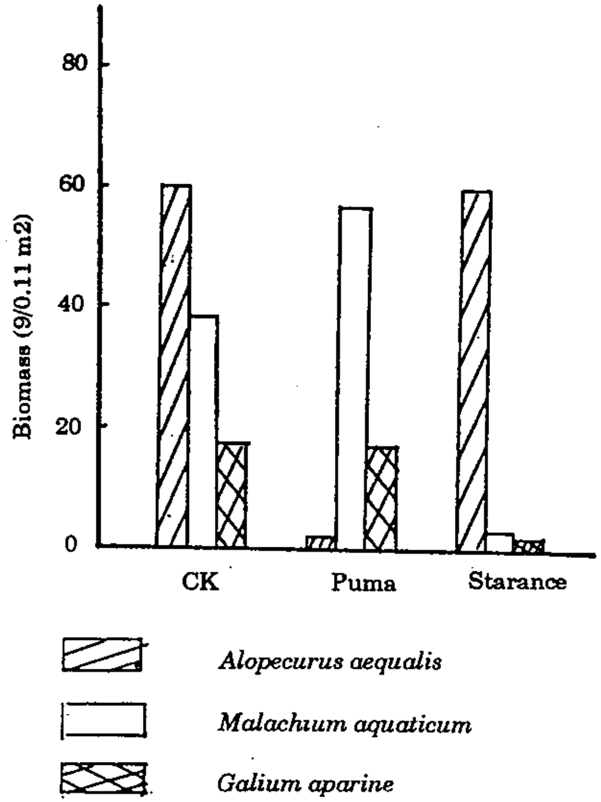


Figure 4. The effect of herbicide treatments on field weed populations.

COMPARISON OF WEED DISTRIBUTION AND INFESTATION IN THE EASTERN AND WESTERN HEMISPHERES ALONG THE 50° NORTH LATITUDE

TANG HONGYUAN AND WANG XUEE[1]

ABSTRACT

Data of field weed distribution and infestation along the 50°N latitude in southeast England, north China and south Canada were investigated. The overlap of field weed flora in these areas includes: *Avena fatua, Cephalanoplos setosum, Chenopodium album, Setaria viridis, Polygonum convolvulus, P. aviculare* and *Agropyron repens*. Some weeds in England such as *Galium aparine, Stellaria media, Veronica didyma, Poa annua* and *Alopecurus myosuroides* can not be found in north China at the same latitude but only in the Yangtze River basin areas. Saskatoon of Canada shares *G. aparine* and *P. annua* with England but some summer weeds like *Portulaca oleracea* can only be found in south Canada. *Sinapis arvense, Viola arvensis, Papaver rhoeas* and *P. trivialis* are found both in England and Canda but it has not been found in China.

INTRODUCTION

The authors had reported the latitudinal distribution and infestation of field weeds in China across the tropical, subtropical, temperate and cold-temperate zones and also the longitudinal distribution and infestation along the north latitudes 26°, 30° and 40° involving south sub-tropical, mid-north sub-tropical and warm temperate zones (Tang *et al.*, 1978a; 1987b; 1988a; 1988b). The authors also investigated the weed flora and infestation in some places located in both eastern and western hemispheres along the 50° north latitude involving Keshan and Yian Counties of Heilongjiang Province, Yakeshi City of the Nei Monggol Autonomous Region, Aletahi City of Xinjiang Uygur Autonomous Region in China, Cambridge and Bristol in United Kingdom and Saskatoon in Canada.

METHODS

Tang's five-scale visual rating method was applied in the investigations. Fifty plots were sampled in each place. The results are shown in Table 1 and analysed according to the climatic data of each area (Tables 2, 3).

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Table 1. The comparison of field weed distribution in the eastern and western hemispheres along the 50° north latitude

Weed species	Keshan 1	Keshan 2	Yakeshi 1	Yakeshi 2	Aletai 1	Aletai 2	Rickwood 1	Rickwood 2	Saskatoon 1
Avena fatua	70.7	32.0	43.2	16.0	72.0	66.0	59.0	34.4	81.5
Cephalanoplos setosum	38.7	21.4	2.0	2.0	2.0	2.0	3.0	2.0	41.8
Setaria viridis	61.6	21.1	17.9	4.2	24.0	16.0	2.0		67.9
Polygonum convolvulus	57.3	29.2	76.8	36.0			2.0		87.8
Polygonum aviculare	28.0				2.0	2.0	3.0	2.0	4.8
Sonchus arvensis	36.0	22.7	23.3	11.7			21.0	15.0	40.8
Agropyron repens					8.0	8.0	25.0	4.0	8.0
Amaranthus retroflexus	1.3	0.3							39.7
Echinochloa crus-galli	22.6	5.3	13.7	3.8	18.0	16.0			1.8
Equisetum arvense	72.0	54.0	69.5	43.0					8.7
Galeopsis tetrahit			66.0	48.0					11.5
Descurainia sophia			7.4						11.5
Galium aparine							76.0	52.0	3.8
Alopecurus aequalis							88.0	83.0	
Stellaria media							4.0	2.0	2.4
Capsella bursa-pastoris							23.0	13.0	8.4
Poa annua							23.0	13.0	
Sinapis arvense							2.0	2.0	41.4
Conyza canadensis									25.3
Kochia scoparia									15.5
Plantago major									36.0
Lappula echinata									34.8
Thlaspia arvense									46.7
Senecio vulgare									2.3
Portulaca oleracea									5.3
Polygonum persicaria									3.0
Bromus sterillis						68.0	43.0		
Poa trivialis						51.6	31.6		
Anagallis arvense						2.0			
Apera spica-venti						2.0			
Viola arvense							3.0	2.0	
Lolium multiflorum						14.0			
Arrhenatherum elatius						2.0	2.0		
Myosotis arvense							2.0		
Lamium amplexicaule							13.0	7.0	
Phragmites communis				48.0	40.0				
Scirpus planiculmis					6.0	6.0			
Fagopyrum esculentum	6.7		40.0	9.5					

Table 2. Data of precipitation of sampling areas, mm

Month	Keshan	Aletai	Rickwood	Saskatoon
January	5.1	16.1	42.4	
February	4.9	21.1	31.7	
Maret	7.5	12.1	42.9	
April	19.1	20.1	36.6	
May	41.9	15.1	51.0	34.0
June	78.2	31.7	49.2	57.4
July	159.8	23.5	40.1	53.1
August	119.1	18.7	51.0	45.2
September	85.9	17.0	40.4	33.0
October	18.8	7.7	47.0	
November	4.2	16.1	52.1	
December	5.8	23.0	44.3	
Annual Average	550.0	221.0	528.7	352.6

Table 3. Climatic data of sampling areas

	Keshan	Yakeshi	Aletai	Rickwood	Saskatoon
Latitude (N)		49°.23′	47°.44′	52°.0′	52°.10′
Longitude	125°.53′E	120°.0′E	88°.05′E	0	106°.41′W
Elevation (m a.s.l.)	236.7	306.5	735.3	---	501.0
Average T (°C)	0.8	-3.4	4.0	9.4	2.5
Min. T (°C)	-42.0	-49.0	-43.0	-6.5	-23.9
Precipitation (mm/y)	550.5	421.3	221.0	528.7	352.6

RESULTS AND DISCUSSION

1. Weed Flora and Infestation along Different Longitudes

Keshan County of Heilongjiang Province

The annual average temperature is 0.8°C, the minimum temperature -41°C, and the annual precipitation is 550.5 mm. The main crops are wheat, soybean and beet sowed in spring with one crop a year. The main field weeds were *Equisetum arvense, Avena fatua, Polygonum convolvulus, Sonchus arvensis, Cephalanoplos setosum* and *Setaria viridis, Echinochloa crus-galli*, the frequencies of each weed species were 72.0, 70.7, 57.3, 36.0, 38.7, 61.1 and 22.6% respectively and the infestation rate were 54.0, 32.0, 29.2, 27.7, 21.1, 21.4, and 5.0% respectively. There were also slight distribution and infestation of *Chenopodium album* and *Amaranthus retroflexus*.

Yakeshi City of Nei Monggol Autonomous Region

The annual average temperature is -3.4°C, the minimum temperature -49°C, and the annual precipitation is 421.3 mm. The main crops are wheat, soybean, corn, sunflower with one crop a year. Main field weeds were *Galeopsis tetrahit, E. arvense, P. convolvulus* and *A. fatua, S. arvense*, the frequency of each weed species was 48.0, 43.0, 36.0, 16.0 and 11.7% respectively. There was also slight infestation of *C. setosum, E. crus-galli, Descurania sophia* and *S. viridis*.

Aletai City of Xinjiang Uygur Autonomous Region

The annual average temperature is 4.0°C, the minimum temperature -43.0°C, and the annual precipitation is 221.0 mm. The main crops are wheat, beet and rice sowed in spring with one crop a year. The main field weeds were *C. album, A. fatua, S. viridis, E. crus-galli, Agropyron repens,* the infestation rate of each weed species was 78, 66, 16, 16, and 8% respectively and the emergence frequency was 96, 72, 24, 18 and 8% respectively. There was also slight infestation of *C. setosum* and *P. aviculare*. Since rice is planted in this area, *Typha* spp. and *Eleocharis acicularis, Scirpus planiculmis* and *Eleocharis acicularis, Scirpus planiculmis* has also been found and may be infestative.

Southeast Britain

The annual average temperature is 10°C, the minimum temperature -6.5°C, and the annual precipitation is 500-700 mm. The main crops are wheat, barley, rape-seed and beet. Winter wheat is generally planted which is sowed in autumn, and spring wheat is also grown. The main field weeds are *Alopecurus myosuroides, Galium aparine, Bromus sterillis,* and *Avena fatua*.

2. Weed Flora and Infestation along the Same Latitude (50°N) in China, Britain and Canada

Similarities

Keshan and Aletai of China, Southeast Britain and Saskatoon of Canada are along the same latitude 50° north which belongs to mid-north temperate zone with a low annual average temperature and one crop a year. The main crops are wheat, barley rape-seed and beet. The field weeds are quite similar, such as *Avena fatua, Sonchus arvensis, Cephaloplos setosum, Chenopodium album, Setaria viridis, Polygonum convolvulus, P. aviculare, Agropyron repens* which are able to germinate in low temperatures. *S. viridis* can also complete its life cycle in a rather short period due to its short reproductive stage which

offsets its requirement for a relative high temperature. No *Eleusine indica* and *Digitaria sanguinalis* have been found in these areas.

China vs. Canada

The latitude of Keshan, Yakeshi and Aletai in China is relatively higher than that of Saskatoon in Canada, hence the annual average temperatures and minimum temperatures tare lower than in Saskatoon due to the influence of continental climate of Siberia and China. Neither crops nor field weeds are able to endure the low temperature in winter. In spring and summer, however, the temperatures are almost the same as in Saskatoon of Canada, with a close annual precipitation concentrating in spring and summer when crops are growing abundantly, thus a similar field weed flora was observed in these areas including *Amaranthus retroflexus, Equisetum arvense, Galeopsis bifida, Descurainia sophia, Echinochloa crus-galli, Plantago major* and the other eight weed species mentioned in last section.

China vs. Britain

Southeast Britain has a unique climate with an even annual precipitation and temperature due to the warm current in the Atlantic Ocean. The average minimum temperature in winter is 3.65°C and the average maximum temperature in summer is 17.5°C. Such a climate is suitable for thermophilous weed species such as *Alopecurus aequalis, Stellaria media, Galium aparine, Poa annua, Lolium multiflorum, Lamium amplexicaule, Capsella bursa-pastoris* and *Veronica didyma* which germinate during autumn-winter and *Chenopodium album* which germinates in spring. Flowering and fruiting of these weeds occur in summer. The distribution of these weeds confines only to south China, none of them has ever been found in Keshan and Aletai due to the low temperature in winter.

The annual average temperature in southeast Britain (9-10°C) is rather close to that in Beijing and Shanhaiguan of China (N 40°) while some popular summer weeds in Beijing and Shanhaiguan such as *Echinochloa crus-galli, Digitaria sanguinalis, Amaranthus retroflexus, Acalypha australis* and *Solanum nigrum* were not found in southeast Britain possibly because of the relative low summer temperature in Britain.

Britain vs. Canada

Although the locations in Britain and Canada are of the same latitude, the temperature and precipitation in each season are quite different. Some summer weeds in Canada such as *Portulaca oleracea* and *Echinochloa crus-galli* could not grow in Britain due to the lack of cumulative temperature and a sufficient growth period with a suitable temperature.

Because of the similar geographic situation and the close historical relationship between Britain and Canada, some weeds are common in both countries, but they have not been found in Chinese fields yet, such as *Sinapis arvense, Pipaver rhoeas, Myosotis arvense, Anagallis arvense* and *Viola arvense*.

GROWTH AND SEED PRODUCTION OF *SCIRPUS JUNCOIDES* ROXB. SUBSP. *JUNCOIDES* UNDER COMPETITION WITH RICE AND THE PERIOD NEEDED FOR ITS CONTROL

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ABSTRACT

In Japan, *Scirpus juncoides* Roxb. subsp. *juncoides* is the most common weed in rice fields which emerges from seed and over-wintering bud; the former is the main reproductive organ. The weed usually emerges just after land puddling and it produces seeds before rice harvest. In the southern part of Japan, seeds are produced by those regenerated plant after rice harvest. Growth and seed production of *Scirpus juncoides* Roxb. were investigated to find the appropriate time to control it in order to inhibit seed production in transplanted rice fields.

Scirpus plants which emerged from over-wintering buds, grew more rapidly than those from seeds, and they produced 1,500 seeds per plant. On the other hand, plants derived from seeds, produced about 100 seeds per plant when the seedlings emerged immediately after rice transplanting, and few mature seeds were produced when seedlings emerged more than one month after transplanting. This was because the period of grain filling of *S. juncoides* Roxb. was too short for seed maturation.

The number of seeds per plant was not different among emergence densities of more than 500 plants per sq. meter. However, the higher the weed emergence density, the fewer the seeds produced per sq. meter, as the weed density at rice harvest, decreased due to competitive pressure. Control of the weed should be implemented in the first month after rice transplanting.

INTRODUCTION

From late 1960s, *Scirpus juncoides* Roxb. subsp. *juncoides* has infested rice fields in Japan. The weed is perennial and it emerges from seed and over-wintering bud. The former is the main reproductive organ in disturbed condition such as puddled rice fields, because over-wintering bud do not sprout easily under the submerged puddled soil (Iwasaki, 1983). Before 1980, the weed was restricted to the north-eastern part of Japan or to areas of early rice harvest where the weed could sprout from the base of the stubble after the rice harvest and produces a lot of seeds before the plant died from frost in winter (Sakamoto *et al.*, 1982). Lately *S. juncoides* Roxb. infested many rice fields all over Japan. Presumably, the weed will retain its position of being the most

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common paddy weed which emerges mainly from seed. Since the longevity of *Scirpus* seeds is very long compared with other annual weed seeds, it is important to keep its seed population at a low level to facilitate its control.

This is the study on the growth and seed production by weeds which emerged from seeds and over-wintering buds, and the relationship between seed production, emerging time and emergence density. The objective is to find the most appropriate time to inhibit weed seed production in transplanted rice fields.

MATERIALS AND METHODS

Experiment I

The experimental site, at the Konosu branch of the National Agriculture Research Center, had clay loam soil. In the rice field for this experiment, there was no recent history of *S. juncoides* Roxb. emergence before the experiment. The field was tilled two times between early April to middle of May in 1984, and half of the field was transplanted with rice seedlings of 3.6-leaf stage at the density of 22.2 hills per sq. meter and three plants per hill on June 14. The remaining half of the field was not transplanted with rice, and left fallow. One meter square concrete pots filled with paddy soil which contained a lot of seeds of *S. juncoides* Roxb. were puddled six times from June 11 to August 7, and three-leaf stage seedlings of the weed which emerged from June 18 to August 12 were sampled from these pots, and were subsequently transplanted in the rice plot and the bare plot at the density of 22.2 plant per sq. meter. Over-wintering buds were also sampled from the same concrete pots before the first puddling, and were transplanted in the rice plot and the bare plot at the same density on June 16. The experimental plots were 1.2 m x 2.5 m and arranged in a randomized complete block with three replications.

Five plants per plot were sampled at the beginning of seed dispersal period for the determination of the number of flowering scapes, spikelets and seeds per plant, and foliage air-dry weight. Ten inflorescences which had been covered with polythene bags, having drainage holes, before seed dispersal, were sampled at rice harvest in the rice plot, and in early December in the bare plot for the determination of percentages of mature seeds and mature seed weight.

Experiment II

The experimental field was the rice field in which a lot of seeds of *S. juncoides* Roxb. had been dispersed in 1984. The field was puddled on June 11 and transplanted with 3.6-leaf stage seedlings of rice at the same density as that of experiment I, on June 12, 1985. Emergence densities of *S. juncoides* Roxb. at 11, 22, 40, 80, 150, 300, 600, and 1,200 plants per sq. meter, were achieved by hand thinning at the beginning of scaping period of the weed. The field plots were 1.6 m^2 to 5.4 m^2, with larger plots for lower densities, and were arranged in two fully randomized blocks.

In the middle of October, rice harvest, the number of plants per sq. meter were counted and ten plants per pot whose inflorescences were covered with nylon mesh bags before seed dispersal, were sampled for determination of the number of seeds, percentages of mature seeds, mature seed weight and foliage air dry weight.

RESULTS AND DISCUSSION

1. Developmental stage of *S. juncoides* Roxb. in rice fields

The life history of *S. juncoides* Roxb. in rice field is shown in Figure 1. The plants emerging from over-wintering buds which elongated their scapes just after emergence, grew more rapidly in the early stage of rice cultivation than those from seeds which had four or six elongated linear leaves before beginning of scape elongation.

In the bare field, the plants from seed which emerged at any time from June 18 to August 12 formed spikelets and flowered (Figure 2). The duration from flowering to seed dispersal of the plants derived from seeds were longer for later emerged plants, and the grain filling period was insufficient for seed maturation when the seedlings emerged after July 16. This is because the foliage died from frost in early December before seed maturation. In the rice field, flowering of *S. juncoides* Roxb. was not observed when the seedlings emerged after July 16, thirty-two days after rice transplanting. The grain filling period before rice harvest was too short for seed maturation when the seedlings emerged on July 2, eighteen days after rice transplanting.

In the case of plants from over-wintering buds, life cycle of the weed was completed before frost took place in winter in the bare field and before rice harvest in the rice field.

2. Difference of seed production between the plants from over-wintering buds and the plants from seeds

In the bare field, plants which emerged from over-wintering buds produced about 15,000 seeds per plant, nearly two times the amount produced by plants from seeds. In the rice field, the same plant source produced about 1,500 seeds, and this was fifteen times the amount produced by plants from seeds (Table 1). Almost all (91.7%) of the seeds produced by the plants from over-wintering buds matured before early December in the bare field, and

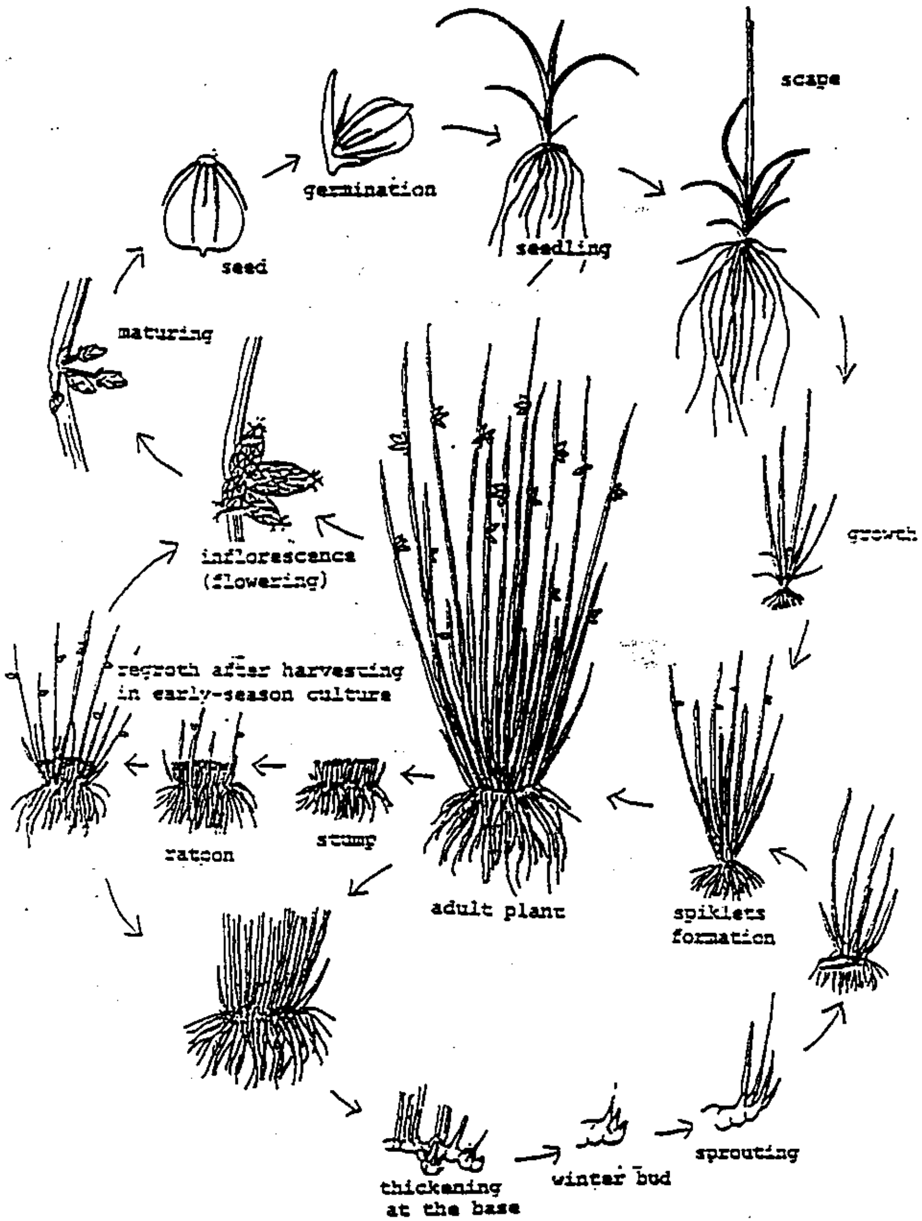

Figure 1. Diagram of the life history of *Scirpus juncoides* in the paddy field (Watanabe, 1987).

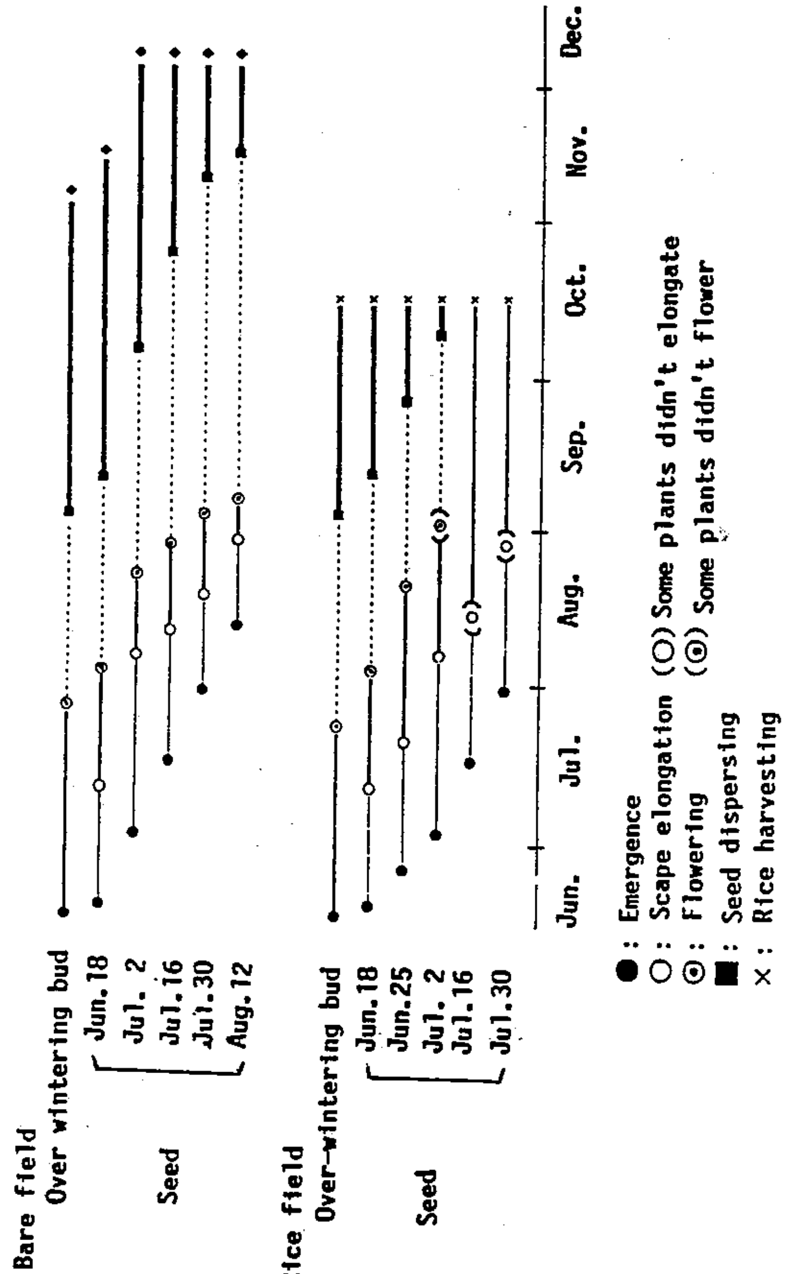

Figure 2. Developmental stages of *Scirpus juncoides* Roxb. in paddy fields (Watanabe *et al.*, 1991)

93.9% of the seeds matured before rice harvest in the rice field. On the other hand, in the rice field, only 69% of the seeds were matured when the plants emerged from seeds on June 18, immediately after rice transplanting, because of the shading effect by rice. In the bare field, more than 90% of the seeds matured.

Table 1. Growth and seed production of *S. juncoides* (Watanabe *et al.*, 1991)

Field plots	Shoot D.W.	Seeds	Maturation
	g pl^{-1}	pl^{-1}	Z
Bare field			
Over-wintering bud	41.4	17,272	91.7
Seed	30.2	9,738	94.1
Rice field			
Over-wintering bud	5.63	1,530	93.9
Seed	0.36	106	69.0

It was calculated from plant density of the experiment I, that there were 22.2 plants per m^2, and the number of mature seeds per plant which was more than two hundred thousand mature seeds per m^2 will be scattered on the paddy soil surface in the bare field, and more seeds will be scattered as more plants from over-wintering buds emerged.

The number of seeds produced by plants derived from seeds in the rice field was only 10% of the seeds produced by the same plants in the bare field. In contrast, it was reported that the seeds production of *Echinochloa oryzicola* Vasing. in rice field, was about 35% of that in bare field (Huruya *et al.*, 1978). Thus *S. juncoides* Roxb. was less competitive than *E. oryzicola* Vasing.

3. Difference of seed production among plants which emerged at various times

The number of seeds per plant was about 9,700 when the seedlings emerged on June 18 in the bare field, and more than 3,000 seeds per plant when the plant emerged before July 16. Thereafter the number of seeds produced were less when the seedlings emerged later (Table 2). In the rice field, the number of seeds per plant was only one hundred when the seedlings emerged on June 18, immediately after rice transplanting. The number of seeds per plant was less when the seedlings emerged later. Only eight seeds were produced by the plant which emerged on July 2, eighteen days after rice transplanting.

Table 2. Difference of seed production among plants which emerged at various times (Watanabe *et al.*, 1991)

Emerging time	Bare field	Rice field
	pl^{-1}(%)	pl^{-1}(%)
Jun. 18	9,738 (100)	106 (100)
Jun. 25	—	31 (12)
Jul. 2	7,688 (79)	8 (8)
Jul. 16	3,147 (32)	0 (0)
Jul. 30	346 (4)	0 (0)
Aug. 12	95 (1)	—

As the seedlings emerged later, the number of flowering scapes, spikelets and seeds decreased more in the rice field than in the bare field (Figure 3). The percentage of mature seeds also decreased with the delay in the emergence of seedlings, especially in the rice field (Figure 4). This was due to the grain filling period being insufficient for seed maturation before rice harvest.

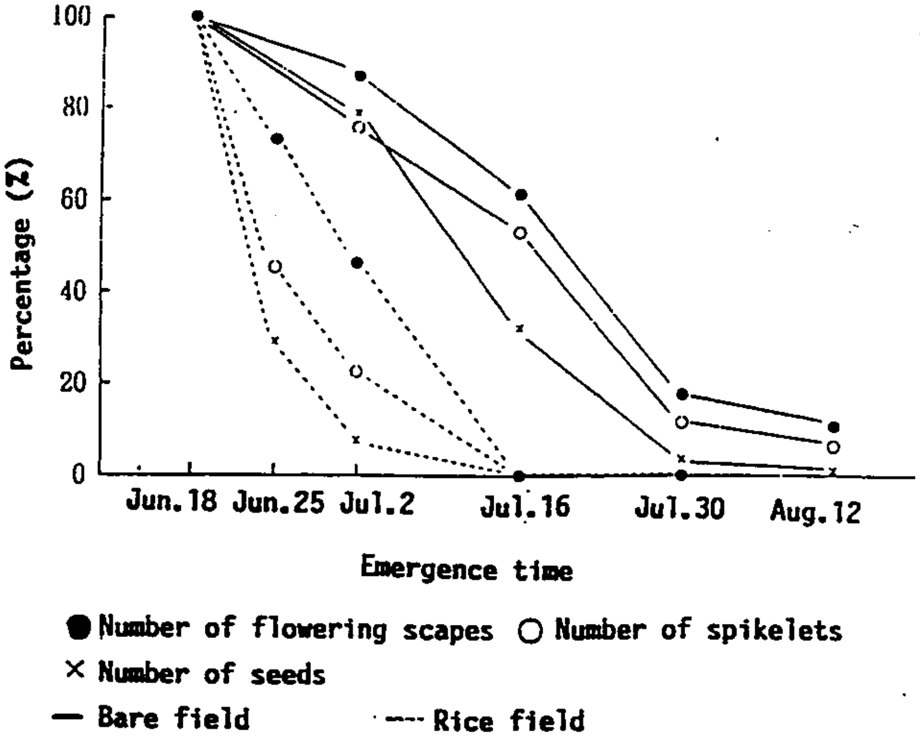

Figure 3. Decrease of floral parameters with the delay in seedling emergence (Watanabe *et al.*, 1991).

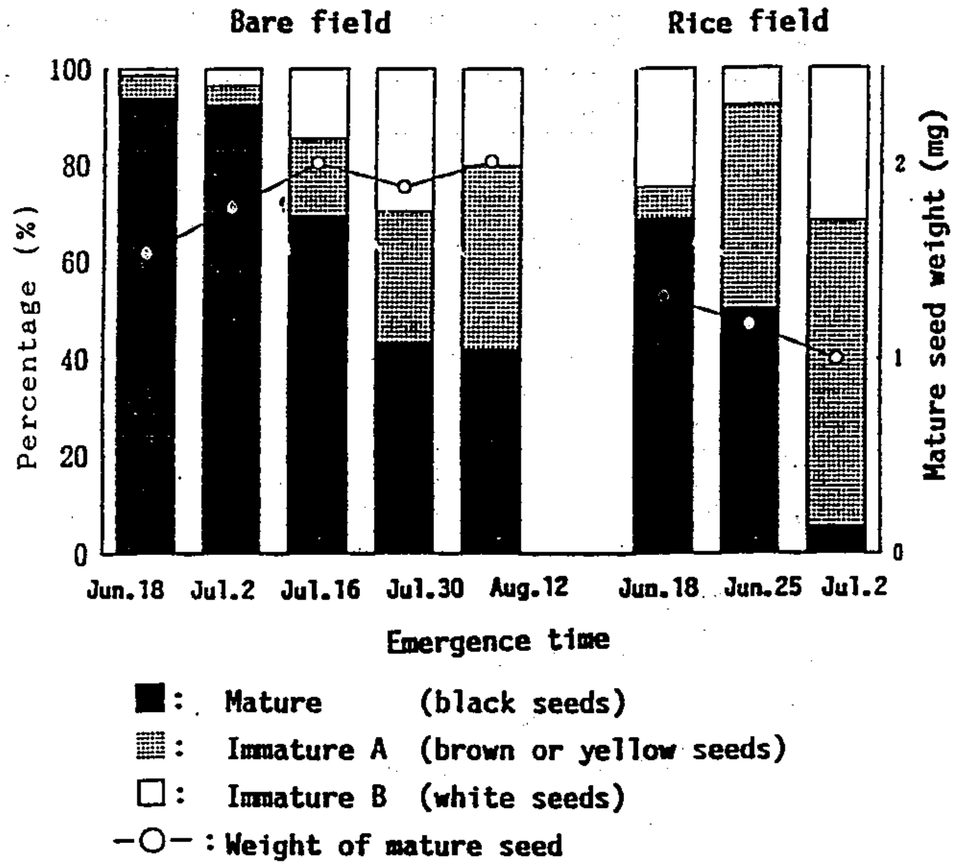

Figure 4. Seed maturation and seed weight (Watanabe *et al.*, 1991)

4. Difference of seed production among the plants at various emergence densities

In the rice field, the number of matured seeds of *S. juncoides* Roxb. per plant varied from 50 to 200 (Figure 5). More seeds were produced at low density, whilst at emergence densities of more than 500 plants per sq. meter, no significant difference were found between plots. Seed production per sq. meter was the highest at the density of 1,000 plants per sq. meter, about 65,000 mature seeds per sq. meter were dispersed on the paddy soil surface. However fewer seeds were produced at higher emergence density, because the plant density at rice harvest decreased due to competitive pressure.

The number of seeds per plant of *S. juncoides* Roxb. was highly correlated with its foliage air-dry weight (Figure 6). Nevertheless, seed production from over-wintering buds was always higher and the plants were also larger in size.

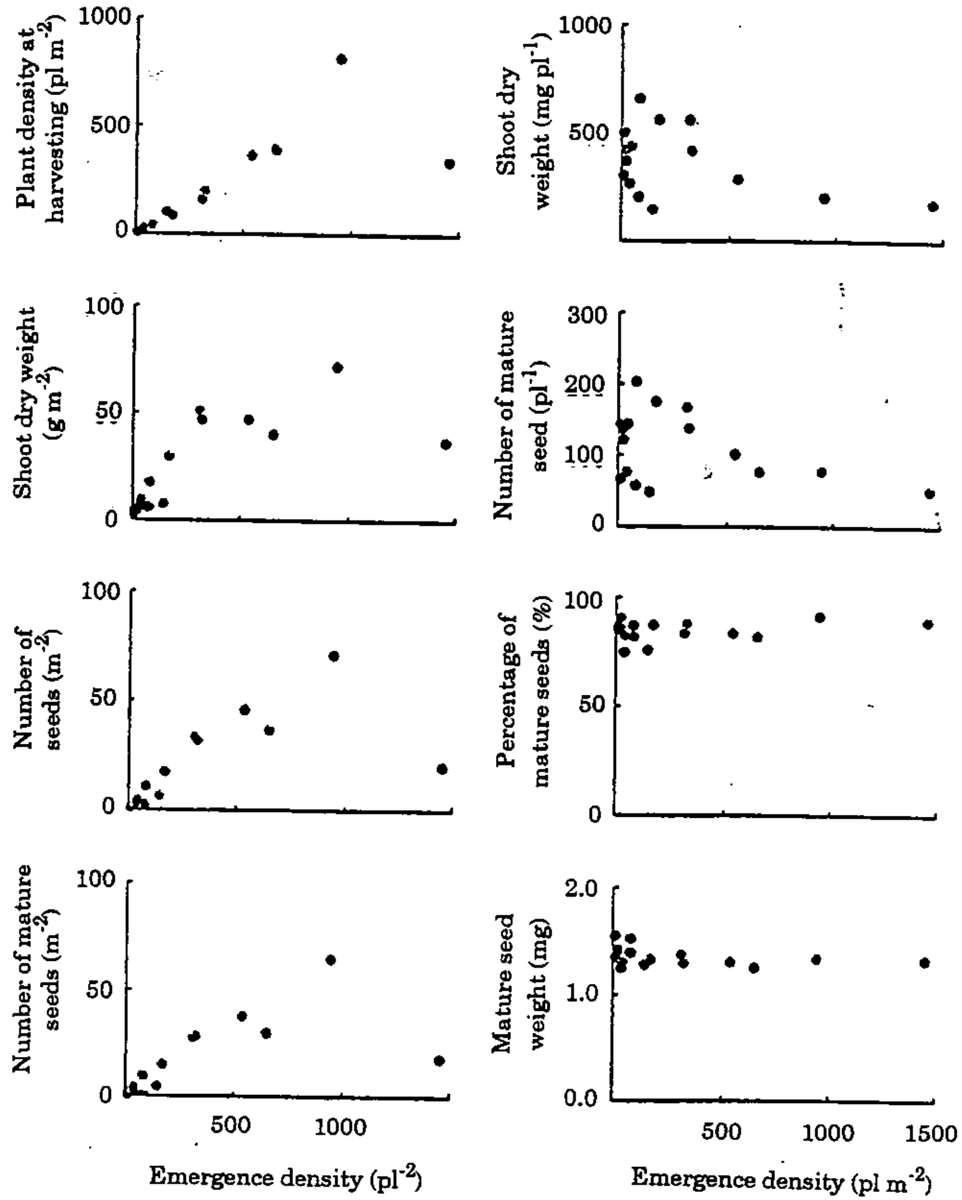

Figure 5. Relationship between emergence density of *Scirpus juncoides* and seed production at rice harvesting time (Watanabe *et al.*, 1991).

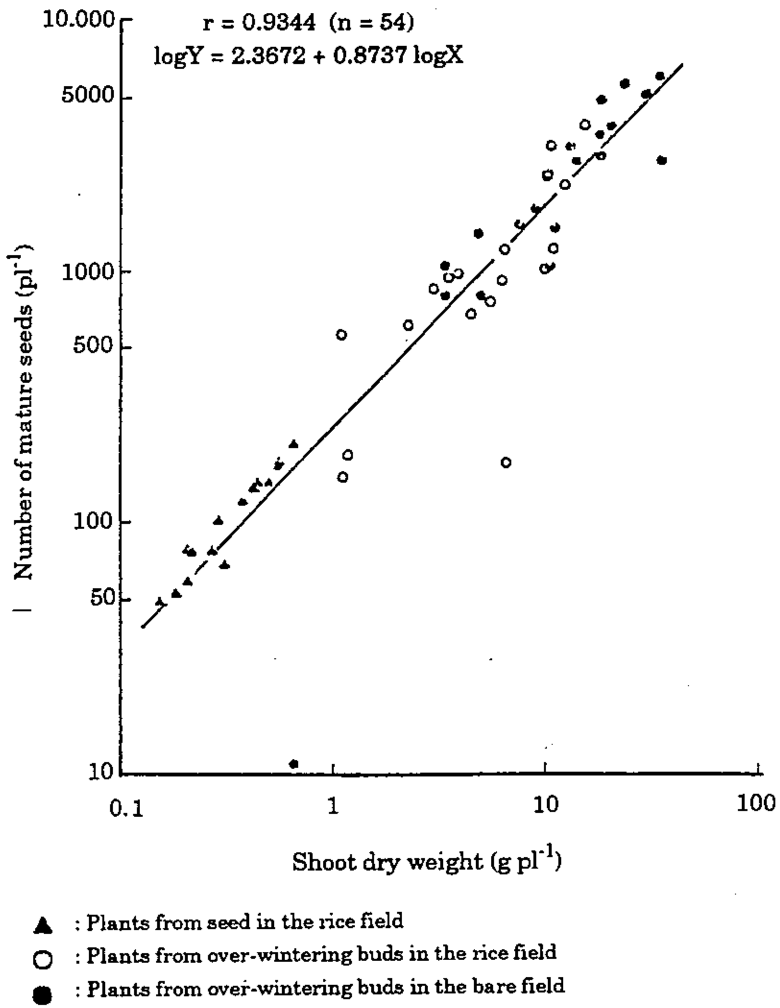

Figure 6. Relationship between shoot dry weight and number of mature seeds per plant (Watanabe *et al.*, 1991).

CONCLUSION

As early emergence and rapid growth of *S. juncoides* Roxb. after rice transplanting was important for its final growth and seed production, effective control at this stage is essential. In this context, control of the weed must be implemented in the first month after rice transplanting in order to inhibit seed production perfectly.

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THE DYNAMICS OF PLANT POPULATIONS WITH SPECIAL REFERENCE TO WEEDS

B.B. BAKI

ABSTRACT

Studies of the population dynamics of weeds seek to explain the numerical changes and the degree of numerical constancy that populations are believed to exhibit. Such studies focus, primarily on the comprehension of the processes of population regulation and the acquisition of actuarial data necessary for the understanding of demographic behaviour. The regulation in number and mass in plant populations, arguably, is the consequence of the heterogeneity of the physical environment in time and space and the mediation of some resource of the environment through competition, predation or parasitism. Examples of the population regulation of weeds at the inter- and intra-species and metamer of modular levels are given and discussed.

> "Plant populations are not dusty museums of plant life where the same faithful individuals are to be found on every visit, but show more the constant activity of a railway station; witnessing a never-ending flow of new arrivals and departures ...."
>
> **J.W. Silvertown (1982)**

INTRODUCTION

The development of a study of the dynamics of plant populations owed itself essentially to two major stimuli. The first stimulus, according to Harper & White (1970) was Malthusian in concept and based on Darwin's emphasis and re-emphasis of the struggle for existence that follows remorselessly from the capacity of organisms to increase their numbers exponentially. The second stimulus stemmed out from the concern and preoccupation of agronomists with optimal plant densities for crops, and the interactions between crops and associated but undesirable plant species, weeds. These two stimuli have developed largely independently; the first one focussed on optimizing plant yields, the other on its concern to understand the evolutionary mechanism and diversity of natural vegetation.

Although plants are sessile and provide ideal material for formal studies of population behaviour, it was the empirical and laboratory studies of animals that predominated population biology for more than a century. Despite this

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apparent monopoly, the first serious attempt to formulate a theoretical mathematical model of the population dynamics of closely related species living together, was made by a botanist Nageli (Nageli, 1974, cited by Harper, 1977). Nageli's models of plant population took account of the life cycles of plants, their seed production, mortality and longevity, and also incorporated concepts of density and even frequency dependence. He appeared to have anticipated the classic treatments of the problem by Volterra (1926) and Lotka (1925) by more than half a century, and in the words of Harper (1974) . . . "Nageli's contribution was so much in advance of its time that it appears to have been wholly ignored." The subsequent works of Tansley (1917), Sukatchew (1928), Clements *et al.* (1929), Gause (1934), Kira *et al.* (1953), Harper and Sagar and their students (1950's onwards) signalled the beginning of a more extensive and concerted interest in the study of plant population biology. The study of population biology is complementary to the study of communities and is an extension of the autecological approach. Population dynamics is only a part of population biology.

In the endeavour to describe and explain the numerical changes of plants, a plant population ecologist is faced primarily with the task of acquiring the actuarial data and comprehending the processes of population regulation necessary for the understanding of demographic behaviour. Nevertheless, such data, as Sagar and Mortimer (1976) lamented, do not identify the causal factors involved in the control.

Arguably, the regulation in number and mass in plant populations, is the consequence of the heterogeneity of the physical environment in time and space and the mediation of some resources of the environment through competition, predation and parasitism. There are, however, four central elements which may influence and regulate the flux of population size in an area, *viz.* the rates of natality and mortality and the numbers of emigrants and immigrants (Baki, 1986). Any attempt to study the population dynamics of a weed (or any other plant species for that matter) must, therefore, involve the quantification, description and explanation of the changes in the above four elements throughout the life cycle of the species.

Some of the most detailed studies on the dynamics of plant populations have been made on weed species (e.g. Sagar, 1959; Sarukhan, 1971; Mortimer, 1976; Law, 1981; Baki, 1986; 1988a; 1988b; Lonsdale *et al.*, 1988; McIntyre *et al.*, 1989; Cain, 1990; Kik *et al.*, 1990). The impressive tradition of field observations in charting the fate of individual plants and observations on the longevity and fluxes of populations, rates of turnover in their vegetative and reproductive composition, etc. in Swedish meadows by Tamm (see e.g. Tamm, 1948, 1956, 1964, 1971a, 1971b) and Rabotnove and co-workers (e.g. Rabotnov, 1950, 1969a, 1969b, 1978a, 1978b) provide us *inter-alia* with detailed actuarial analyses of weed populations and their dynamics.

Many of these studies had their origins in ecological theories, yet the central issue in weed management is none other than the maximization of mortality and the lowering of fecundity. The connection between the pure and the applied is obvious. Identification of the factors that regulate the size of weed populations is indeed of prime importance if weed control programmes are to be critically evaluated against the background of grower economics. Sagar & Morgimer (1976) and Mortimer (1938) believe that this understanding can be achieved by studying the dynamics of weed populations; it is these studies that can then form the basis of strategic planning for weed control (Cussains, 1980).

According to Sagar (1982) the study of the population dynamics of weeds has three parts. They are: a) the determination of the theoretical potential for increase, b) the quantification of real rates of increase (or decrease) in populations and c) the identification of the factors, resources or agents which may be responsible for the discrepancy and actual rates of change in population size. Such studies require a holistic approach. Basically in such studies, two questions need to be posed : (a) when are weed populations regulated?, and (b) how are weed populations regulated? Sagar (1970) proposed and idealized skeletal diagram (Figure 1) incorporating some of the factors which may control the size of plant populations. Detailed discussion of some of such factors will be dealt with in the later part of this paper.

Harper (1970) proposed that the two types of experimental study, the 'synthetic' and 'analytic', be pursued concurrently. In the synthetic approach, the study or reactions at the inter- and intra-species and metameric levels of weed and crop plants may be pursued in controlled environments and controlled densities, and detailed and sophisticated relationships established with a high degree of precision. The analytic approach involves direct manipulation of naturally occurring weed populations by artificial changes in their density, or the selective removal of individual species. Modern herbicides used as ecological tools may facilities this approach.

The remainder of the paper is an attempt to sketch a basic model that describes the behaviour of plant populations at the community, species and metamer levels. Linkages and extension whereever possible are made between the model and the life histories of a few selected plant species with comments on some of the possible mechanisms of population regulation.

THE MODEL

The schematic model begins with dispersed seeds- the seed rain which forms an inoculum (Figure 2). This may be stored in a dormant state forming a living "bank" (*sensu* Harper, 1977) of quiescent plants in or on the soil (I). From this "bank", seedlings may be recruited, depending on the physical

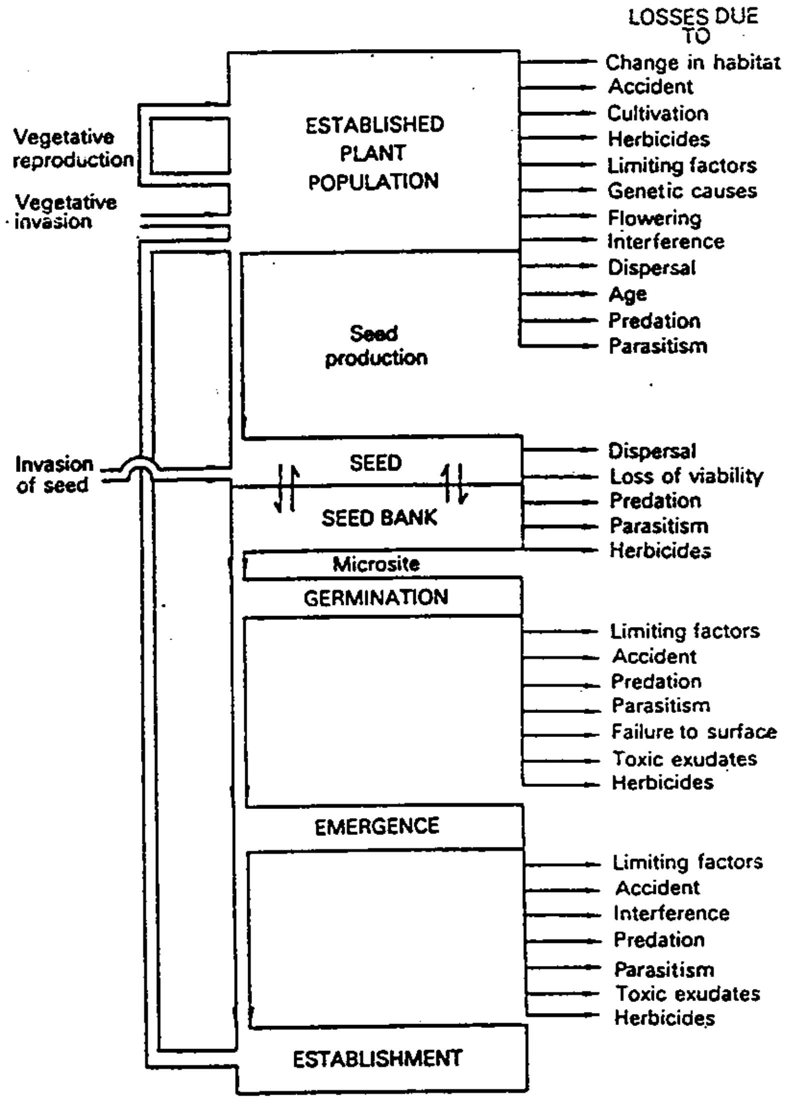


Figure 1. Some of the factors which may control the size of plant population (modified from Sagar, 1970)

conditions that they experience (II). The population of growing seedlings, shifted in numbers and variety in the soil bank, makes demands on resources of the environment which may be inadequate to allow vigorous growth. Death or a depauperate condition may occur. The survivors are depicted in the model as modules, potentially branching exponentially but constrained within the resource limits III. During plant developments from episodic recruitments, there may be a feedback on subsequent processes of recruitment from the bank - the growth of a plant changes its own environment and that of its successors. As depicted in Figure 2, the growth of a plant seems to culminate in phases of seed production. The seeds are dispersed (IV) and enter the cycle again.

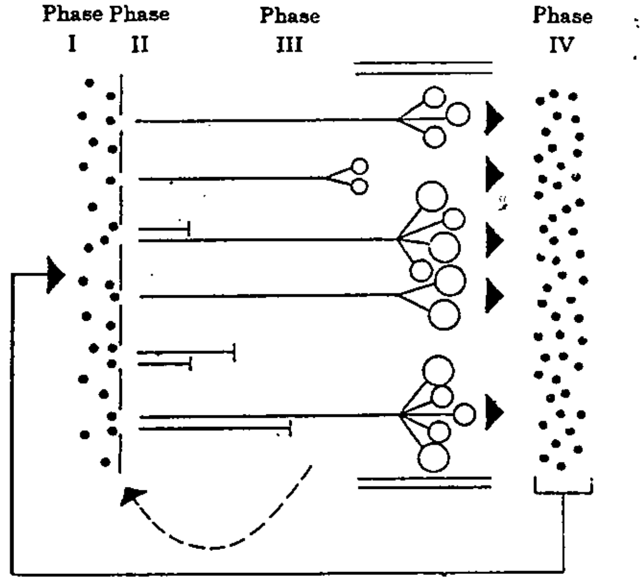


Figure 2. Elements of the population dynamics of a monocarpic (semelparous) plant.

Phase I = the bank of seeds in the soil
Phase II = the recruitment of seedlings (the environmental sieve)
Phase III = the phase of growth in mass and in number of modular units
Phase IV = the terminal phase of seed production
(Adapted from Harper and White, 1970)

The sequential events in the model is not necessarily neat and tidy but adequate enough to summarize the essential features of most plant life cycles, predation, and parasitism, and the physical hazards of the environment can be readily envisaged as acting at any point in the life cycle. Let us examine the various elements and factors that may determine the regulation of number in plant populations in greater details.

Seed Rain and Seed Bank Dynamics

The availability and flux of seed (or other propagules) into and out of a unit of habitat and the conditions affecting seedling establishment are crucial to our understanding of mechanisms controlling the abundances of adult plants (Harper, 1977; Grubb *et al.*, 1982). A full analysis of the population dynamics of seed generation phase requires the quantification of the number of seeds produced and of the vegetation producing them, seed viability, seasonal fluctuations in the sizes of seed banks, seedling emergence and survival.

It may be convenient to consider a bare area onto which a rain of seeds of a single species is falling (Figure 2, Phase I). In nature the seed rain can be very high. Roberts (1970) mentions influxes of up to 62 x 10^3 in^{-2} of viable seeds at the soil surface. The parallel figures recorded by Baki (1986), McIntyre *et al.* (1989) and Peart (1990) were 2.60 x 10^6 in $^{-2}$ for *Oxalis corniculata*, 4.8 x 10^4 in^{-2} for *Diplachne fusa*, and 8.2 x 10^4 in^{-2} for *Holcus lanatus*, respectively. Undoubtedly, many of these seeds may be less due to predation or parasitism. The seed landing may be dormant or non-dormant depending on species. Further, not all of the seeds landing on the hypothetical bare area will land in safe sites suitable for germination. As such, the soil surface may therefore be considered to operate as a sieve, determining what fraction of the coming seed rain germinates to produce young plants (Figure 2, Phase II). Invariably, the intensity of seed rain should be considered as a factor describing the change that a seed will produce a plant.

The concept of soil surface acting as a sieve has been worked out in some detail by a number of workers (e.g. Sagar, 1959; Harper *et al.*, 1965; Hutchings & Russell, 1989; Peart, 1989a) in which it has been shown that quite a slight variation in soil surface determines a minute scale of heterogeneity of safe and unsafe sites, which selects seeds from the seed rain on the area those that will germinate and those that will not. Harper *et al.* (1970) reviewed the species subtlety in the requirement of safe sites and the variations in seed size and shape and their relevance to germination on heterogeneous media. Bakker (1960) recorded maximum germination of *Cirsium arvense* and *Tussilago farfara* at 30°C and at alternating (10-28°C) temperatures. Likewise Ismail & Md.Sofawat (1988) for *Echinochloa crus-galli* at alternating temperatures of 20-30°C. The safety of a microsite for a particular seed may be sufficient water in the substrate and be protected against loss of water (Harper & Benton, 1966). With species exhibiting genetic and somatic seed polymorphism, two or more safe sites may be deploited by the seed population. It may be pertinent as a general principle to agree with Koller's (1969, in Harper & White, 1974) observation that evolution has led to an almost universal imposition of regulatory mechanisms on seed germination which will prevent the entire reproductive capacity of the species being used up in any given habitat at a given time, except where and when the probability of survival is maximal.

Phase II, the sieve, selects the seeds which ones germinate at a given time and place. The remaining portion of the seed rain may be thrown (often by burial as seed banks) into a state of indured or enforced dormany from which it may later emerge to contribute to a later generation of seedlings, or in which a state it may persist.

The study of the seed bank dynamics (in the various states of dormancy) is interesting in itself. According to Robberts and Dawkin (1967), the buried seed population has apparently a constant death risk, so that it may be assigned a constant half-life. This half-life is highly species-specific and also depends on the frequency of cultivation.

Cohen (1966) attempted to model the parameters affecting the size of the seed bank in such a way that optimal strategies might be calculated for different theoretical environments. In Cohen's model the following parameters were introduced :

S = Number of seeds present, i.e. the size of the seed bank

Y = The number of seeds per germinated seedling, a random variable depending on environmental conditions that in this model are assumed to be independent population density (in practice they often be density-dependent). In a sence the parameter Y represents the return to the seed bank of the investment that is represented by the fraction of the bank that germinates.

G = The fraction of the total seeds present in the bank that germinate each year (the fraction of the capital of the seed bank that is invested in germination).

D = The fraction of the seed bank that decays each year. This represents a depreciation of uninvested capital.

P_i = The probability associated with Y_i

The relationship between the size of the seed bank in year t and its size in year (t + 1) can then be written as :

$$S_{t+1} = S_t - S_t.G - D.(S_t - S_tG) + G.\ Y_tS_t$$

Intuitively it would appear that decreasing D, the fraction that decays each year, and increasing Y, the number of seeds per germinating seedling, increases the growth rate expectation of the seed bank. Cohen then poses the specific question, how do variations in G influence the expection of growth of the seed bank at any combination of D, Y and P_i. Figure 3 shows the long-term expectation of the growth rate of the seed bank plotted against the fraction of the seed germinating each year, i.e. G, for a variety of abstracted environmental conditions. These environmental conditions are :

a) two different values of P_i, a probability of successful reproduction of 0.1 or 0.8;
b) two values of Y_i, the number of seeds produced per germinating seedling, 5 or 500;
c) two values of D, the fraction decaying each year, 0.1 or 0.8.

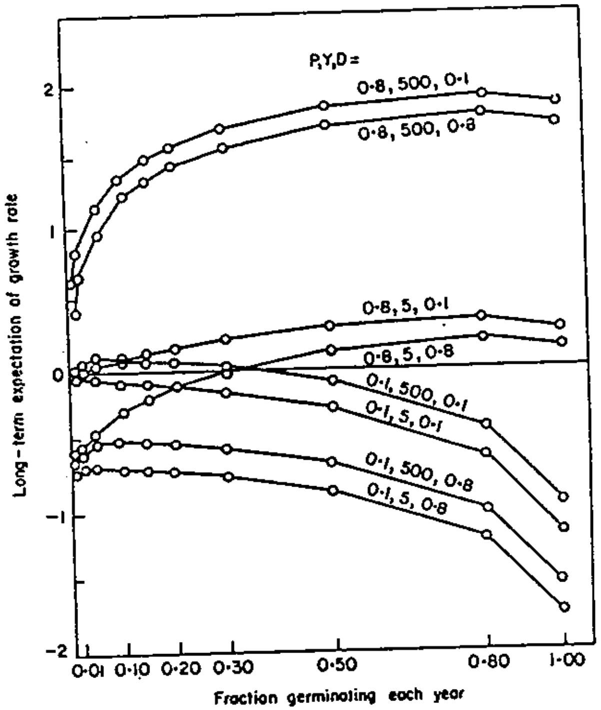


Figure 3. Theoretical relationships between the long-term expectation of growth of the seed bank, and the fraction of the seed bank germinating each year. Calculated for : various probabilities of a seen producing a seed-bearing plant (P); a low or high seed output (Y); and different seed decay rates (D). (From Cohen, 1966).

A number of interesting conclusions emerge. If there is a high probability of successful reproduction (P = 0.8, Y = 500) the optimal strategy is for a high fraction of the seeds to germinate each year and the proportion decaying is almost irrelevant. However, if there is a high probability of low reproduction (P = 0.8, Y = 5) the rate of decay is irrelevant if most of the seeds germinate each year, but becomes very important if there is dormancy. In contrast, if there is a low probability of reproduction, whether it be at a high or a low rate, a high germination percentage is disastrous and so is a high decay rate.

Figure 3 was Cohen's consideration on the theoretical relationship between the long-term expectation of growth of the seed bank and the proportion of the seed bank germinating each year.

When fresh seed rain was prevented, weed seed banks were reduced by as much as 90% in 4-6 years (Roberts, 1968; Schweizer & Zimdahl, 1984a, 1984b; Burnside *et al.*, 1986). Studies by Roberts (1970), Egley & Williams (1990) and Ball & Miller (1990) recorded an exponential decline in viable weed seeds and emergence following soil disturbances.

There is limited quantitative information on the relationship between buried viable seed banks and seedlings produced following soil disturbance by cultivation, but seedlings appear to represent only a small proportion of the viable seeds present (Chancellor, 1965; Roberts & Richetts, 1979; Baki, 1986; McIntyre *et al.*, 1989). Baki (1988) working on synthetic populations of *Echinochloa crus-galli* recorded a 56-75% probability of successful transfer from total seed bank to seedling emergence. The parallel figures recorded for *Avena sterilis* spp. *ludoviciana* were 31-46% (Fernandez-Quintanilla *et al.*, 1986).

Life Table and Fecundity Schedule

Harper (1977) proposed two schedules to define the behaviours of a population, the age structure (the life table) of the population and the fecundity. The former describes the number of organism present in different age classes and the second describes the contribution made by individuals in the different age classes to future population growth. By combining the schedules, it is posibble to calculate the present value of future off springs, as follows :

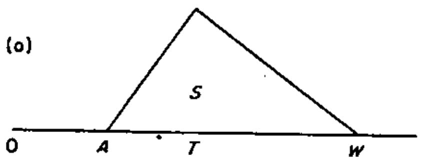
$$Vx/Vo = \frac{e^{mx}}{lx} \int_{x}^{\infty} E^{-mt}\, l_t b_t dt, \text{ where}$$

lx - the number of individuals living to age x
bx - the rate of reproduction at age x
m - the Malthusian parameter of population
Vx - the reproduction value at age x

An idealized fecundity schedule is shown in Figure 4a, and a series of variations in the form of life cycles is illustrated in Figures 4b-e.

Self-thinning

The inverse relationship between the size and the density of plants in closed systems has long been recognized and was probably most evident to foresters concerned with the management of trees to maximize timber produc-



Generalized fecundity schedule: O = birth, A = age at the beginning of fecundity period, T = peak period of fecundity, W = age at end of period of fecundity, S = total number of offspring.

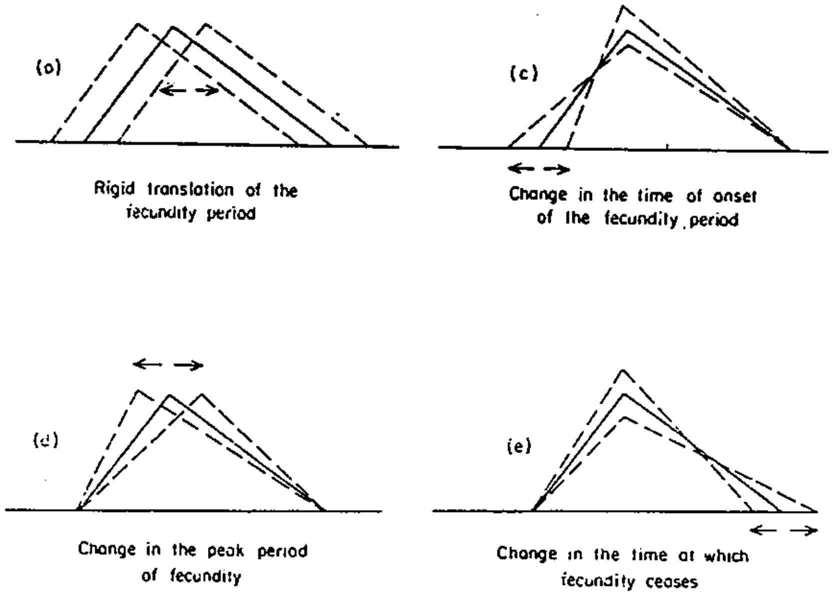


Figure 4. Theoretical variations in a model fecundity schedule. (From Lewontin, 1965).

tion. The size-density relationshop is one of the most fundamental aspects of the population dynamics of organisms with plastic morphological expression and is particularly relevant to plants with metameric construction (White, 1984). The first formal statement of the reciprocal relationship between size and numbers in dense single-species populations is apparently that of Reineke (1933). The concept was further treated and approised by T. Kira's School at the Osaka City University in a notable series of papers on intraspecific competition among higher plants, where they proposed the rationship W & N,

where W is meant plant weight and typically has values about 1.5 (Yoda *et al.*, 1963) (Figure 5). They suggested that this was a very general relationship. They even proposed a law, which they termed the "-3/2 power law" applicable to weed plant populations (Figures 6a, 6b). Later it was realized that the equation could be made more precise by reducing the parameter values to standard, uniform dimensions (White, 1975), $W = K.N.^{-1.5}$, where K typically has values between 3.2×10^3 and 2.5×10^4 when W was expressed in grammes dry weight and N in plants per m^2. The mechanism of the self-thinning phenomenon is only dimly understood by Harper (1977). The plants that are most likely to die in natural thinning (as in forest) are the smallest and "weakest". The clearest direct evicence that this is the case comes from an

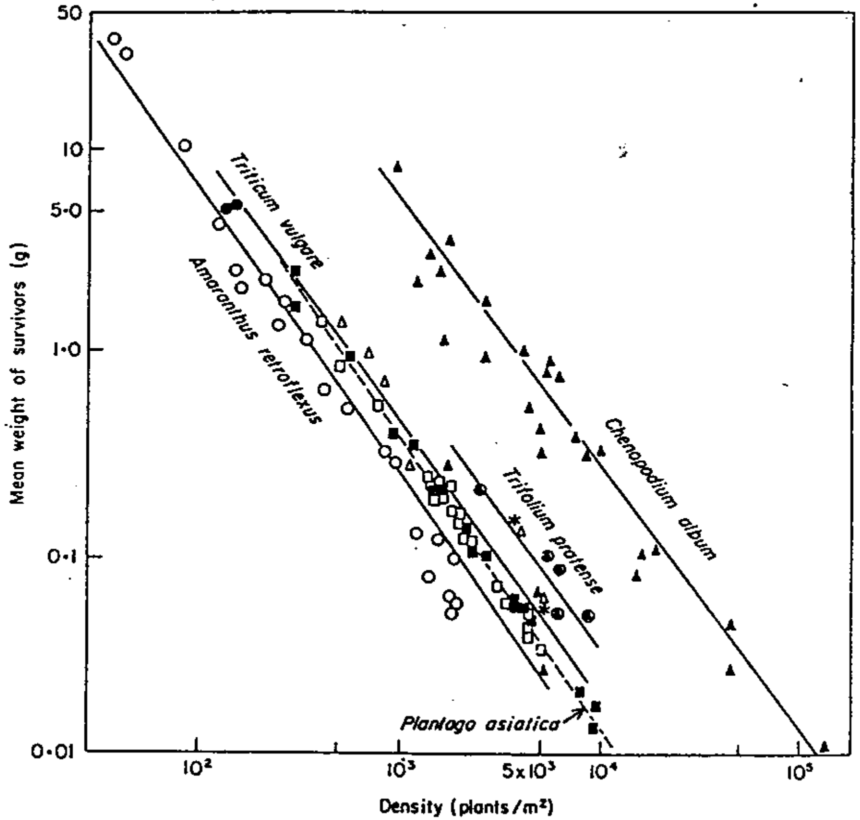


Figure 5. Changes in plant density and in mean plant weight with the passage of time. Data for *Chenopodium*, *Amaranthus*, and *Plantago* from Yoda *et al.* (1963); data for *Trifolium* and *Triticum* from Harper and White (1970) after data of Black and of Purckeridge.

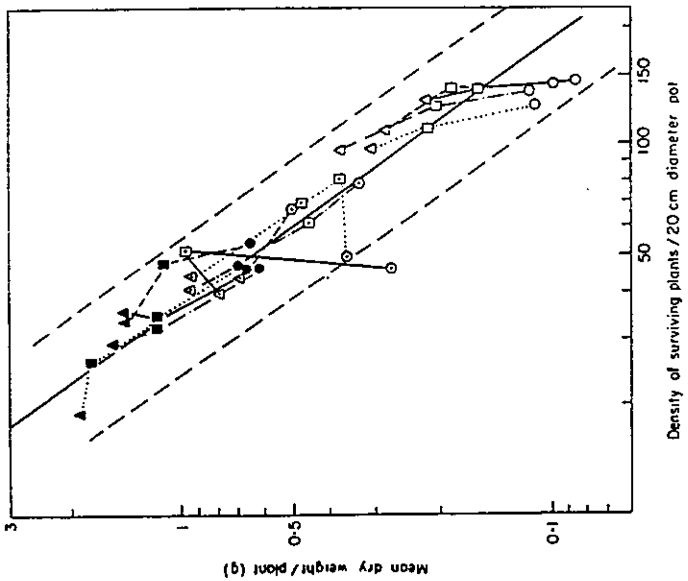


Figure 6b. Change in number and mean plant weight with time of *Brassica napus* ____ and *Raphanus sativus* . . . . in pure stands and in mixtures - - - and - . - . - . The confidence limits are given for $P = 0.05$.
○ = low fertility, □ = medium fertility, △ = high fertility.
○, □, △ = first harvest, ○, □, △ = second harvest,
●, ■, ▲ = third harvest. (From White and Harper, 1970)

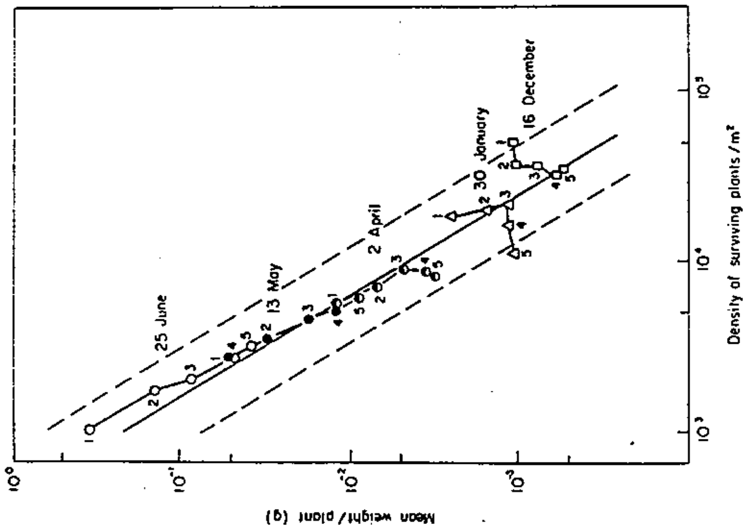


Figure 6a. Change in number and individual plant weight of *Erigeron canadensis* with time. The numbers 1, 2, 3, 4 and 5 represent a gradient of decreasing fertility. (From Yoda *et al.*, 1963, redrawn with calculated regression and 0.95 confidence limits - the first harvest, Nov. 7, is omitted).

experiment made on populations of *Trifolium subterraneum* by Black (1958). This species produces a rather wide range of seed sizes even from a single plant. Samples of large and small seeds were sown in pure stands and in equiproportioned mixtures all at high density. Self-thinning occurred in the seedling population after about 40 days' growth. The population from large seeds suffered more rapid mortality than those derived from small seeds (Figure 5). The size of the seedlings is closely related to the size of the seeds and the real growth rate is a function of the seedling size, particularly the cotyledon area. Apparently the faster-growing, larger, and more vigorous seedlings produced a density stress amongst themselves which resulted in a greater mortality than in the populations of the same density but of the smaller and slower growing seedlings. When small and large seeds were sown together, the mortality was concentrated almost exclusively amongst the plants derived from the small seeds: the stress of density was absorbed by the death of the smaller numbers. Not only did the plants from large seeds come to dominate the canopy of the mixed stands but at the end of the experiment (after 120 days) the plants from the small seeds were intercepting only *ca* 3% of the total light intercepted by the canopy of the mixture. It is not possible to make a rigid argument that the plants that died did so because they were "starved" of light, but this seems the most probable direct or indirect cause.

If the self-thinning process involves the progressive elimination of the weakest individuals it immediately becomes pertinent to ask questions about the nature of the hierarchy of size or vigour that develops in a growing population. It has already been pointed out that plant populations growing under density stress develop a long-normal distribution of weights and that this may arise because of differences in "space occupancy" at very early stages in establishment. Self-thinning removes the smaller individuals from the population and tends to stabilize the degree of skewness. Harper & White (1970) lamented that there is a need therefore, to build into the model description of plant populations such a process of reduction of numbers associated with the increase in individual size of these plants which passed through the environmental sieve (Figure 9, Phase III).

A relevant consideration in the study of population regulation among plants and animals alike is the growing body of literature dealing with oscillatory dynamics (e.g. May, 1974; May & Oster, 1976; Lomnicki & Ombach, 1984; Lomnicki, 1988). Oscillatory dynamics can result from density-dependent regulation even in a constant driven changes in birth and death. In fact, simple models of density-dependent regulation in constant environments may exhibit extremely complicated dynamics, such as higher order limit cycles and chaos (May, 1974).

It is particularly appropriate to highlight the theoretical (Pacala & Silander, 1985) and illustrated considerations (Thrall *et al.*, 1989) on oscillatory dynamics and the later's relevance to the study of population regulation in plants, among them an annual weed, *Abutilon theophrasti* Mill. Figure 7 shows the possible dynamic states that monocultures of *Abutilos* could exhibit depending on the germination rate. When germination success is low, non oscillatory dynamics are predicted by the neighbourhood model (Figure 7). For intermediate levels of germination success, stable limit cycles are predicted (Figure 7b, c). Finally, at high rates of germination, the dynamics are predicted to be chaotic (Figure 7d). Accordingly, monocultures of *A. theophrasti* in a controlled environment exhibited negative slopes in the seed-set-density relations over a wide range of plant densities, which can show oscillatory and chaotic dynamics. Field populations, however, are in a state of damped rather than persistent oscillations solely due to the effect of delayer germination of seeds. According to Thrall *et al.* (1989), oscillatory reponses are likely to be found in populations of annuals that lack seed dormancy, have high seed survival, grow in locations with high soil fertility, and have a minimum plant-size thresholds for seed production.

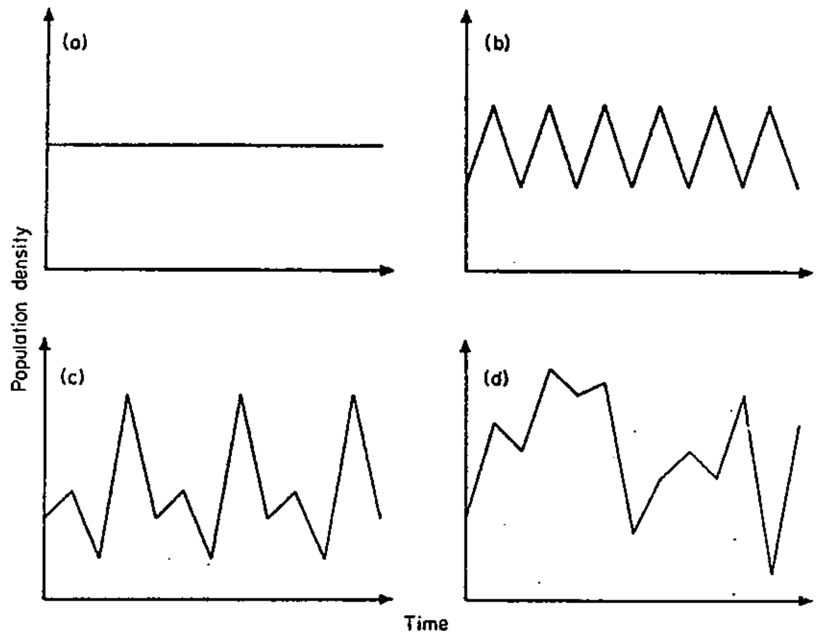


Figure 7. Population-dynamic trajectories predicted to occur with different rates of germination success (Pacala & Silander, 1985): (a) non-oscillatory dynamics as a result of low germination success: (b) and (c) stable limit cycles with intermediate rates of germination; (d) chaotic oscillations when germination success in high.

Other Features of the Model

Invariably the model (Figure 2) envisages a population emerging from the environmental sieve and developing by increasing biomass and decreasing plant numbers within an environmental constraint that places limits on the total mass that the population may achieve. This subsequently places limits on the rate at which new seeds are produced from the plant population which will initiate the next cycle of generations. In this respect, the actions of the 'environmental constraint' on the biomass are not necessarily correlated; optium seed production may occur before the upper limit of plant numbers or biomass per unit area has been achieved (Harper & White, 1970). If two species are brought together into this model, the relative intensity of the seed rains and the extent to which the environmental sieves operate differentially upon them may determine the densities at which they start to interact among themselves and with each other and subsequently (Phase III) the process of thinning and individual development, both at genet and metamer levels. The elegant models developed by Peart (Peart, 1989a, 1989b; Thorhallsdottir, 1990a, 1990b) on species interactions in a successional grassland focussed on the competitive interrelationships of two or more species and in a way is suitable for introduction into the model. Studies by, e.g. Harper & McNaughton (1962) and Thorahallsdottir (1990b) indicated that in mixed populations some species may depend rather specifically on their densities in determining their growth and mortality rates. The model, accordingly, has to allow for the existence of both density and frequency dependent relationships. The latter relationship depends on the frequency of the interacting species within Phase III). A central element to be brought into the model is the change that is brought about by the overlapping generations of populations and the nature and role of such populations on the selectivity of the sieve, which may affect the performance of subsequent generations of seed rain. Work by Thrall *et al.* (1989) *inter-alia* provided ample evidence that the change of seeds germinating in an area is very much influenced by the presence of a growing vegetation, agroclimatic conditions, and autotoxic regulation as in the case if *Typha latifolia* (McNaughton, 1978).

The Model in Relation to Perennial Plants

A graphical representation of the behaviour of a system involving perennial plants is given in Figure 8, an extension of the model shown in Figure 2. The varying patterns of frequency of seed production by individuals are depicted, coupled with some indications of mortality and recruitment. The influence of growing plants on the sieve (Phase II) is shown; many seeds may germinate but not become established through failure to negotiate the complex network of selective barriers that consitute the sieve. The population of seed in this model (Phase I) may exist largely in a dormant condition and be released from the seed bank after relaxation of the factors enforcing dormancy. A proportion of this seed reservoir will suffer death and decay before an opportunity arises for the individuals to germinate and the mortality patterns displayed may be quite regular in some cases (Roberts, 1970).

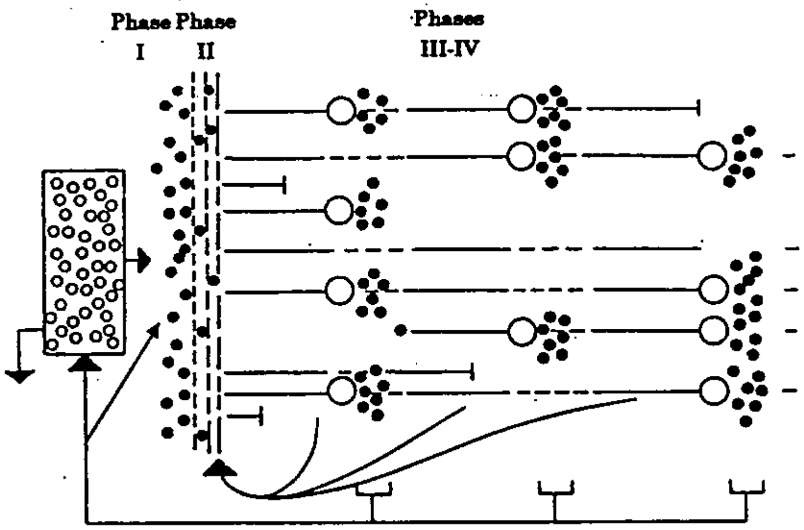


Figure 8. Elements of the population dynamics of 1 cohort (one generation) of a (iteroparous) plant. Symbols as in Fig. 2. (From Harper and White, 1970).

Two strikingly different features of life-history strategies among perennials are recognizable: the repeating producer and the "big bang" (Gadgil & Bossert, 1970) producers. In plants, either kinds may prevail depending on environmental circumstances. Rabotnov (1960) observed the populations of *Trifolium pratense* from 1940 to 1959. The number of clover plants fluctuated greatly where they flowered once within two years of seedling establishment and died in years of favourable climatic conditions. Clonal individuals were transformed into luxuriant reproductive ones, followed as a rule by mass death.

Data which might contribute towards the formulation of general principles concerning Phases III and IV of the model (Figure 8), that is the numerical variation in numbers from annual rates of decay and the frequency and productivity of seed yield, are very rare. In fact, there is a paucity of such information on perennial weeds. The work of Tamm (1956) on species of

Sanicula europes and *Anemone hepatica* over a period of 14 years showed very stable populations of mature plants with large seedling recruitments but only small fractions persisted; reproduction by seedlings was not very important for population maintenance. Phase IV of the model (Figure 8) is concerned with seed production. Plants species differ in the fraction of their assimilates which is devoted to reproductive efforts. In general, perennials, mostly plants of stable habitats devote a greater proportion of the available energy to the persistent clonal organs, conferring advantages in crowded resource-limited environment. In terms of actual numbers of seed production by perennials, only very meager data are available. Here again we have to turn to the work or Rabotnov and his colleagues. Of 102 species studied, in subalpine meadow, 8% produced <100 seeds m^{-2}, 38% produced 100-1000 seeds m^{-2} and 16% produced >10.000 seeds m^{-2} (Rabotnov, 1969b).

The Role of Animals and Pathogens

The role of predation and disease in plant population dynamics it still very much unexplored except in relation to biocontrol. Work done by Burdon *et al.* (1981), Burdon (1985), Dirzo (1985), Julien *et al.* (1987), Julien & Bourne (1988), Moran & Hoffmann (1989), and Baki *et al.* (1991) *inter-alia* showed debilitating effect of the pathogens or bioagents on the target weed species both at the genet or metamer level. It may, however, be useful in future studies of plant-animal or plant-pathogen relationships to consider the action of herbivores or pathogens in relation to the Harperian models expounded in this paper. The herbivore or pathogen, clearly, can influence plant population size and composition and on the sieve, which determine which seeds are exposed to further predation of infection after landing. Invariably, the co-occurring processes of individual genet's or metamer's growth and mortality are affected by the timing of activity of the grazing or predating animals or the infection of pathogens on the host plants.

MODULAR DYNAMICS

The concept of plants as assemblages of some basic modular units of construction (Hallé *et al.*, 1978; White, 1979, 1980, 1984; Waller & Stingraeber, 1985) or modules (*sensu* Harper, 1981) is not new and it has its roots in several, sometimes independent schools of thought (Cusset, 1982). The resultant interactive duplications of such units (which are usually considered to comprise the leaf-node-internode-axillary meristem groupings on a shoot or metamer (*sensu* White, 1984) by meristems can be termed as plant growth. These modules are assembled according to specific architectural patterns of meristem behaviour (Hallé *et al.*, 1978), phyllotaxy, branching angles, leaf display and bifurcation ratios (see review by Fisher 1984) which together contribute to the particular shape of a plant. In most plants, the number of elements is not static, because of growth and senescence processes, plant to plant interaction because of plasticity, species-specific diversity and genetic variability.

The Growth of Populations Modules

It was Harper (1968) who first proposed the study of individual plants as populations of repeating units and viewed changes in such units as demographic events of birth and death. A full appreciation of the demographic processes taking place in a population of plants requires a "hierarchial" approach (Harper & Bell, 1979; Hickman, 1979). The population must be considered at least at two distinct levels: that of the individual genotype, or **genet**, and that of the **module** (s) composing each genet. It is convenient to distinguish these two levels by symbols N and n, respectively. Such populational events can be written in two equations :

$$nt + 1 = nt + \text{module births} - \text{module deaths}$$

which describes the growth of genets, and

$$N_{t+1} = N_1 + \text{Births} - \text{Deaths} + \text{Immigrants} - \text{Emigrants}$$

which describles the changes in numbers of genets. The importance of hierarchial approach in demographic processes is illustrated *inter-alia* by the studies of Kays and Harper (1974), Abul- Fatih & Bazzaz (1980), Harnett & Bazzaz (1985a, 1985b, 1985c), Maillette (1985, 1986), Dickerman & Wetzel (1985), Baki (1986, 1988), Garnier & Roy (1988), Eriksson (1988), and Briske & Butler (1989). In Kays & Harper's studies *Lolium perence* is grown from seed, and birth and death rates of whole plants (genets) and tillers (modules) were monitored. They found that the density of moduler over time reached a point at which it became independent of genet densities. This was attributed through total death of some genets and all their modules, while the surviving genets had varying numbers of modules. Hardly this sward produces seeds, the seed progeny would have carried a biased representation of genes from the parental population as a consequence of (a) by the elimination of some genets and (b) by the differential production of modules (and hence, flowers and seed) by the surviving genets.

The fitness of a genet is highly dependent on the demography of its modules, an understanding of the modular dynamics of an individual (genet or ramet) and the way they are affected by changes in the environment, such **as the presence of neighbours, is the starting point for the presence of neighbours, is the starting point for the understading of the demography of genetically separate individuals (White, 1980).**

Modular Demography: Some Examples

Modular organisms have an internal age structure-part are born at different times and death may occur throughout the life of a genet. The age structure of a plant at a level can often be followed so that the effects of neighbours or the physiological environment can be measured in demographic terms.

In this respect, the underlying difficulties in constructing any sort of static life table for plants that are not only iteroparous with overlapping generations but also modular are emphasized in Figure 9. *Carex bigelowii* has an extensive underground rhizome system which produces tillers (aerial shoots) at intervals along its length as it grows. It initiates modular growth by producing a lateral meristem in the axil of a leaf belonging to a 'parent' tiller. The meristem is at first completely dependent on the parent tiller, and consists of one or a few non- photosynthetic leaves; but each lateral is potentially capable of developing into a vegetative parent tiller itself, and is also potentially capable of flowering, which it does when it has produced a total of 16 or more leaves. Flowering, however, is always followed by tiller death, i.e. the tillers are semelparous though the genets are iteroparous.

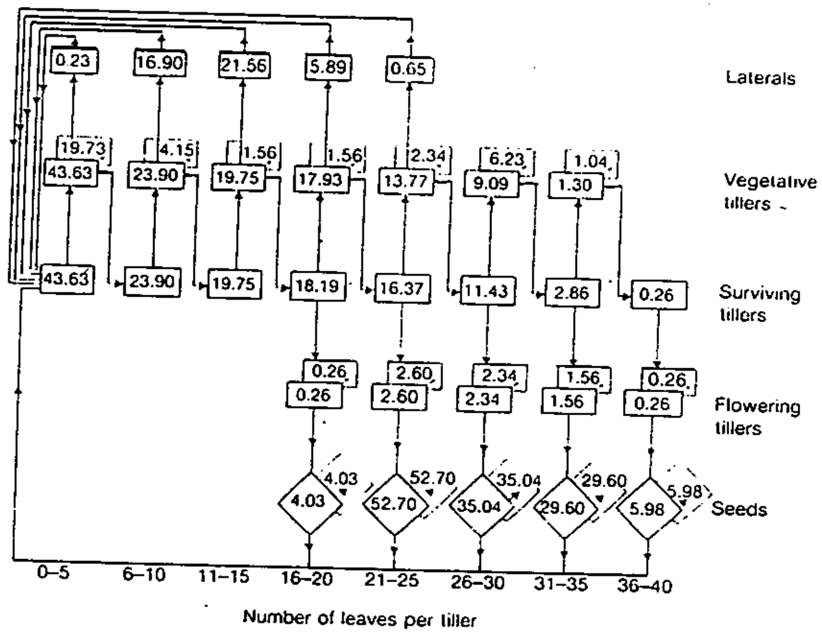


Figure 9. A reconstructed static life-table for the modules (tillers) of a Carex bigelowii populations. Rows represent tiller types while columns depict size-classer of tiller. Thin-walled boxes represent dead tiller compartments, and arrows denote pathways between size-classes, death or reproduction. Within each box, the density per m^2 is present. (After Callaghan, 1976).

Callaghan (1976) took a number of weel-separated young tillers, and excavated their rhizome systems through progressively older generations of parent tillers. This was made possible by the persistence of tillers after death. He excavated 23 such systems containing a total of 360 tillers, and was able, as Figure 9 shows, to construct a type of static life-table (and fecundity schedule) based on stages rather than ageclasses. There were, for example, 1.04 dead vegetative tillers (per square metre) with 31-35 leaves. Thus, since there were also 0.26 tillers in the next (36-40) stage, it can be assumed that a total of 1.30 (i.e. 1.04 + 0.26) living vegetative tillers entered the 31- 35 leaf in the 31-35 leaf stage, 2.86 tillers must have survival from the 26-30 stage. It is in this way that the life-table was constructed.

Note, however, (a) that the life-table applied not to individual genets but to tillers (i.e. modules); (b) that there appeared to be no successful seed germination in this particular population (not new genets), so that tiller numbers were being maintained by modular growth alone; and (c) that a 'modular growth schedule', analogous to a fecundity schedule, can sensibly be constructed for this population. Note most of all though, how difficult it is to collect data and construct a life-table which fully conveys the modularity of modular organisms.

Individual higher plants, notably clonal ones, have multiple levels of population structure and demographic behaviour. Responses to neighbours may occur at different levels of whole clones population, population of ramets which comprise the genets, populations of the modular units-leaves, branchers, tillers, etc. - that comprise each ramet, or a combination of these. The birth and death schedules of genets affect genet population size and genetic combination and are evolutionary relevant, whereas the birth and death of ramets affect the size and fitness of genets. In their detailed studies on the dynamics and regulation of genets and ramets and leaf populations of the rhizomatous perennial *Solidago canadensis*, Harnett and Bazzaz (1985a, 1985b, 1985c) bring to the fore several interesting observations. Both genet survivorship and clonal growth were inversely related to the time of recruitment, so that after a few years the populations were composed mainly of genets that established during the first year of colonization. These established genets exhibited rapid clonal expansion with increased densities interdependence and integrated ramets showing little differential mortality among genotypes. Clonal growth was density dependent; both the length of new rhizomes and the number produced per ramet were reduced with increasing density. So were leaf-population growth rates, ramet biomass, number of flower head, and reproductive allocation and a delay in flowering; although there were negligible mortality in response to density during the first growing season. In the clonal herb *Potentilla auserina*, ramet behaviour and mortality were significantly size related (Eriksson, 1988), suggesting that flowers and stolons are initiated when the physiological condition of ramets has reached certain internal resource threshold. Further, stolon production have negative consequences both for the survivorship and for future reproduction of ramets although reproduction *per sé* apparently did not incur any cost for ramets.

The above examples are in tandem with the suggestion by Harper (1977) that studies in plant demography and regulation in plant populations either at the inter- and intra-specific (genet) or modular levels require a holistic approach so as to understand the degree of integration prevailing. Further, a complete interpretation of population dynamics is difficult without concern for demographic processes at both levels. A consideration of the dynamics of only ramets, ignoring the identity of genets, provides no information relevant to the genetic structure variation, or evolution of the population. In contrast, the demography of genets alone may be relevant to explanations of population behaviour in evolutionary terms but tell us little about the ecological activity, growth and deminance, etc. of the population.

A WORKING SCHEME

For an examination of the population dynamics of any higher plant species devoid of clonal multiplication, the life-cycle may be stylized as in Figure 10 (Sagar, 1970). This presentation shows two routes by which the population of ecologic individuals of size A1 in generation Gt may occur in the succeeding generation Gt+1. The population A2 in generation Gt+1 comes from genet productions and sometimes from survivors from previous generation. Route I is genet production from seed and may be divided into five intermediates (B-F). Eight interphases are recognized (a) to (i). The invasion interphase (g) is further sub-divided to distinguish (g1), to the surface bank (g2) and to the buried seed bank (g3). Route II indicates a probability of an interphase for the fraction of the population A1 which survives a generation Gt+1. This route is found in all species except ephemerals and annuals.

For an idealized biennial species the interphace (i) may carry a value of 0.5, for half the plants in the population. A1 would flower and die and half remain vegetative and survive into population A2.

Figure 10 needs a slight modification for biennial species because of the overlap in generations and is inappropriate for species which have mixed populations of genets and ramets (Harper & White, 1974; Kays & Harper, 1974), in part due to differential survival may be expected for each component and in part because of difficulties in independently assimilating plant units.

It is reproduction by ramets which makes the numerical handling of plant populations difficult, ecologic individuals no longer being equivalant to genetic ones. Invariably, the identity of the individuals becomes especially difficult when considering those species which produce shoots from subterranean

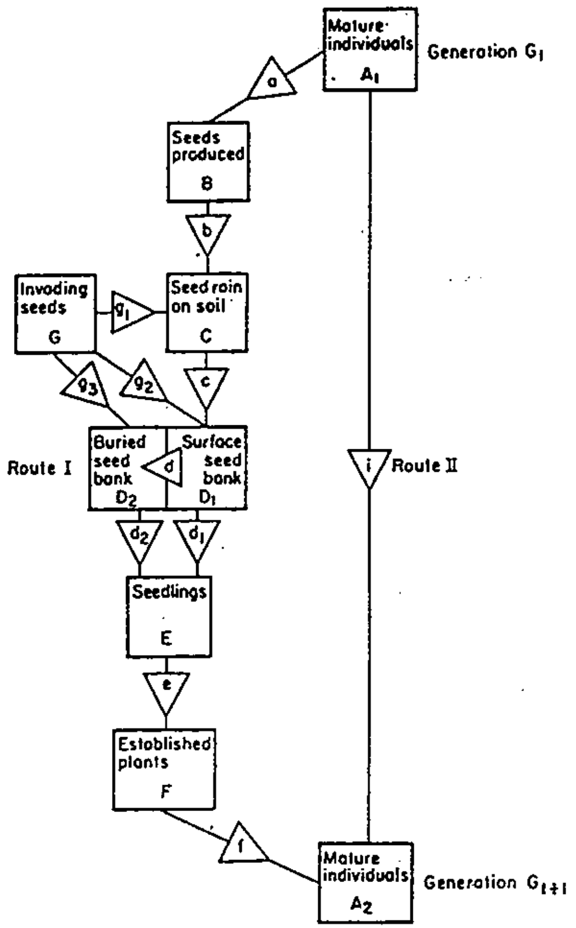


Figure 10. A generalized life-table for a higher plant species which does not have ramet production. (After Sagar, 1970).

organs. As the obvious question is "when is a shoot an ecological individual?". Sagar & Mortimer (1976) suggested further subdivision of the terms genet and ramet to serve better numerical handling of the populations. A genet might be unbranched (a unigenet-Type 1) or branched (each branch would be a sub-genet-Type 2). The incipient ramet (Type 3) is introduced to cover situations where branches produce their own-root systems but where modular continuity between branches remains functional, and Type 4, the ramet, a term to include individuals produced by vegetative means and permanently independent on

the individual from which they are produced. In practice, the presentation of the dynamics of species which are multiplied by vegetative means (i.e. ultimately producing ramets) demands a different display from the ones depicted in Figure 10. We shall discuss them with examples in the later part of this paper. The flow diagram forms the basis for the construction of a population matrix (for a general treatment of matrix applications to population biology (see Leslie, 1945, 1948; and Usher, 1973). An imaginary population might have the following categories of members: 0 = seed, 1 = ramet, 2 = non- flowering adult, 3 = flowering adult and 4 = flowering and ramet- producing adult. Various transitions between the categories may take place in a time step : (i) a seed may remain a seed ($a_{00} = P_0$; (ii) a seed may germinate to become a non-flowering adult ($a_{20} = G$); (iii) a non-flowering adult may develop in to a flowering adult ($a_{32} = P_2$); (iv) a ramet may become a flowering adult ($a_{31} = P_1$); (v) a flowering adult may become a flowering and ramet-producing adult ($a_{43} = P_3$); (vi) a flowering adult may produce seeds ($a_{03} = F_3$); (vii) a flowering and ramet-producing adult may remain in that category ($a_{44} = P_4$) or (viii) it may produce seeds ($a_{04} = P_4$) or (ix) it may produce ramets ($a_{14} = V$). The projection matrix for such a system may be represented in this way :

$$\begin{matrix} P_0 & O & O & F_3 & F_4 \\ O & O & O & O & V \\ G & O & O & O & O \\ O & P_1 & P_2 & O & O \\ O & O & O & P_3 & P_4 \end{matrix}$$

The transition matrix defines the transition from one time step to the next and if the year is divided into seasons, the projection matrix can be specified for each season of the year. The matrices may then be used to determine the rate of growth or decline of the populations, given the values found in the field censuses. It is known that, for a fixed schedule of mortality and fertility rates, a population generally achieves a stable age distribution irrespective of its original state. The assumption is made that the population have constant growth rate :

$$N_{(t+1)} = \lambda N_{(t)} = N_{(t)}e^{m}$$

λ is used as an estimator of population growth rate and when λ = i or m = 0, the population is constant.

At the modular level, say the behaviour of the leaf population, it can be simulated by making use of a Leslie-type matrix system (Leslie, 1945, 1948; see also Maillete, 1982; McGraw & Antonovics, 1983) of the following from :

$$\begin{bmatrix} f_0 \\ f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_n \end{bmatrix}_{t+1} = \begin{bmatrix} m_0 & m_1 & m_2 & \dots & m_n \\ p_0 & 0 & 0 & \dots & 0 \\ 0 & p_1 & 0 & \dots & 0 \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ o & o & o & & o \end{bmatrix} \begin{bmatrix} f_0 \\ f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_n \end{bmatrix}_{t}$$

where :

Px = the probability that a leaf aged x at time t will be alive in the age group x + 1 at time t + 1

mx mean amount of foliage produced in the interval t to t + a by a unit amount of leaf aged x

fx = amount of foliage aged x present per unit area.

The total amount of foliage present at time t + 1 is obviously :

$$F_{t+1} = \sum_{x} f_{x.t+1}$$

One might expect the parameters mx and px to be a decreasing function of density (LAI) and an increasing function of soil fertility or introduce some sort of random environmental variation from year to year.

SOME EXAMPLES

1. *Echinochloa crus-gali*

The demographic characteristics of *E. crus-galli* are an interplay and a compromise between the production of remarkably large numbers of viable seeds (many of which germinate synchronously, given the right environmental conditions) and seedlings that emerged which face the rick of high juvenile mortality (92.0 - 95.2%) (Figure 11), leaving a small fraction to establish and produce seeds. This coupled with vigorous clonal growth (the production of large number of tillers), arguably, is an optimal strategies for the survival and spread of this weed (Baki, 1988). In the first generation life-cycle a population

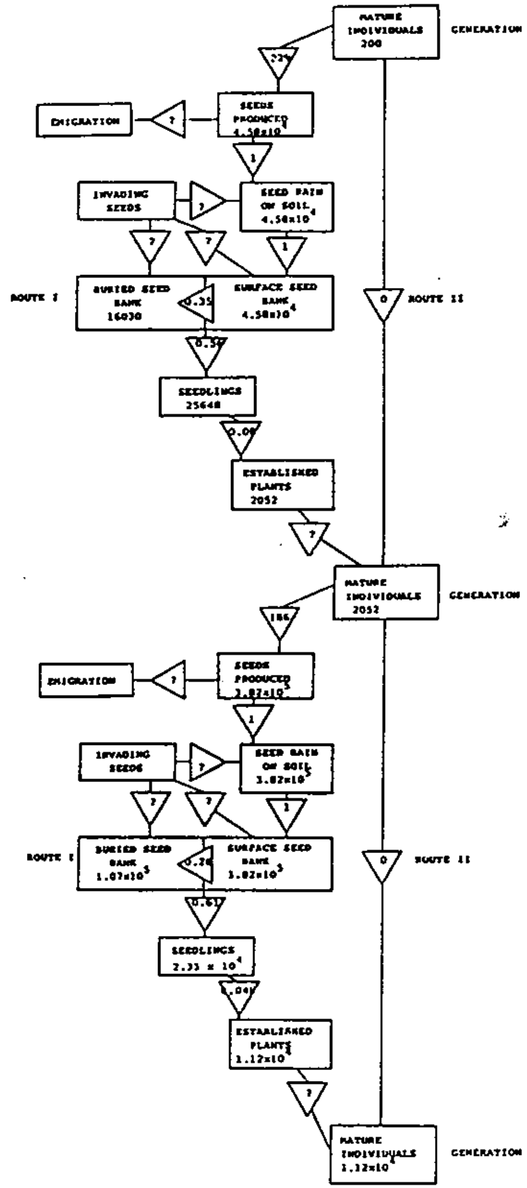


Figure 11. A life-table of *Echinochloa crus-galli* in the first and second generation life cycle 44 weeks after first sowing (inclusive of 4 weeks fallow period imposed in the first generation life cycle). Figures are number m^{-2}. (After Baki, 1988)

of 200 plants/m^2 produced 45,800 seeds/m2 which presumably fell as seed rain onto the soil surface to become the soil surface seed bank. Some 35% of the surface bank is buried. The probability of successful transition from total seed bank to seedling emergence 5.6%. The established plant represented only 8% of the total number of emerged seedlings or 4.5% of the total seed rain. The steps illustrated above represent Route I of the life-table of *E. crus-galli*. In the second generation life-cycle, 2,052 established plants/m^2 produced 382,00 seeds/m^2, which is assumed to have had 100% probability of falling as seed rain onto the soil surface. About 28% of these seeds were buried. Emerged seedlings represented only 61% of the total seed bank. The established plants that matured to produce seeds accounted for 4.8% of the total numbers of seedlings that emerged or 2.93% of the seed rain.

2. *Oxalis corniculata*

Although *O. corniculata* shows some pereniality, the diagramatic life-table which best serves to summarise the behaviour of the species in the present study is the one used for biennials by Sagar & Mortimer (1976). In the first generation life cycle (Figure 12) a population of 165 plants m^{-2} produced about 1.8 x 10^6 m^{-2} seeds which it is assumed fell as seed rain onto the soil surface to become the soil surface seed bank. Some 27% of the surface bank was buried. The probability of successful transition from total seed bank to seedling emergence was about 64%. The established plants represented only about 5% of the total number of emerged seedlings or 3.46% of the total seed rain. The steps illustrated above represent Route I of the life-table of *O. corniculata*.

In the second generation life cycle, 6.24 x 10^4 established plants m^{-2} produced about 2.6 x 10^6 m^{-2} seeds, which it is assumed had 100% probability of falling as seed rain onto the soil surface (Figure 12). About 22% of these seeds were buried. Emerged seedlings represented only about 45% of the total seed bank. The established plants that matured to produce seeds accounted for about 5% of the total number of seedlings that emerged or 2.25% of the total seed bank.

3. *Eupatorium odoratum* (syn. *Chromolaena odorata*)

A five - year old study on the population flux of *E. odoratum* in India was conducted by Tripathi (1985). Out of a population of 27 adult plants per square metre in June 1977, on a 5 year-old fallow, only about 63% survived until June 1978. Niniteen individuals, a small fraction of the 1385 recruited over a 1 year period, were added to the original population (Figure 13). There was a net gain of nine plants to the weed population that existed in June 1977, despite a very high seed production (c. 87,900 per square metre). This shows that the

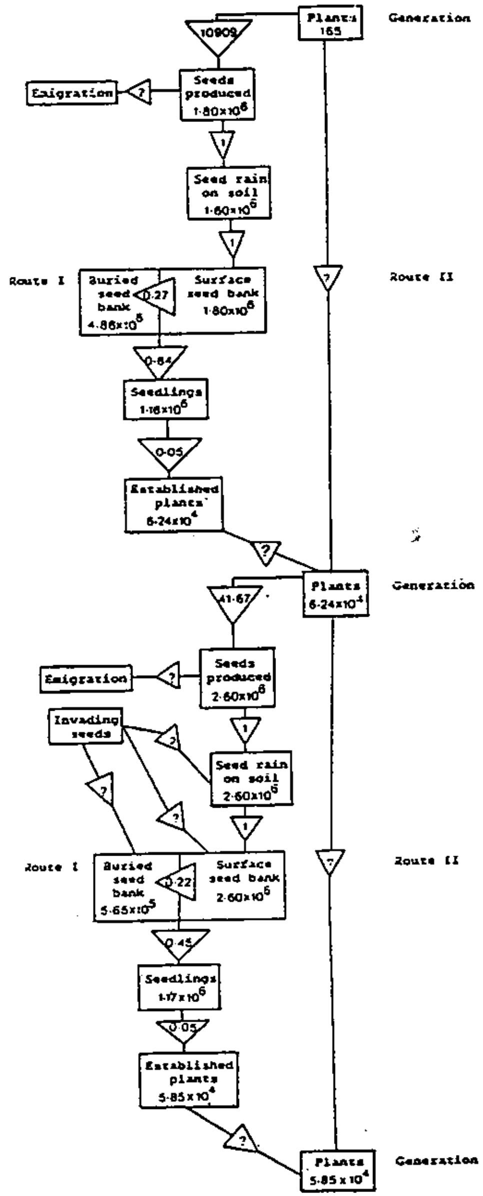


Figure 12. A life-table for *Oxalis corniculata* in the first and second generation life sycle 48 weeks after first sowing (inclusive of 8 weeks fallow period imposed in the first generation life cycle). Figures are numbers m^{-2}. (After Baki, 1986).

populations of seeds and plants decreased with time because of various regulatory forces operating at different stages of the life cycle of the weed. The factors that contribute to the population regulation of *E. odoratum* (as summarised in Fig. 13) have been discussed by Yadav and Tripathi (1981). The effects of the associated vegetation on the reproductive behaviour of this weed are worth examining.

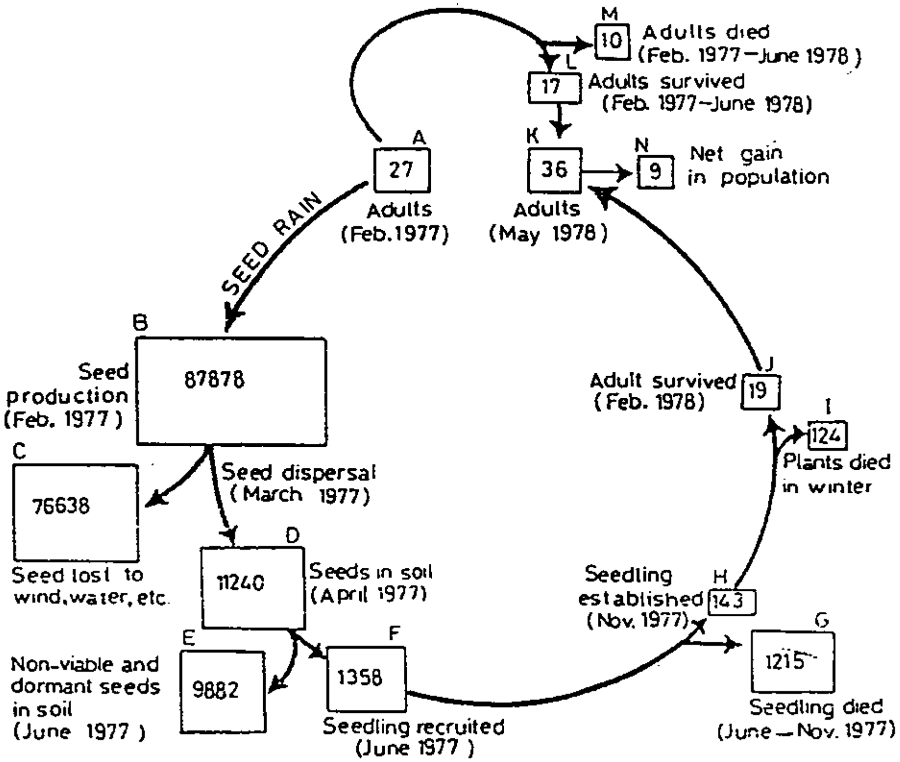


Figure 13. Schematic summary of the population flux of *E. odoratum* in a 5-year-old fallow. Data in boxes refer to the population of individual (seeds or plants) per square metre. Box A, adult population in February 1977 that remained unchanged until June 1977. Box J, Population of adults that survived in February 1978 remained unchanged until June 1978. Other boxes are explained in the figure. [Redrawn from Yadav & Tripathi (1981).]

EPILOGUE

I have tried to cover a wide field and the treatment is inevitably uneven. In this context, it appears that the views of a few, prevailed. This has arisen here since there are but few studies on the population dynamics of weeds and moreover there appears a genuine need, borne of economic adversity to attemp an integrated view. Research on weed science in the part has laid emphasis on the description of effects of weed on crops or the static composition of weed species at a particular point in time and space with relatively little attempt to understand an analyse the mechanism involved.

It is the integration of population dynamics studies of weeds in a holistic approach at the modular, genetic and community levels incorporating the elements of spatial and temporal heterogeneities that appears lacking. This is particularly so for weeds species in the tropics. Further, there is a need for studies on the temporal and spatial dynamics of weeds following chemical and agrotechnical manipulations of the environment and weed communities. Data from such studies and elements such as herbicide resistance, etc. are important, to augment information needed for better understanding of weed community dynamics and density- related agents or agencies involved in the population regulation in our pursuit for weed management planning and grower economics.

Sagar & Mortimer (1976) lamented . . "Plant populations are usually regulated". The impact of such truisms of population regulation in weed communities have not been fully understood and certainly remains a venue for further research.

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YEARLY CHANGE OF VARIATION IN GROWTH OF INDIVIDUAL PLANTS OF WEED SPECIES IN DRY SEEDED RICE FIELDS

A.Q. LIU[1], H. SHIBAYAMA[2] AND H. WATANABE[2]

ABSTRACT

The height growth of individual plants of each weed species in dry seeded rice fields varied considerably during three years of investigation. These variations often caused unsuccessful chemical weed control, because the bigger plants are usually tolerant to herbicide applications, and also because the smaller plants emerged after the disappearance of the effectivity of the applied herbicides.

There are four different types of the relation between plant height and the number of plants per m^2 of each weed species in fields. In the first type, the percentage of the smaller plants was more; in the second one, that of middle-size plants was more; in the third one, a few plants were found for all plant heights; and, in the fourth one, the smaller and the bigger plants were more than the middle-size ones.

Some species, such as *Cyperus* spp. (mainly *C. iria*) belong to the same type during three years, while other species belong to different types in different years or in different planting seasons, probably because of the difference in climatic or soil conditions and of the emerged number of the species.

INTRODUCTION

The dry seeded rice in Japan is flooded at about one month after dry seeding to be in the paddy condition, but one of its serious problems is how to control weeds satisfactorily which emerge at dry condition, because both the pre- and the post-emergence herbicides applied at dry condition are frequently not so effective. These weeds usually grow big after flooding the fields and cause severe damage to rice, if they are not eradicated.

The height or length growth of the shoot of individual plants of each weed species in dry seeded fields varied considerably during three years of investigation. These variations were often found to cause unsuccessful chemical weed control, because the bigger plants were usually tolerant to herbicide applications, and also because the smaller plants emerged after the disappearance of the effectivity of the applied herbicides.

The variation of plant heights of weeds at dry seeded rice fields has been reported in 1989 (Sabri *et al.* 1989). And the purpose of this study is to

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investigate the annual and seasonal changes in the type of variation in the heights of individual plants of each species which emerged at dry condition.

MATERIALS AND METHODS

Weeds in the dry seeded rice fields were studied during three years. Rice, the cultivar Musashiogane, was seeded on May 11, 1988, on May 24, 1989, on May 17 and on June 15, 1990, to fields at dry condition at the National Agriculture Research Center in Tsukuba, Japan. Four of 100 m^2 size fields were used for the weed experiments. Fertilizer was applied there at the rate of 20 kg ai/ha of nitrogen, phosphorus and potassium according to the recommendation to farmers as the basal dressing before cultivation and seeding. Fields were at the dry condition until about one month after seeding when weed investigations were conducted.

Weeds in 30 cm x 30 cm or 50 cm x 50 cm frames were collected with 4 to 8 replications. The number of growing plants of each species and shoot heights of individual plants were investigated to know the variation in emergence and growth.

RESULTS AND DISCUSSION

Table 1 shows the main weed species in the investigated fields during three years (Sabri *et al.*, 1989). Among them, *Digitaria ciliaris, Cyperus iria,*

Table 1. Main weeds at the investigated dry seeded rice fields

English name	Species	Family
Barnyardgrass	*Echinochloa* spp.	Gramineae
Crabgrass	*Digitaria ciliaris* (Retz.) Koeler	Gramineae
Violet crabgrass	*D. violascens* Link.	Gramineae
Water foxtail	*Alopecurus aequalis* Sobol. var. *amurensis* (Komar.) Ohwi	*Gramineae*
Flatsedge	*Cyperus* spp. (mainly *C. iria* L.)	Cyperaceae
Fringerush	*Fimbristylis miliacea* (L.) Vahl	Cyperaceae
Eclipta	*Eclipta prostrata* (L.) L.	Compositae
Spreading sneezeweed	*Centipeda minima* (L.) A. Braun. et Aschers.	Compositae
Bittercress	*Cardamine flexuosa* With	Cruciferae
Marsh yellowcress	*Rorippa islandica* (Oeder) Borb.	Cruciferae
Chickweed	*Stellaria media* (L.) Villars	Caryophyllaceae
Nominofusuma	*S. alsine* Grimm var. *undulata* (Thunb.) Ohwi	Caryophyllaceae
Purslane	*Portulaca oleracea* L.	Portulacaceae
Smartweed	*Persicaria (Polygonum)* spp.	Polygonaceae
Japanese mazus	*Mazus pumilus* (Burm f.) V. Steenis	Scrophulariaceae

Fimbristylis miliacea, Centipeda minima, Cardamine flexuosa, Rorippa islandica, Stellaria media, and *Portulaca oleracea* emerged more than the other species.

There were four types of variation in the number of plants per m^2 for each plant height of each species. In Type I, the number of smaller plants was more than the bigger ones and their number decreased as the plant height increased. In Type II, the number of middle-size ones was more and the number of plants decreased as the plant height decreased or increased. In Type III, the height of plants varied from big to small ones, but there were a few individuals at any height. In Type IV, the smaller and the bigger plants were more than the middle size ones (Figure 1) (Sabri *et al.*, 1989).

Some species, such as *Cyperus* spp. (mainly *C. iria*), *Stellaria* spp. and *Centipeda minima*, belong to the same type, namely Type I, during three years of investigation, and the smaller plants were more in number, while the number of whole growing plants of *Stellaria* and *Centipeda* was less than that of *Cyperus iria*. On the other hand other species belong to different types in different years or in different planting seasons. *Fimbristylis miliacea, Cardamine flexuosa* and *Portulaca oleracea* in 1989 and *Rorippa islandica* in 1990 had more of the middle-size plants (belonged to Type II), although *F. miliacea* in 1989 and *P. oleracea* in 1990 belonged to Type I, as there were plenty of emerged plants and the smaller plants were more than the bigger ones. *Digitaria ciliaris* in 1988, *Rorippa islandica* in 1988~1989 and *Alopecurus aequalis* var. *amurensis* in 1988 belonged to Type III with a few growing plants. *D. ciliaris* and *D. violascens* in 1989 belonged to Type IV and there were big difference in heights of individual plants. *D. ciliaris* in 1990 emerged more plants and belonged to Type I or II (Figure 1).

These variation in heights of individual plants of each weed species are mainly caused by the difference in time of emergence and the number of plants after seeding rice. When the season, climatic and soil conditions are suitable for seed germination of the species at the time of cultivation and rice seeding (Liu *et al.*, 1991), the weeds grow as Type II, and when the good condition, such as rainfall, is there during the dry period (Liu *et al.*, 1991), they grow as Type I. But if there will not be enough buried seeds of the species in soil to infest the field and/or conditions will not be suitable for seed germination of the weed, they grow as Type III, and when the conditions are sufficiently good during dry period, they grow as Type IV.

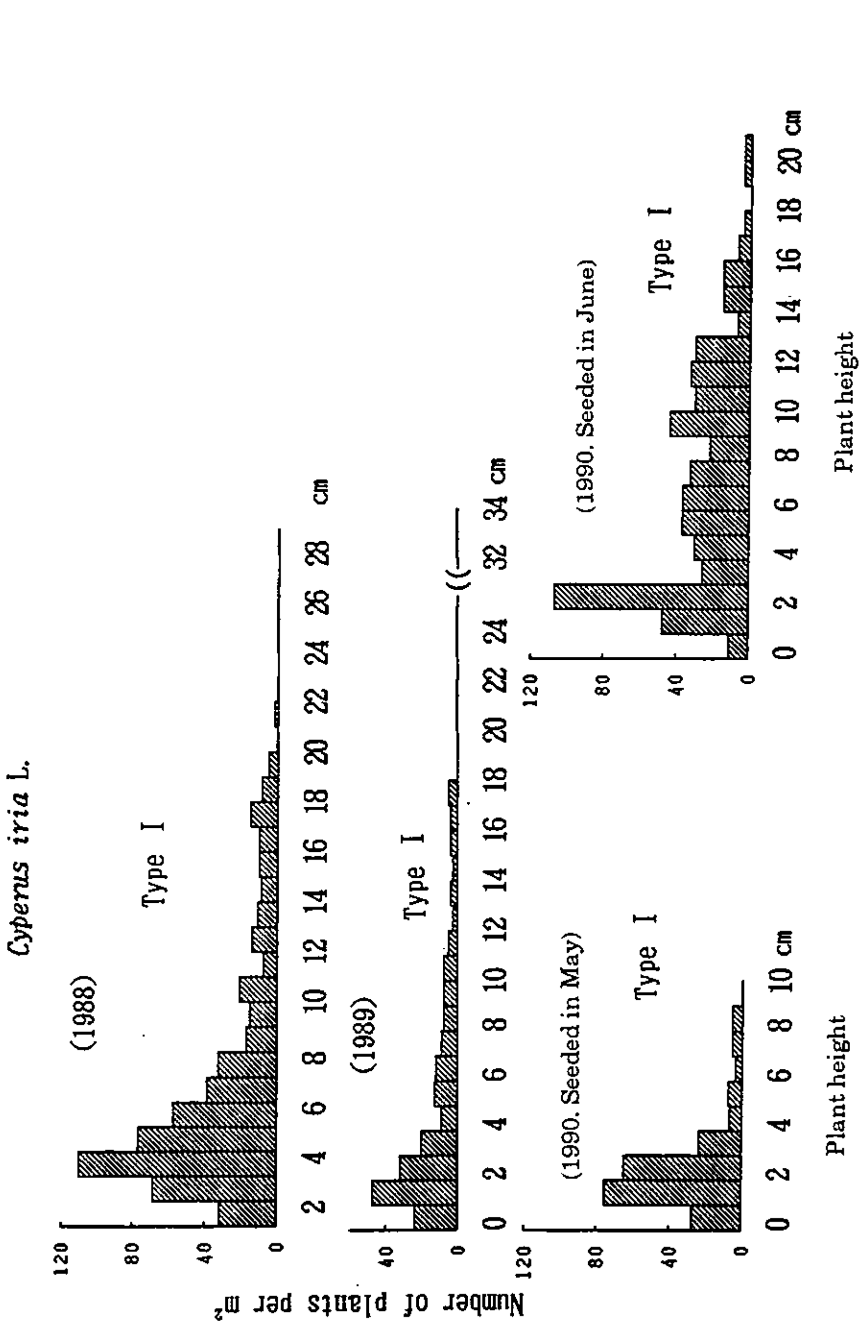

Figure 1a. Number for plants per m^2 in each plant height.
( ) : year of investigation

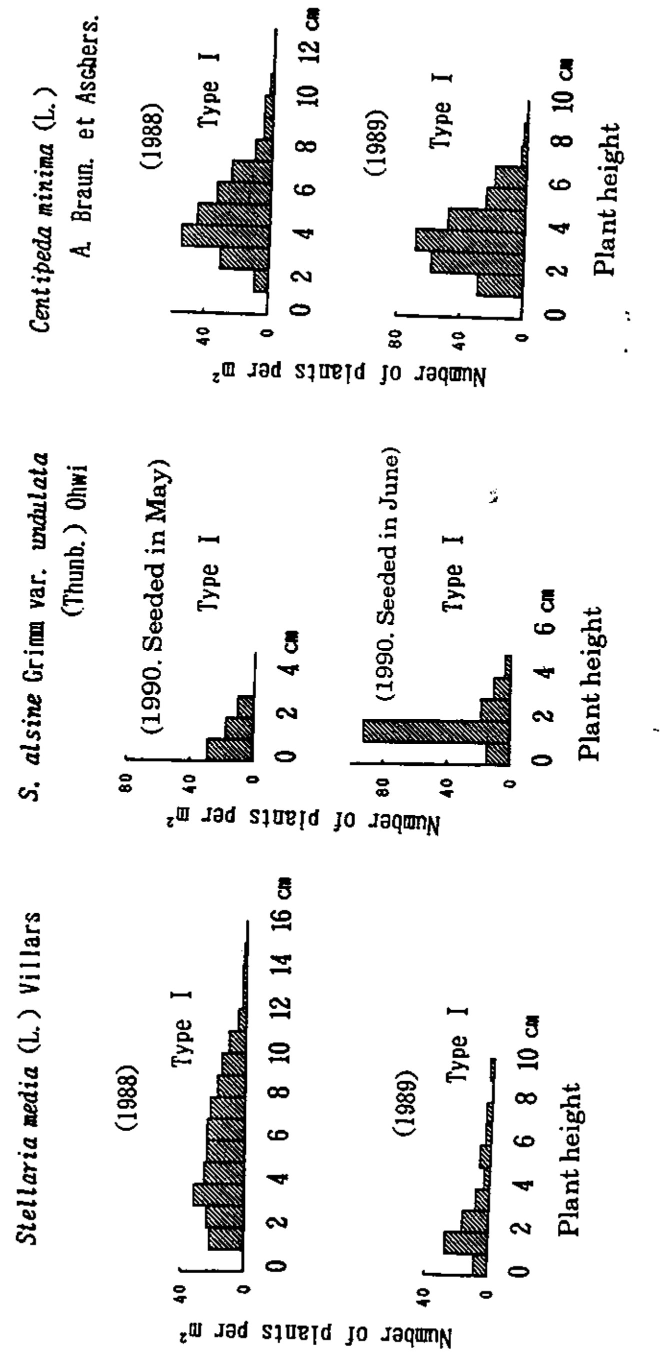

Figure 1b. Number for plants per m^2 in each plant height (*continued*).
( ) : year of investigation

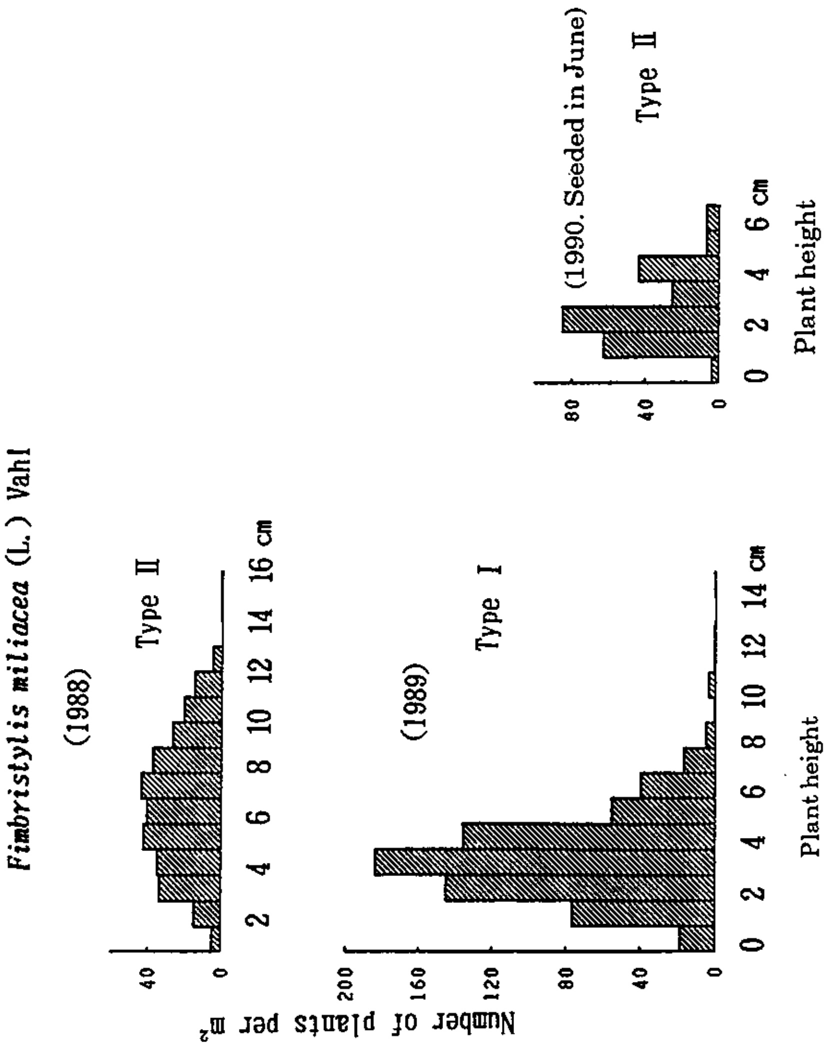

Figure 1c. Number for plants per m^2 in each plant height (*continued*).
( ) : year of investigation

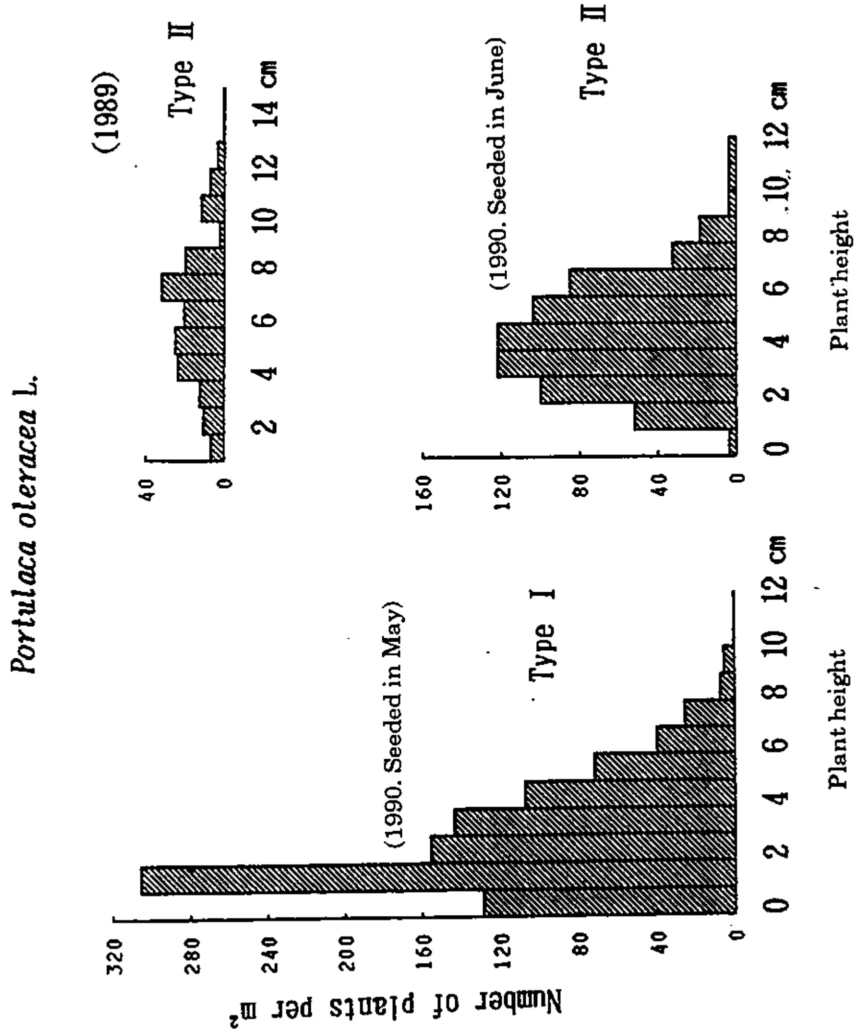

Figure 1d. Number for plants per m^2 in each plant height (*continued*).
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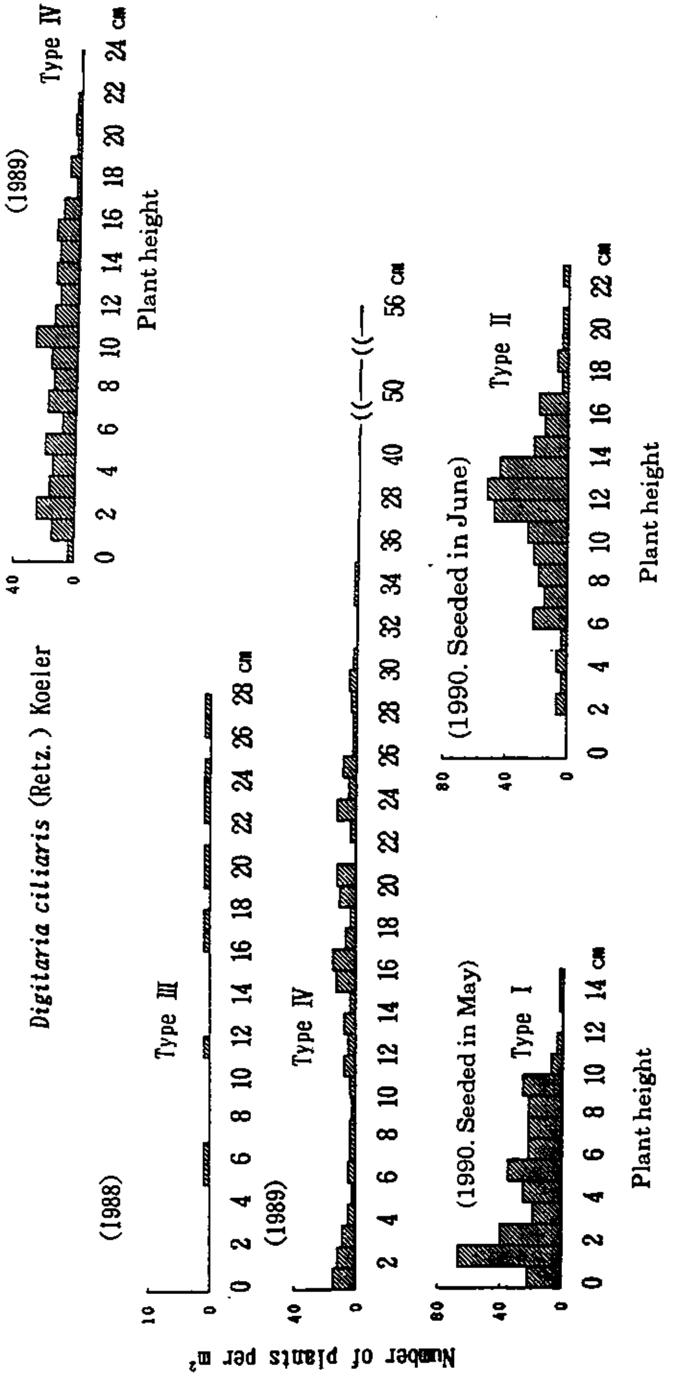

Figure 1e. Number for plants per m^2 in each plant height (*continued*).
( ) : year of investigation

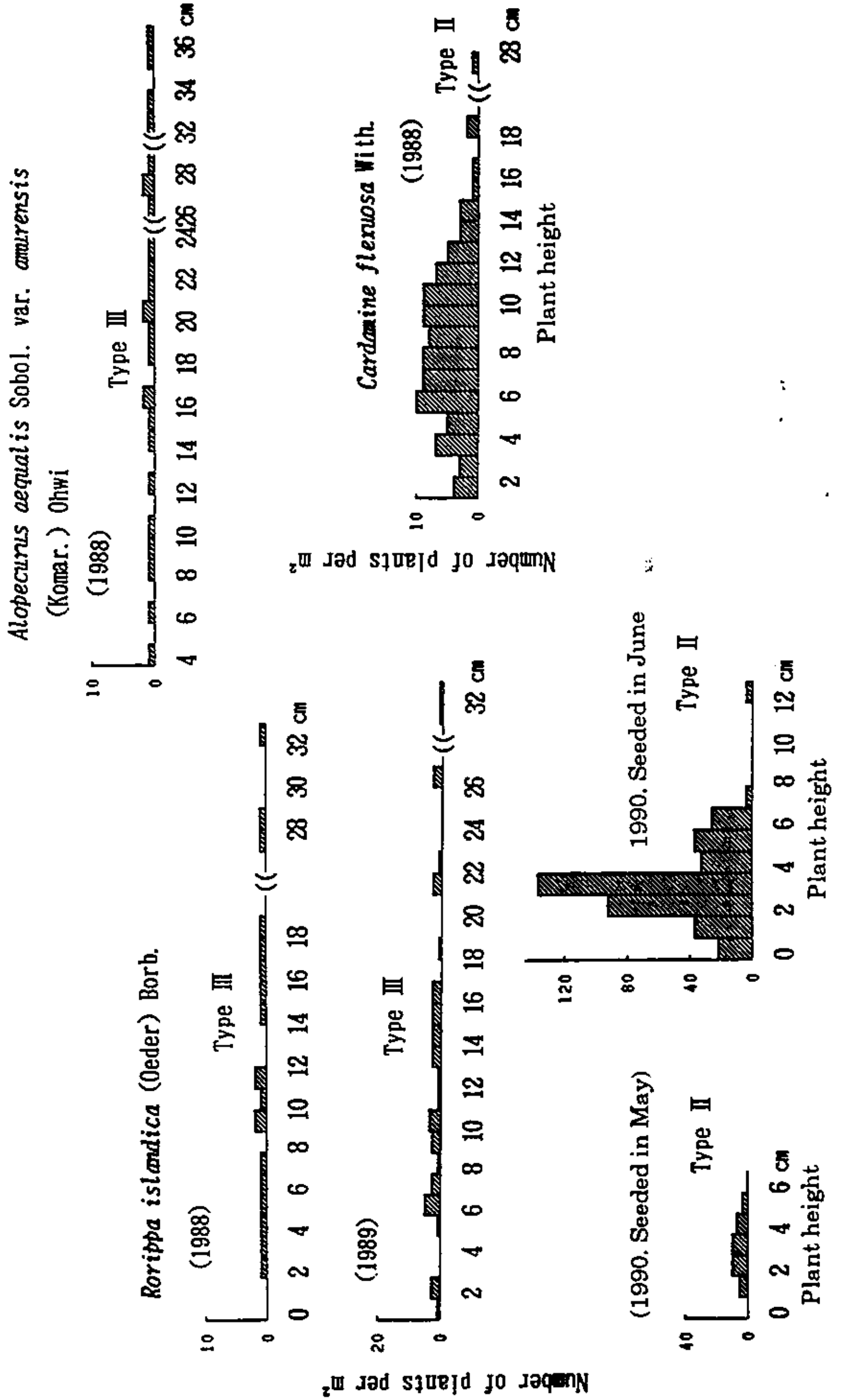

Figure 1f. Number for plants per m^2 in each plant height (*continued*).
( ) : year of investigation

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THE EFFECT OF SOIL MOISTURE REGIME ON THE PERSISTENCE OF BURIED WEED SEEDS

J.D.K.M. JAYAWARDENA[1] AND S. K. DE DATTA[2]

ABSTRACT

The effect of storage in saturated, flooded and air dried soil on the persistence of buried seeds of barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.) and fimbristylis (*Fimbristylis miliacea* (L.) Vahl) was investigated. Flooded soil encouraged longer persistence of buried barnyardgrass seeds in clay soil, whereas saturated soil increased the rate of germination loss. Persistence of fimbristylis seeds in flooded and in saturated soil did not differ significantly. In both weed species the lowest weed seed persistence occurred in air dried soil.

INTRODUCTION

Weeds have become major constraints for high rice yield since the introduction of modern rice cultivars and a greater emphasis has been placed on their weed control in modern rice cultivars. Despite various weed control methods including cultural and chemical that have been developed over the last two decades, weeds still remain a major constraint on rice production. One major hinderance for effective weed control is the persistence of weed seed reserves in soil. Estimates of weed seed population in the soil have been commonly tens of millions per hectare (Roberts, 1970). Year after year thousands of weed seeds are being introduced to the soil, e.g. one plant of barnyardgrass can produce more than 42,000 seeds, 75% of which were viable (Mercado, 1979). Even under favourable environmental conditions all seeds introduced to the soil will not germinate at once due to their survival mechanisms, and many persist in the soil for long periods. Most seeds found in agricultural soils might be brought on or near to the soil surface during tillage operations, and in lowland rice fields they may be exposed to a favourable environment for germination after irrigation and/or rainfall. This causes the emergence of periodic weed flushes throughout the season, as a result of which repeated weed control practices are needed for sustainable crop yields. Various weed control methods only control weeds either during germination or the early seedling stage. None kill ungerminated viable seeds in

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the soil. Therefore, the longevity of weed seeds in the soil is important, since potential weed problems exist as long as weed seeds remain viable in the soil.

Information is lacking on the longevity of weed seeds in the soil under tropical condition. The present paper discusses the persistence of the seeds of two common weeds of wet seeded rice: barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.) and fimbristylis (*Fimbristylis miliacea* (L.) Vahl).

METHODOLOGY

Experiments were conducted in the green house at the International Rice Research Institute (IRRI), Los Banos, Philippines in 1988-1989. Seeds of barnyardgrass and fimbristylis were collected from the IRRI farm area where herbicidal screening tests were conducted.

Five centimeter long sections of 2.5 cm diameter polyvinyl pipe with nylon screen attached to each end were used as containers for burying weed seeds in soil at three soil moisture levels: saturated (125 % gravimetric moisture), flooded (5 cm standing water) and air dried (10 % gravimetric moisture). A clay soil with 5.7 pH (1:1 w/v H_2O) was used for this study.

The polyvinyl containers were filled with sterilized soil. One hundred barnyardgrass seeds with initial germination of 11 % and viability of 100 % and 0.025 g fimbristylis seeds (equivalent to 1,000 seeds) with an initial 37 % germination were placed separately in each container. Seed containers were buried at 10 cm depth from the soil surface. Four samples per treatment were exhumed monthly for 12 months. The contents of the pipes with barnyardgrass seeds were each spread in a 100 x 22 mm petri dish, whereas the soil with fimbristylis seeds was spread in a 150 x 25 mm petri dish. Seeds were germinated in an incubator at 35°C day and night temperature under 15/9 hours light/dark condition. Germination counts were taken up to two weeks.

Non germinated barnyardgrass seeds were then separated by washing the soil and incubated at 35°C with 6 ml of 3 % (w/v) triphenyl tetrazolium chloride (TTC) solution at pH 7.0 for one week (Lindenbein, 1965). After one week seeds were cut open and the embryos that adopted a light red to purple colour were considered viable. Seeds that remained brown were considered non-viable. Fimbristylis seeds were subjected to alternating temperature (35°C/6°C) cycles under 15/9 hours light/dark condition in an incubator for 48 hours in each temperature. Seeds that germinated were considered viable until no further germination was observed.

Percentage germination, total viability and percentage decay were calculated as follows.

$$\%\ \text{germination} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds buried}} \times 100\ \%$$

$$\begin{array}{c}\%\ \text{total viability}\\ \text{(Barnyardgrass)}\end{array} = \frac{\text{Germinated seeds} + \text{TTC responsive seeds}}{\text{Total number of recovered seeds}} \times 100\ \%$$

$$\begin{array}{c}\%\ \text{total viability}\\ \text{(Fimbristylis)}\end{array} = \frac{\text{Germinated seeds} + \text{Germinated seeds after viability test}}{\text{Total number of seeds buried}} \times 100\ \%$$

$$\begin{array}{c}\%\ \text{decay}\\ \text{(Barnyardgrass)}\end{array} = \frac{\text{Total number of seeds buried} - \text{Total number of seeds recovered}}{\text{Total number of seeds buried}} \times 100\ \%$$

RESULTS AND DISCUSSION

Germination and Viability in Saturated Soil

Germination of the buried seeds increased from 11 to 46 % under saturated soil moisture conditions after one month burial period (Table 1.) and decreased with further increases in burial period. The viability of the seeds under the same moisture conditions remained at 100 % for one month then also decreased with time. This significant decrease in seed germination and viability when seeds were buried in saturated soil could be due to the *in-situ* germination in a favourable environment, and thus reduced survival of seeds. Roberts and Feast (1972, 1973) suggested that much of the losses in buried seeds were due to seeds that germinated in the soil but failed to emerge, and the phenomenon was referred to as fatal germination. Murdoch and Roberts (1982) reported that fatal germination was the primary means of seed loss for buried wild oat (*Avena fatua* L.) seeds.

Even though the reduction in germination of fimbristylis seeds was observed in the soils with all three moisture conditions (Table 2), the highest germination was observed with saturated soil after one month burial, after which it decréased with time. However, the total viability remained high during the first three months of burial, after which a significant drop in viability was observed. Horng and Leu (1978) observed the germination response of burial fimbristylis seeds at 7.5 cm depth for one year under temperate conditions. They found low total germination in seeds after burial of one month in loamy soil, however after 60 days burial, germination increased to 92 %. The moisture content of this soil was not mentioned and germination was considered as the sum of *in situ* germination and germination of exhumed seeds in the petri dish. In the present study *in situ* germination of fimbristylis seeds buried at 10 cm depth can not be expected since it has already been proven that these seeds were highly light dependent for their germination in lowland soil (Jayawardena 1989). Therefore, the high viability percentage observed with low germination of fimbristylis seeds during the early burial period may possibly be due to the induction of secondary dormancy in the absence of light.

Table 1. Effect of duration of seed burial on the germination, viability and decay of *Echinochloa crus-galli* seeds under different moisture regimes*

Burial duration (Month)	Germination (%)			Viability (%)			Decay (%)		
	Saturated	Flooded	Air dried	Saturated	Flooded	Air dried	Saturated	Flooded	Air dried
1	46 (46)	30 (33)	6 (13)	100 (87)	66 (58)	59 (50)	0 (3)	0 (3)	3 (9)
2	29 (32)	20 (25)	9 (17)	72 (58)	51 (46)	51 (46)	0 (3)	0 (3)	1 (4)
3	30 (33)	20 (25)	6 (13)	80 (64)	71 (57)	30 (33)	18 (24)	3 (9)	17 (18)
4	21 (27)	25 (29)	3 (8)	62 (52)	71 (57)	16 (23)	9 (15)	4 (10)	27 (19)
5	16 (23)	26 (29)	6 (13)	52 (46)	61 (52)	17 (24)	6 (14)	7 (13)	20 (18)
6	10 (18)	24 (27)	4 (10)	61 (52)	39 (38)	13 (18)	17 (22)	33 (35)	19 (28)
7	6 (14)	15 (23)	3 (9)	44 (41)	26 (30)	12 (18)	15 (22)	32 (27)	27 (27)
8	9 (17)	4 (9)	1 (4)	44 (41)	34 (35)	10 (17)	18 (25)	50 (45)	25 (33)
9	8 (14)	6 (12)	1 (4)	18 (25)	39 (38)	1 (6)	44 (41)	78 (63)	47 (49)
10	8 (16)	1 (4)	2 (6)	14 (22)	14 (21)	2 (6)	41 (40)	89 (71)	41 (50)
11	3 (8)	2 (7)	1 (4)	6 (13)	12 (20)	1 (6)	39 (38)	77 (63)	40 (47)
(Moisture regime)									
LSD (0.05)		(10)			(13)			(12)	
(0.01)		(13)			(18)			(16)	
(Burial duration)									
LSD (0.05)		(9)			(12)			(11)	
(0.01)		(12)			(16)			(15)	

* Analysis is based on Arcsine transformation. Transformed values are in parentheses.

Germination and Viability in Flooded Soil

Germination of barnyardgrass seeds was 30 % in flooded soil after one month of burial. The subsequent percentage germination up to seven months was not significantly different (Table 1). The low germination percentage when compared with viability under flooded conditions could be attributed to seed dormancy due to lack of oxygen and/or low temperature. Lewis (1961) has suggested that the effect of water table in the soil is important in seed longevity. He found that the seeds of most species were able to survive for a longer period when submerged due to enforced or secondary dormancy, probably because of lack of aeration and low soil temperature. Therefore, low germination percentage and high viability of barnyardgrass seeds in flooded soil suggests that *in situ* germination of barnyardgrass seeds may be reduced by secondary dormancy in flooded soil. Viability still remained high and was not significantly different until after five months of burial.

Table 2. Effect of different burial duration on the germination and viability of *Fimbristylis miliacea* seeds under different moisture regimes*

Burial duration (Month)	Germination (%)			Viability (%)		
	Saturated	Flooded	Air dried	Saturated	Flooded	Air dried
1	28 (32)	17 (24)	6 (14)	94 (79)	100 (89)	92 (78)
2	10 (18)	17 (24)	4 (11)	64 (53)	85 (70)	90 (75)
3	10 (17)	13 (21)	2 (8)	82 (68)	98 (85)	75 (60)
4	5 (13)	10 (17)	2 (8)	31 (33)	34 (35)	32 (34)
5	3 (8)	8 (16)	2 (7)	33 (35)	34 (35)	32 (34)
6	4 (11)	3 (9)	2 (8)	31 (33)	31 (33)	14 (21)
7	2 (8)	2 (8)	1 (6)	35 (36)	31 (33)	9 (17)
8	0 (0.9)	1 (4)	1 (6)	29 (32)	26 (30)	10 (18)
9	0 (0.9)	1 (4)	1 (6)	29 (32)	42 (40)	6 (13)
10	0 (0.9)	1 (4)	1 (6)	13 (21)	12 (19)	5 (13)
11	0 (0.9)	0 (0.9)	1 (5)	11 (20)	12 (19)	4 (11)
(Moisture regime)						
LSD (0.05)		(5)			(12)	
(0.01)		(7)			(16)	
(Burial duration)						
LSD (0.05)		(5)			(12)	
(0.01)		(6)			(16)	

* Analysis is based on Arcsine transformation. Tranformed values are in parentheses.

Germination percentage of fimbristylis seeds under flooded conditions were lower than under saturated soil, and differences remained non significant until the burial period reached six month (Table 2). The changes of viability percentage showed a similar trend as in saturated soil, however unlike barnyardgrass seeds, the percentage viability remained similar between saturated and flooded soils at 11 to 12 % even after 11 month of burial (Table 2). This could be due to the adaptability of the fimbristylis seeds to low oxygen condition.

Germination and Viability in Air Dried Soil

The lowest germination percentage of barnyardgrass seeds was observed in air dried soil, with only 6 % germination after one month (Table 1). This result could be attributed to enforced or secondary dormancy caused by low soil moisture in the soil, confirmed by the high viability percentage during the early burial period. The seeds could have entered enforced dormancy during the early period of burial and lost their viability with time, probably due to high temperature and extremely low soil moisture. Villiers (1974) hypothesized that weed seed longevity is maintained by hydrated non germinated seeds through self-repair and replacement of cellular components during storage. However, seeds that dried to below a critical level would not have sufficient moisture to support the metabolism necessary for the repair. Furuya and Kataoka (1983) observed that the dormancy of *E. crus-galli* var. *oryzicola* and var. *caudata* was released at 30°C in air dried soil under temperate conditions. There was no mention of the soil moisture content. Germination and viability percentage of fimbristylis seeds showed a similar trend as in barnyardgrass seeds (Table 2).

Decay

The percentage decay of barnyardgrass seeds gave the opposite trend to germination and viability. The highest percentage of decay was observed under flooded conditions after 11 month burial period. However, the viability of recovered seeds was also high under the same condition (Table 1). Therefore, these results indicate that the decay of buried seeds occurs although it is not apparent from the number of seeds recovered. In addition to *in-situ* germination, decay probably accounts for the depletion of seed population. Bacteria and fungi play a major role in the decay of buried seeds and the higher microbial action which may be possible even under anaerobic condition could be responsible for the higher percentage decay observed under flooded condition. Lewis (1961) reported that there was little evidence of deterioration in seed buried in free drained soil but under water-logged condition some losses may have occurred from bacterial and fungal attack. The low percentage decay of barnyardgrass seeds in air-dried soil could be at least due to the highly dehydrated medium which prohibited the growth and population increase of microbes. The percentage decay of fimbristylis could not be determined as the method of separation was not suitable for small seed types.

CONCLUSION

In general, germination, viability and decay of buried barnyardgrass and fimbristylis seeds at 10 cm soil depth were all significantly affected by the moisture content of the soil in which they were buried. Knowledge of the germination and persistence of seeds in soil with different moisture contents can be used to control weeds using alternative cultural practices. The high rate of viability loss in buried barnyardgrass seeds in saturated soil indicates the decline in weed seed population in free drained fields. The high persistence of buried seeds under flooded conditions must influence the increase in weed

population in successive seasons, since these viable seeds can be brought to the soil surface during cultivation. Both saturated and flooded moisture regimes are conducive to the persistence of fimbristylis seeds. Therefore similar methods in alternative cultural practices may deplete the number of particular weed seeds while favouring the persistence of some others. As the lowest persistence was observed from both weed seeds in air-dried soil, dry land preparation can possibly decrease both barnyardgrass and fimbristylis seeds.

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EFFECTS OF DEPTH OF TUBER BURIAL, SOIL TEMPERATURE, AND SOIL MOISTURE ON TUBER SPROUTING OF *ELEOCHARIS KUROGUWAI* OHWI

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ABSTRACT

A study was conducted to determine the effects of depth of burial, soil temperature and/or moisture on tuber sprouting of *E. kuroguwai*. Tubers were evenly distributed in the upper 30 cm of soil. Tuber weight increased as depth of tuber increased. No dormancy in freshly harvested white tubers (immature) was found, whereas dark brown tubers (mature) were dormant. When immature tubers were subjected both to continuous 5°C and to gradual decreasing temperatures from 20° to 1°C for 30 days, the tubers remained non-dormant. Viability of tubers was reduced when buried at 5 cm depth in dry and moist soil conditions, but no reduction was obtained when buried at 25 cm depth, regardless of soil moisture conditions. Percent sprouting of tubers buried at 25 cm depth increased with increasing duration of burial in three soil moisture conditions studied, whereas in dry and moist conditions percent sprouting of tubers buried at 5 cm depth increased by 60-day burial, but decreased. In submerged condition, tuber sprouting was greater when buried at 5 cm depth than when buried at 25 cm depth, and increased as duration of burial increased at both depths.

INTRODUCTION

E. kuroguwai, a member of Cyperaceae, is a herbaceous perennial weed that is reportedly confined to Korea and Japan (Ohwi, 1984) and occurs in transplanted lowland rice (*Oryza sativa* L.) fields. This weed is capable of causing serious yield reduction of rice. It has become the most troublesome weed since various herbicides effective to annual weeds which have been widely used in most areas of the rice culture but with little success (Ahn *et al.*, 1975; Ueki and Kobayashi, 1975). Control with herbicides is often unsatisfactory. In addition, the plant remains in the fall and poses harvesting problem.

Tubers of *E. kurogawai* are recognized as the primary dispersal unit (Ueki *et al.*, 1969; Ryang *et al.*, 1976; Kusanagi, 1984). In the fall *E. kuroguwai* rhizomes differentiate into tubers as daylength shortens (Ueki *et al.*, 1969) and the tubers are most dormant at the end of the season they were produced. Ueki *et al.* (1969) reported that low temperature treatment was not effective to break the dormancy.

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Ryang *et al.* (1976) and Kusanagi (1984) found that tubers of *E. kuroguwai* were usually found in the top 30 cm of soil. At different soil depths the tubers are exposed to different environmental conditions for over-wintering period, resulting in different depths of dormancy. Studies have shown large influences of temperature and moisture on tuber sprouting of perennial weeds (Stoller *et al.*, 1972; Blackshaw, 1990). Therefore, the present study was initiated to determine the effects of soil temperature and/or moisture on tuber dormancy of *E. kuroguwai* at different soil depths.

MATERIALS AND METHODS

Tuber Collection and Tuber Maturity

E. kuroguwai tubers were obtained from the University lowland field in late October 1990. At collecting time, the soil depth where the tubers were situated was recorded and the fresh weight of the tubers was measured after rinsing with tap water several times to remove soil and drying with blotting paper.

From the freshly collected tubers immature and mature tubers were selected on the basis of tuber color. White tubers were considered immature, whereas dark brown ones were considered mature.

Tuber Sprouting

The uniform tubers were placed on a Whatman no. 1 filter paper in a petridish (9 cm diameter) moistened with 10 ml distilled water. The petridish was kept in a growth chamber maintained at 29±2 °C. The tuber was considered sprouted when one or more buds on the tuber was 5 mm long. There were four replications.

Soil Temperature and Moisture

The relation between soil temperature and moisture and tuber sprouting was observed in closed-plastic pots (33 x 27 x 42 cm) installed in paddy field. The pots were buried at the same height as the soil surface. After 16 replicates of ten mature tubers were placed in 5 and 25 cm depth on November 7, 1990, the pots were filled with the paddy soil and subjected to different moisture conditions; dry, moist, and submerged. For dry condition, no water was allowed to enter in to the pots during the experimental period, whereas moist condition was maintained at pF 2.0 (tension meter, Takemura Electric Works, Ltd., Japan) by watering. To keep in submerged condition, standing water was always controlled at 1 cm high. Changes in soil temperature at the buried depths of the tubers ware recorded at 09.00 hour at six-day intervals starting

from November 13, 1990 for four months. At one-month intervals four replicates were selected at random to determine tuber viability and sprouting. Out of the ten tubers selected, half were used to determine percent described above. The rest were used to observe tuber viability using 2,3,5-triphenyl-2H-tetrazolium chloride (TTC). Approximately 300 mg of tuber fragments were placed in a test tube containing 5 ml of 0.1% TTC solution prepared in 0.1 M phosphate buffer (pH 7.0). After three hours storage in the dark at 30°C, the tuber fragments were rinsed with distilled water and ground in a mortar with 12 ml of ethyl acetate. The extract was then filtered through a Whatman No. 1 filter paper, and light absorbance of the filtrate was determined in a colorimeter at a wavelength of 585 nm. If the absorbance was greater than 0.05, the tuber was considered viable.

Temperature Simulation

The temperatures affecting tuber sprouting were controlled by Refrigerated Constant Temperature Circulator (Model 9100 PolyScience, U.S.A.). The temperature regime employed ranged from 20° to 1°C using liquid medium of a mixture of ethylene glycol and water (90/10 v/v). After freshly harvested, immature or mature tubers were placed in 300 ml beakers covered with aluminum foil, the beakers were kept in the liquid medium for an appropriate period depending on the experimental conditions. On completing the temperature treatments four replicates of ten tubers were selected at random from the beakers, washed, and used for sprouting test as described above.

RESULTS AND DISCUSSION

Distribution of Tubers in Soil

More than 95% of *E. kuroguwai* tubers were formed within 30 cm soil depths. The tubers were distributed evenly at the soil depths, but tuber size as determined by weight was variable (Figure 1). About 36% of the total tubers that weighed less than 1.6 g occurred in the upper 10 cm of soil. In the second 10 cm of soil, however, about 35% of the tubers weighed 0.6 to 2.8 g. The rest, weighing between 1.4 and 3.4 g were found in the third 10 cm of soil. This indicated that the tuber size was a function of tuber depth in the soil; tuber weight increased as its depth in the soil increased. A similar trend was also obtained by Matsubara and Nakamura (1969) and Ryang *et al.* (1976).

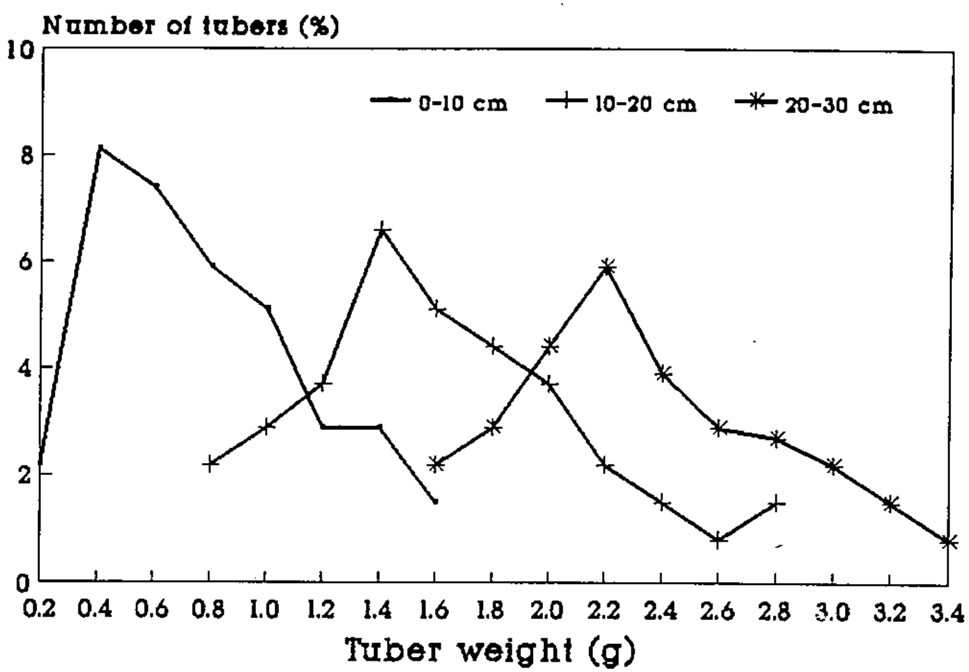

Figure 1. Percent distribution of *Eleocharis kuroguwai* tubers with respect to the tuber weights at different soil depths.

The formation of large tubers in deeper soils may have an ecological significance for *E. kuroguwai*. At sprouting, tubers situated at deeper soil would take more time to reach the soil surface, resulting in higher requirement for food as compared with those situated near the soil surface. Large tubers would supply more food to establish the seedling. Tuber size is positively correlated with seedling vigor. This fact was confirmed with tubers of *Sagittaria pygmaea* Miq. by Chun and Shin (1989).

Effect of Temperature

As tuber formation proceeds, tuber color changes from white to brown and finally to dark brown, depending on tuber maturity. When the new tubers were allowed to sprout, percent sprouting varied with the maturity (Table 1). At 10 days after planting (DAP) white immature tuber sprouted by 50% and the percent sprouting increased with time. However, only 10% of dark brown mature tubers sprouted at 80 DAP. This was due probably to dormancy difference between immature and mature tubers. The dormancy seems to be developed as the tuber matures.

Table 1. Percent sprouting of freshly harvested tubers of *Eleocharis kuroguwai*

Tuber maturity	Accumulative percent sprouting[1)] Days after planting,				
	10	20	40	60	80
Mature	0 b	0 b	0 b	10 b	10 b
Immature	50 a	80 a	85 a	85 a	85 a

1) Means in a column followed by a common letter are not significantly different at 5% level by Duncan's multiple range test.

Effect of simulated temperatures on tuber sprouting revealed that dormancy of new tubers was greatly affected by temperature to which the tubers were exposed. Non-dormant immature tubers were able to sprout after subjecting them to 5°C for 30 days, whereas percent sprouting decreased by about 30% when subjected to 20°C (Table 2). On the other hand, dormancy of mature tubers lasted longer under the temperature regime of 20°C. Slight dormancy break for the mature tubers was obtained when treated with 5°C for 30 days. This result clearly indicated that at 20°C mature tuber remained dormant, but dormancy was developed in immature tuber. However, at 5°C immature tuber remained non-dormant, but dormancy of mature tuber was slightly broken. Low temperature appeared to play an important role in dormancy characteristic of *E. kuroguwai* tubers.

Table 2. Tuber sprouting of freshly harvested tubers stored at two temperature regimes

Tuber maturity	Simulated temperature (c)	Accumulative percent sprouting[1)] Days after planting			
		5	10	30	60
Mature	5	0 c	30 b	45 b	45 b
	20	0 c	10 c	10 c	10 c
Immature	5	50 a	88 a	100 a	100 a
	20	10 b	33 b	33 b	33 b

1) Means in a column followed by a common letter are not significantly different at 5% level by Duncan's multiple range test.

Effect of low temperature on dormancy of immature tuber was confirmed under gradual decreasing temperature conditions (Table 3). When the immature tuber was subjected to 20°C, percent sprouting reached 20% at 20 days after planting (DAP). With decreasing the temperature to 15°C or lower the sprouting accelerated and increased. Further decrease to 1°C resulted in complete sprouting even at 5 DAP. In contrast, lowering the temperature did not affect dormancy breaking of mature tuber (data not presented).

Table 3. Percent sprouting of freshly harvested immature tubers as affected by simulated temperature regimes

Temperature regime (C)[1]	Accumulative percent sprouting[2]			
	Days after planting,			
	5	10	15	20
20	0 d	0 d	20 d	20 d
20-15	0 d	5 d	45 c	58 c
20-15-12	0 d	35 c	80 b	80 b
20-15-12-10	10 c	78 b	80 b	80 b
20-15-12-10-5	55 b	100 a	100 a	100 a
20-15-12-10-5-1	100 a	100 a	100 a	100 a

1) The respective temperature regime lasted for 5 days.
2) Means in a column followed by a common letter are not significantly different at 5% level by Duncan's multiple range test.

Effect of Soil Moisture and Depth of Burial

In the field, tubers formed in the soil are exposed to different soil environmental conditions. When tubers were subjected to different soil moisture conditions, viability of tubers buried at different depths varied (Table 4). In dry or moist soil condition viability of tubers buried at 25 cm depth was not affected, but when buried at 5 cm depth tuber viability was reduced as days after tuber burial increased. The reduction was greater in dry soil condition than in moist/one. However, no reduction occurred in submerged soil condition, regardless of depths of burial employed. The result indicated that tuber viability was influenced by both soil moisture condition and depth of burial. This influence would be affected by soil temperature fluctuation as shown in

Table 4. Viability of freshly harvested mature tubers buried at different soil depths as affected by soil moisture conditions

Moisture condition	Depth of burial (cm)	Percent survival[1]			
		Days after burial,			
		30	60	90	120
Dry	5	100 a	75 c	10 c	10 c
	25	100 a	100 a	100 a	100 a
Moist	5	100 a	88 b	75 b	75 b
	25	100 a	100 a	100 a	100 a
Submerged	5	100 a	100 a	100 a	100 a
	25	100 a	100 a	100 a	100 a

1) Means in a column followed by a common letter are not significantly different at 5% level by Duncan's multiple range test.

Figure 2. Soil temperature at 25 cm depth in dry soil condition ranged from 3° to 7°C, whereas at 5 cm depth the temperature sharply decreased to 0°C on December 7 and thereafter fluctuated between 0 and -3°C. Tubers near the soil surface would be susceptible to winterkill due to the effect of frozen surface soil. Under a simulated temperature condition, about 62% and 91% of the tubers were killed at -3 and -5°C, respectively, when exposed for 48 h (unpublished data). In submerged soil condition, however, tubers even at 5 cm depth escaped from freezing due probably to the insulating effect of frozen standing water. Although the standing water was frozen during the experimental period, soils below the soil surface were hardly frozen.

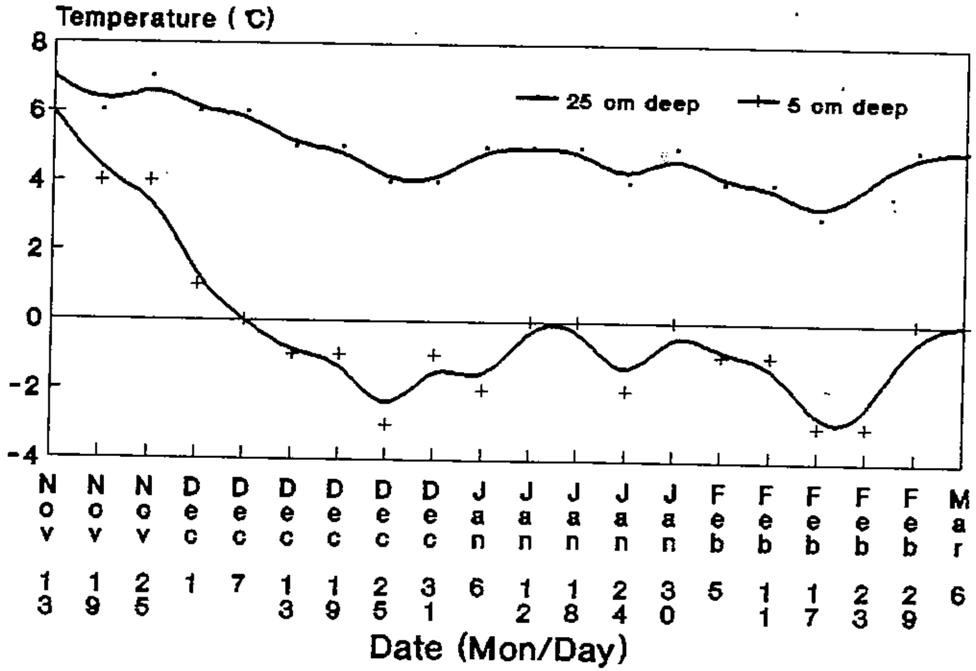

Figure 2. Changes in soil temperature at 5 and 25 cm soil depths in dry soil condition between November, 1990 and March, 1991.

Tuber dormancy was also affected by soil moisture and depth of burial (Table 5). Percent sprouting of tubers buried at 25 cm depth increased with increasing duration of burial, regardless of soil moisture conditions employed, whereas in dry and moist soil conditions percent sprouting of tubers buried at 5 cm depth increased by 60-day burial and thereafter decreased. The decrease in percent sprouting was greater in dry soil condition than in moist. This was attributed to different influences of soil temperature either on dormancy breaking or tuber viability or both. In submerged condition tubers at 5 cm depth sprouted significantly greater percentage than tubers at 25 cm depth during the experimental period, indicating great dormancy breaking of tubers at the upper soil layer.

Table 5. Percent sprouting of freshly harvested mature tubers buried at different soil depths as affected by soil moisture conditions

Moisture Condition	Depth of burial (cm)	Percent sprouting[1]			
		Days after burial			
		30	60	90	120
Dry	5	48a	73 a	8 c	5 d
	25	10c	38 b	60 b	73 b
Moist	5	40a	75 a	60 b	58 c
	25	10c	18 c	58 b	68 bc
Submerged	5	43a	65 a	83 a	88 a
	25	20b	40 b	53 b	63 bc

1) Means in a column followed by a common letter are not significantly different at 5% level by Duncan's multiple range test.

Results indicated that edaphic factors such as temperature, moisture, and depth of tuber burial markedly affect dormancy and viability of *E. kurogawai* tubers. Tuber sprouting test with immature and mature tubers revealed that tuber dormancy was obtained during the maturing process right after the formation of tubers. Once mature tuber became dormant, the tubers were not easily sprouted under a favorable environmental condition. In addition, the fact that immature tubers remained non-dormant when subjected to low temperature suggested that induction of dormancy would not be related with exposure to low temperature.

After the tubers of *E. kuroguwai* are formed in the upper 30 cm of soil in the fall, they are exposed to different soil temperature and/or moisture during the subsequent winter. Tubers situated near the soil surface are more influenced by soil moisture conditions than those situated at lower levels of soil, so that less viable tubers and percent sprouting in the former. This effect appeared to be related with differences in soil temperature at different soil depths. For example, in dry soil condition temperature is lower and more fluctuating near the soil surface than at lower levels. Considering the susceptible response of tubers situated near the soil surface to soil temperature and moisture, tillage operations in early winter followed by keeping the soil dry would bring the tubers to the soil surface and winterkill the tubers.

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HERBICIDE TECHNOLOGY

LOW VOLUME SPRAYING WITH GLUFOSINATE AMMONIUM, AN EVALUATION OF COMMERCIAL EXPERIENCE IN RUBBER AND OIL PALM PLANTATIONS

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ABSTRACT

A replicated small plot trial was initiated to see if rates of glufosinate ammonium could be reduced using low volume spraying. The rates that gave good efficacy from the small plot trial were then sprayed on commercial scale covering 2433 ha of oil palm and 208 ha of rubber. In low volume spraying, micron herbi (spinning disc) and solopump (modified mist blower) were compared. The average water volume used in low volume spraying ranged from 45 to 60 l/ha. One hundred ha of rubber were sprayed with high volume spraying. In high water volume spraying, Brass conventional knapsack sprayer and tractor mounted sprayer were compared. The average water volume used in high volume spraying ranged from 450 to 650 l/ha. All spraying were done under matured crops above 9 years old. The results from the small plot trial could be reproduced under commercial applications. There was approximately 26% to 46 % cost saving when compared to conventional knapsack spraying. The reduction in labour cost when using the micron herbi or solopump becomes a vital consideration under the present labour shortage in the Malaysian plantations.

INTRODUCTION

Herbicide application in the plantation is another field operation which is labour intensive. The 1989-90 annual report of the United Planting Association of Malaysia (UPAM) cited the estate sector is short of 7% of its labour requirement which is approximately 10,000 workers. Beside the 7% shortage, the estates are faced with high labour turnover of 20%. In some cases it is reported that the turnover could be as high as 40 to 60% (Editorial-The Planter 66, 1990). The labour force in Malaysia is not only facing shortage with a high turnover, but it is also getting expensive due to the rise in wages. This increase in wages has not been compensated by the increase in productivity. In 1975 one worker was required per 5.66 ha, and by 1987 the requirement rose up to 9.6 ha (Tan, 1990; Chew *et al.*, 1990).

For the last years, the emphasis on mechanization is on the increase and in many aspects significant development has contributed in maximizing labour output (Bek-Nielsen, 1989; Shuib *et al.*, 1989).

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In the area of herbicide application there has been many attempts to optimize spraying operations; one area where considerable research was done is in Low Volume Application Techniques (Liu and Faiz, 1981; Han and Maclean, 1983; Lee and Hitam, 1989).

Among the many new herbicides introduced for weed management in the last decade, glufosinate ammonium was found suitable in many aspects of weed control. Glufosinate ammonium is a new non-selective herbicide which effectively controls mixed weeds in plantation crops (Langelueddeke *et al.*, 1983; Purusotman *et al.*, 1985). The product was compared in sequential spraying or alternate spraying for general weed control (Chung and Chang, 1988) and in young oil palm and rubber where *Ottochloa nodosa* needs to be controlled (Chang *et al.*, 1988). The new compound was also acceptable in controlling weeds in sensitive crops like papaya (Lee *et al.*, 1987; Lim *et al.*, 1990) and durian (Lee and Yang, 1990). Crop tolerance was verified in oil palm and cocoa (Kuah *et al.*, 1987; Purusotman *et al.*, 1987). For general weed control in mature rubber plantations, glufosinate ammonium with partial systemic activity was found effective in low volume spraying (Purusotman and Langelueddeke, 1987; Kocher and Lotzsch. 1985). For the control of *Hedyotis verticillata*, glufosinate ammonium + metribuzin was applied with micron herbi and recommended in cocoa, based on crop tolerance and efficacy (Ong, 1990).

In 1991 more evaluations were done with glufosinate ammonium and glufosinate mixtures to further research on the efficacy of general weed control by adopting low volume spraying. The cost-effectiveness of this method was studied in a commercial scale. This paper reports on 3 areas:

1. Glufosinate ammonium and glufosinate ammonium mixtures recommendation for low volume spraying,
2. Actual rates used in commercial condition, and
3. Cost-effectiveness in adopting this technique.

MATERIALS AND METHODS

Small Plot Trial 1

The trial was done in mature oil palm with 70 to 80% shade. Four treatments of three replicates were sprayed on plot size 1.2 m by 20 m. The heights of the weeds were 8 to 10 inches. The weed composition was *Assystasia coromandeliana, Assystasia intrusa, Borreria latifolia, Paspalum paniculatum, Paspalum conjugatum, Ottochloa nodosa, Mikania micrantha, Nephrolepis biserrata* and *Hedyotis verticillata*. A single headed micron herbi with red restrictor was used to attain 60 l of water volume per ha. Visual observations were made on 0, 15, 30, 60, and 90 days after application.

Commercial Spraying

Four methods of spraying equipment were compared:

1. Modified mist blower (solopump)
2. Spinning disc (micron herbi)
3. Tractor mounted sprayer
4. Brass knapsack sprayer.

Plantations with oil palm and rubber were chosen in the state of Pahang and Johore. The following were recorded daily during herbicide applications wherever possible:

1. Crop and age
2. Weed spectrum
3. Number of hectar sprayed
4. Type of equipment
5. Petrol used
6. Type and chemical used for the day
7. Labour.

In every field, weed composition was recorded as % of broadleaf, fern and grass. It was then classified as mixed or grass dominant. Actual amounts of chemical and petrol used were noted. The number of people spraying and carrying water for the day were recorded. The chemical consumption per day was measured in litres and it was then calibrated in litres per ha based on the treated area (i.e. 25% and 30% of the area is treated in oil palm and rubber respectively). The labour requirement was calculated as man-day based on 8 hours of spraying per day per person. The average water volume for both micron herbi and solopump was approximately 40 to 60 l/ha. Details of main weeds, chemicals used and other relevant information are summarized in Appendix 1 and Appendix 2.

RESULTS OF SMALL PLOT TRIAL 1

At 30 days after application all treatments reached 90 % control. At 90 days after application glufosinate ammonium at 1.0, 1.5 l/ha and glufosinate ammonium at 1.5 l/ha + 0.1 2,4-D amine l/ha gave similar control and glufosinate ammonium at 2.0 l/ha gave slightly better control.

COMMERCIAL RESULTS (LOW VOLUME SPRAYING)

Results With Micron Herbi (Spinning Disc)

Oil Palm - crop, age 17-28 years (854 ha)

A total of 854.4 ha were sprayed with glufosinate ammonium . The crop age ranged from 17 to 28 years. The shade was 80% and the weed spectrum was dominated by *A. conyzoides, B. latifolia* mixed with *P. conjugatum* and *O. nodosa*. The heights of the weeds were as low as 8 to 10 inches; the density was sparse. The total cost per ha ranged from $5.72 to $9.96. The labour cost ranged from $3.12 to $3.60. The chemical cost per ha ranged from $2.60 to $6.84. The chemical rate ranged from 0.75 l/ha to 1.96 l/ha (refer Table 1). The values of labour, chemical and total cost/ha were plotted out against the rate l/ha in Figure 1. The trends showed that there was a positive corelation between the total cost/ha and the chemical rate l/ha. The trend lines for the total cost/ha and the chemical cost/ha have almost the same gradient. The labour cost was stable which indicated that the increase in cost/ha was mainly due to chemical cost.

Oil Palm - crop, age 11 years (1212 ha)

In Table 2 and Figure 2, fields with 11 years old oil palm were compared, where the shade was somewhat less compared to the fields in Table 1. The weeds spectrum was mixed, growing up to heights of 18 to 24 inches. The rate of glufosinate ammonium ranged between 1.25 to 1.78 l/ha + 2,4-D amine with the rate of 0.5 to 0.05 l/ha. The labour cost per ha ranged between $4.03 to $5.18 and the chemical cost per ha ranged from $5.44 to $7.92. These observation were made on 1212 ha.

Rubber - crop, age 13 to 16 years (178 ha)

In mature fields of rubber with age ranging from 13 to 16 years old, the evaluation was conducted in an area of 178 ha (Table 3). Infestation of weeds were similar to the fields in Table 2. There was a slight drop in the average labour cost at $3.26, but the average chemical cost was at $6.52 and the average total cost per ha was $9.78. Costing trends were similar to the first two graphs. The rates applied were glufosinate ammonium from 1.14 to 1.64 l/ha and 2,4-D amine from 0.71 to 1.02 l/ha.

Results With Solopump (Modifief Mist Blower)

Rubber - crop, age 10 to 20 years (150 ha)

One hundred and fifty ha of mature rubber of between 10 to 20 years were sprayed with solopump. Rates of glufosinate ammonium applied were 1.00 to 1.71 l/ha and 2,4-D amine from 1.00 to 1.71 l/ha. These fields had high infestation of ferns (mainly *N. biserrata, Scleria bancana, Dicranopteris linearis*) growing to a height of 30 inches. The shade intensity ranged from 70 to 80%. The data are summarised in Table 4. The results show a similar trend as in the micron herbi field results. The average chemical cost/ha was high at $7.16 l/ha, however the labour cost/ha dropped to $2.35/ha. There was also an additional average cost of petrol at $1.17 l/ha. The average cumulative cost/ha was at $10.68 which is slightly higher than for micron herbi in Table 3.

Oil Palm - crop, age 16 to 24 years (177 ha)

Another 177 ha of oil palms were sprayed with glufosinate ammonium at rate from 0.67 to 1.33 l/ha + Dasaflo from 1.33 to 2.67 l/ha, The palm age was between 16 to 24 years old. The shade was approximately 80%. The weed spectrum was similar to the fields described in Table 4. The average labour cost at $2.62 and chemical cost at $8.66 accumulated to a total cost of $12.53/ha. The cost trends were similar to the previous graphs (Table 5, Figure 5).

Oil Palm - crop, age 5 to 9 years (190 ha)

One hundred and ninety ha (Table 6 and Figure 6) of oil palm were sprayed with solopump. The weeds infestation were dominated by grass. The glufosinate ammonium rate of application was from 0.93 to 1.3 l/ha + Dasaflo from 1.85 to 1.67 l/ha. The average labour cost was $2.93, the average chemical cost was $10.19 and the average total cost was $14.53. The cost trends were similar to the other graphs (Table 6, Figure 6).

COMMERCIAL RESULTS (HIGH VOLUME SPRAYING)

Results of Tractor Mounted Spraye

Rubber - crop, age 13 years (66 ha)

Sixty-six ha of rubber were sprayed with tractor mounted sprayer. The age of the rubber was 13 years old. The shade was approximately 80% with a weed spectrum of mixed grass and broadleaf. Glufosinate + 2,4-D amine were applied in these fields. The rate of glufosinate ammonium ranged from 1.3 to 1.71 l/ha and 2,4-D amine from 0.4 to 0.57 l/ha. The average labour cost was $2.76 and the average chemical cost was $5.92. Beside these, there was an additional cost of tractor charges at $4.84, which accumulated to a total cost of $13.58/ha. The cost trends were again similar as in micron herbi and solopump. The average water volume applied was 600 - 700 l/ha (Table 7, Figure 7).

Results of Conventional Knapsack Sprayer

Rubber - crop, age 16 years (54 ha)

Fifty-four ha of 16 years old rubber with 80% shade were sprayed with conventional knapsack sprayer. Glufosinate + dasaflo at an average rate of 1.5 l/ha + 3.11 l/ha were applied. The weed spectrum was grass dominant. The average labour cost was $5.90/ha and the average chemical cost was $11.67 l/ha and the average total cost was $17.96. Trends in costs were similar to those for micron herbi, solopump and tractor mounted sprayer. The average water volume applied was 400-450 l/ha (Table 8, Figure 8).

DISCUSSION

Small Plot Trial 1

The trial indicated that by using micron herbi it was possible to reduce the rate to 1 l/ha under this very low density of weeds. Previous studies showed that under high density population higher rates are required (Purusotman *et al.*, 1985).

Commercial Spraying

It was found that there were little differences in active ingredient used to get comparable efficacy with all forms of spray equipment under heavy weed pressure. When comparing the different equipment there is cost saving from 27% to 47% from micron herbi and solopump when compared to conventional knapsack sprayer (Table 9). The cost saving comes from labour. This can be inferred from manday per ha (refer Figure 9); where for conventional knapsack sprayer is approximately 1.8 ha/manday compared to 4.8 ha/manday for solopump, 4.4 ha/manday for micron herbi and 3.8 ha/manday tractor mounted sprayer. These findings are similar to that of Han (1982).

One part not considered in this paper is the transport charged to carry large quantitities of water (where necessary) for conventional knapsack sprayers. Maintenance of equipment is more critical with low volume application to ensure cost savings and safety. Even though studies have shown that using controlled droplet application, the contamination could be less compared to conventional knapsack sprayer using cone nozzle (Lee, 1989), one should strictly adhere to the protective clothing policy by wearing long trousers, long shirt with hand gloves added with face mask (Lee and Yang, 1990). When operating with the solopump the speed of the motor should be maintained constantly (5000 rpm) as any increases in the speed could atomise finer droplets which could increase the chances of inhaling the spray drift.

Modification, Replacement and Depreciation of Equipment

In micron herbi the present spray solution container with a capacity of 2.5 l/ha was found to be too small. This needed frequent refilling. In most areas 4 liter containers (usually empty weedicide containers) were modified and attached.

In some cases discarded solopumps (without the motor) were fixed to a spinning disc; basically making use of the bigger tank capacity was found to further cut down refilling time. Several methods of power were used, from dry cell to wet cell (attached to the waist), to rechargeable battery. The present thoughts seem to favour rechargeable batteries, due to ease of handling and long lasting capabilities.

The depreciation cost of the micron herbi and solopump could only be estimated. Most parts of the micron herbi can be repaired or replaced at the estate workshop by using local parts. The only part that needs replacement is the motor. The cost of the motor is $115.00 per unit. It is expected to last 500 hours of running time. To optimize life span of the motor, it is best to use 6 volts battery, not 12 volts as this may overload the motor (Han, K.C., *pers. comm.*).

Solopump which costs $985.00 is expected to last 1000 to 1500 hours under normal field use. Proper maintenance is essential to overcome breakdown during spraying.

Chemical Recommendations

In trial situation it is possible to reduce rates with glufosinate ammonium to 1 l/ha under low infestation of weeds. However in actual field condition it is best to follow the recomended rate at:

1. Glufosinate ammonium 1 l/ha + Dasaflo 2 l/ha
2. Glufosinate ammonium 1.5 l/ha + 2,4-D amine 0.1 l/ha.

The rate of 2,4-D amine could be increased depending on the intensity of broadleaf infestation.

CONCLUSION

Using low volume spraying technique can be one way to further improve labour productivity and certainly could be instrumental in solving the labour shortage in Malaysian plantations. Under actual field conditions, glufosinate ammonium effectively controlled mixed weeds with low volume spraying. The present range of relative low toxic and translocative herbicide allows plantations to switch to this method of application. With the need in the industries coupled with favorable herbicides, the low volume spraying will be the preferred technique in the very near future. One other aspect of low volume spraying is to have mandatory training from the executives to the sprayers on the techniques. Many would shy away if not convinced on the spraying techniques. Proper calibration and safety standards are essential to avoid high fluctuation in cost and control.

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TOLERANCE OF GUAVA AND STARFRUIT TO GLUFOSINATE-AMMONIUM APPLICATION WITH SIMULATED DRIFT

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ABSTRACT

There is a need to look for suitable herbicides for use in tropical fruit crops. A suitable herbicide should take into consideration crop tolerance, since tropical fruit crops are very sensitive. A tolerance trial to determine the sensitivity of two important fruit crops, guava and starfruit was carried out. It compare glufosinate ammonium at 500 g a.i./ha with paraquat at a rate of 560 g a.i./ha and glyphosate at 540 g a.i./ha. Results after nine months indicated that while all three herbicide treatments showed higher stem girth increases than the control which was manually weeded, the stem girth increase for guava was highest in the glufosinate treated plot; while in starfruit, a high girth increase similar to paraquat treatment was shown.

INTRODUCTION

The fruit industry in Malaysia has undergone growth in planting area and increased productivity between 1980 to 1988. The total fruit exports have increased from M$6.9 million in 1980 to M$96.8 million in 1988 (Department of Agriculture, 1989/1990). Tropical fruits such as *Psidium guajava L.* and *Averrhoea carrambola L.*, commonly known as guava and starfruit respectively have grown increasingly important in Malaysia. Guava and starfruits have high local consumption and constitute 1.4% and 15.2% of the total fruit export value (Departement of Agriculture, 1989/1990).

As a result of intense promotional activity and the realization of its high nutritional value, demands for these fruits from the EEC, Hongkong and Japan have increased tremendously and is seen to have further growth potential. Figures collected in 1987 showed that 1540 hectares and 550 hectares is cultivated under guava and starfruit respectively (Department of Agriculture).

Cultivated land for these two crops has increased and the management practices have also improved. This among others has led to an intensified use of herbicides. However, susceptibility of fruit crops to different herbicides has limited the use to only a few with the most common being glufosinate ammonium, glyphosate and paraquat herbicides. For example, Lee and Chan

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(1990) reported that slight phytotoxicity on durian was induced by paraquat and diuron, glyphosate, MSMA, fluazifop- butyl, 2,4-D Amine and metsulfuron methyl after four weeks. Similar observations were also reported by others for some herbicides thought to be safe to fruit crops. A trial to determine crop tolerance of guava and starfruit to herbicide application was designed and implemented to substantiate these reports.

Guava and starfruit crops were chosen because of their increasing import
tant to the fruit industry in Malaysia.

MATERIALS AND METHODS

The field experiment was carried out on six month old immature guava and starfruit plants at the Hoechst Experimental Station, Malaysia. Selected three month old polybag stage guava and starfruit plants were transplanted into the field in late May 1990 and the first application of herbicide commenced three months later in late August. Both crops were planted alternately in strips with an intrarow distance of 2 m and a interrow of 3 m. This was replicated four times. Table 1 lists the treatments used in this trial.

Table 1. List of treatments and rates

Treatment a.i.	g a.i. prod/l	g a.i./ha	prod l/ha
1. Control	-	-	-
2. Glufosinate	150	500	3.3
3. Glyphosate	360	540	1.5
4. Paraquat	200	560	2.8

The trial was of a Randomized Complete Block Design (RCBD). The method used was strip spraying where treatments were carefully applied in planting strips. Also a simulation of spray drift was carried out by painting the two lowest leaves using a brush paint dipped in the spray solution to simulate spray drift.

Treatment solutions were based on a 450 litres of water volume per hectare and applied using a hand operated knapsack sprayer fitted with a 55/64 hollow cone nozzle.

1. Management Practices

All aspects of management practices vital for proper plant development and survival were adhered to. These included regular plant watering, manuring, manual weeding during the first three months, providing adequate shad-

ing and pest management. After the commencement of this trial, these factors were kept uniform and only the herbicide treatments varied.

Complesal 15:15:15 was used as fertilizer for top dressing with each plant receiving 60 grams at two months and then 120 grams at seven months. For pest control, Decis (deltamethrin) at the rate of 5 and 10 ml per 4.55 litres tankmix was used to control common pest of guava and starfruits. These include leaf eating beetle, leaf eating grasshoppers and sucking insects such as *Helopeltis*. At one stage, Thiodan 10 ml/4.5 litres was used on grasshoppers (*Valanga nigricornis*).

2. Application of Treatments

The application of treatments was initially scheduled for every third month or four applications per year. However, additional applications had to be made at more frequent intervals due to rain interference. Table 2 shows the schedule for the applications carried out.

Table 2. Treatment of application

Application no.	Months after 1st applic.	Remarks
1st Application	0	17 mm rain after 3 hours
2nd Application	2	13 mm rain after 5.5 hours
3rd Application	4	Rainfree
4th Application	7	15 mm rain after 4 hours
5th Application	9	Rainfree

Rain fell in three of the applications. The first application recieved 17 mm rain after 3 hours of application, the second 13 mm at 5 hours and the fourth recieved a 15 mm of rainfall at four hours after application. This resulted in a second application required within 60 days of a first application. Figures 1 and 2 show the rain intensity and number of rain days for the month during the trial. Although the amount of rain received was highest for the month of December 1990 reaching 2140 mm, the number of rainy days was highest for the months of September, October, November in 1990 and in April 1991 (above 15 days of rain per month).

3. Assessment Method

Assessments were carried out with the objective of determining the following:

a. Crop tolerance

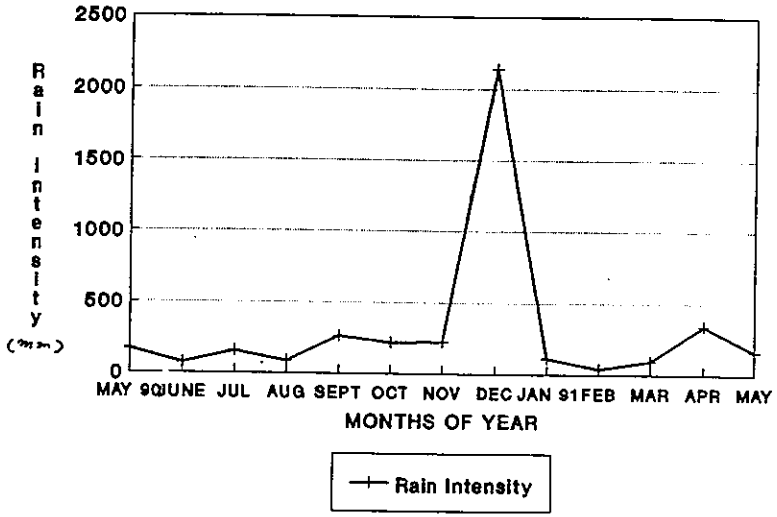

Figure 1. Rain intensity per month.

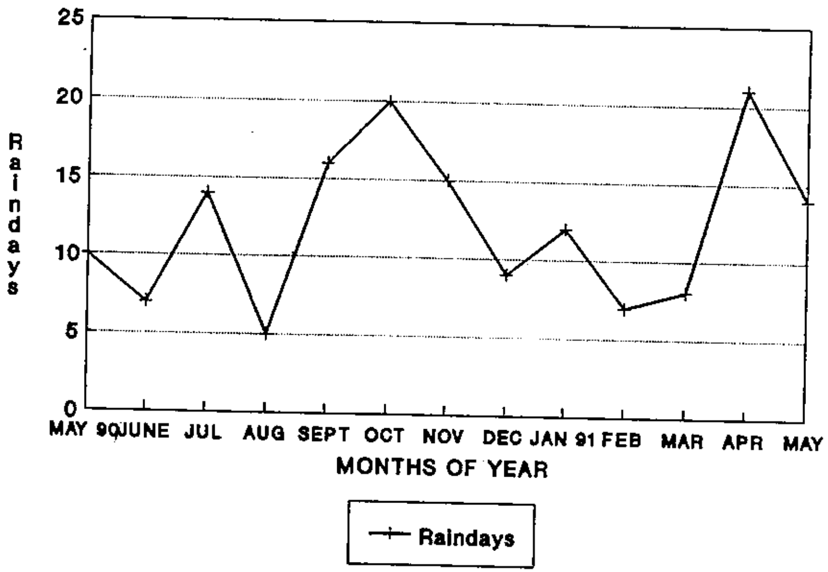

Figure 2. Number of raindays per month.

b. Efficacy.

a. Crop tolerance

As a means of determiining the crop tolerance of guava and starfruit to the treatments, the following criteria were adopted.

(1) Stem girth measurement (cm)

(2) Plant length measurement (cm).

Observations were also made on damage symptoms to the plant.

Assessments on the stem girth and plant length were made at three month intervals while observations of visual symptoms were made on a regular basis. The stem girth and plant length measurements were analysed. The percent increase after nine months of trial were then compared for herbicidal effects. A statistical analysis was then conducted and the Duncan Multiple Range Test carried out to determine significance at 95% confidence level.

b. Efficacy

The precent kill of weeds was recorded and later the percent green of reemerging weeds was converted using the Henderson-Tilton formula and then graphically analysed.

RESULTS AND DISCUSSION

1. Missing Plants

The plant samples in this experiment were transplanted from the nursery to the field and were allowed to adapt but being very young and sensitive were found to be vulnerable to three factors which were:

a. Transplanting shock

b. Harsh weather conditions

c. Chemical exposure.

Guava and starfruit crops were tested for crop tolerance in this experiment and appeared that the starfruit was more hardy than guava. This conclussion was drawn because there were no missing plants recorded among starfruits while guava suffered five plant losses.

Table 3 shows the total number of guava plant losses suffered.

Table 3. Guava plant losses in strip spraying plus leaf painting method

Treatments	Rate g a.i./ha	Total number of plants	Missing plant	Dead through herbicide injury
1. Control	-	11	1	0
2. Glufosinate	500	11	1	0
3. Glyphosate	540	11	1	0
4. Paraquat	560	11	1	0
Total		44	4	1

Plant losses are classified as missing or dead. Missing plants are those excluded from this experiment by virtue of being killed due to factors apart from chemical contact. These were due to the harsh weather condition (dry at some points of the trial) and mechanical injury. Dry periods were experienced between mid-May to mid-August 1990 and then again between January till the end of March 1991. Plants killed as a result of chemical contact were classified "dead" and these were considered in the analysis.

It was found that a total of four guava plants, one each from the control (manually weeded), glufosinate, glyphosate and paraquat treated plots were missing while a single plant from the glyphosate plot was classified "dead". Severe symptoms of chemical spray damage were observed on this particular plant and it eventually did not survive. The symptoms were bright yellow discolouration of the leaves, drooping leaves followed by defoliation.

2. Crop Tolerance

a. Guava

Tables 4a and 4b show results of the treatment effects on stem girth and plant length development of guava. The plants were subjected to strip spraying plus simulated drift by leaf painting of two lowest leaves with the treatment solution.

Results from Table 4a shows that glufosinate at 500 g a.i./ha and paraquat at 560 g a.i./ha treatments recorded almost similar stem girth increases of 121% and 106% respectively, while glyphosate at a rate of 540 g a.i./ha showed only a 77% increase.

This indicates that there is risk of injury to guava through physical development if spray drift were to occur when applying glyphosate herbicide at this rate.

On plant length (Table 4b), stem girth increases were similar. Glufosinate, glyphosate and paraquat treatments each recorded 142%, 154% and 157% gains respectively.

Table 4a. Treatment effects on stem girth development of guava (strip spraying and leaf painting method)

Treatments	Rate g a.i./ha	Months after 1st application (stem girth means = cm)				Stem girth increase
		0	3	6	9	
1. Control	-	3.9a*)	4.4a*)	6.0a*)	5.8a*)	49%
2. Basta 15 (150 g/l)	500	3.4a	4.4a	6.1a	7.5a	121%
3. Roundup (360 g/l)	540	3.5a	4.5a	5.2a	6.2a	77%
4. Paraquat (200 g/l)	560	3.6a	4.9a	6.5a	7.4a	106%

*) Means followed by the same letter are not significantly different.

Table 4b. Treatment effects on stem girth development of guava (strip spraying and leaf painting method)

Treatments	Rate g a.i./ha	Months after 1st application (stem girth means = cm)				Stem girth increase
		0	3	6	9	
1. Control	-	75a*)	100a*)	158a*)	153a*)	104%
2. Basta 15 (150 g/l)	500	77a	110a	155a	186a	142%
3. Roundup (360 g/l)	540	61a	99a	127a	155a	154%
4. Paraquat (200 g/l)	560	74a	112a	154a	190a	157%

*) Means followed by the same letter are not significantly different.

All herbicide treatments recorded a higher increase in plant length compared to the 104% increase recorded from the control which was manually weeded.

b. Starfruits

Tables 5a and 5b show results of treatment effects on stem girth and plant length development of starfruits when sprayed in strips with the simulation of drift. Substantial stem girth increases were recorded for glufosinate at 500 g a.i./ha and paraquat at 560 g a.i./ha gaining 236% and 252% respectively. Glyphosate at 540 g a.i./ha once again recorded a lower 197% stem girth increase. The control plot which was manually weeded recorded a similar 198% girth increase.

On the plant length development, an increase of 233% was recorded from glufosinate at 500 g a.i./ha in comparison to 216% and 208% from the 560 g a.i./ha paraquat treatment and control respectively.

Glyphosate treatment on the other hand showed only a 177% increase in the plant length. These results again suggest that lowest risk is posed when applying glufosinate at the recommended rate in starfruits. As these results show, glufosinate does not interfere with the development of the stem girth and plant length in immature starfruit even when drift is introduced through simulation.

Table 5a. Treatment effects on stem girth development of guava (strip spraying and leaf painting method)

Treatments	Rate g a.i./ha	Months after 1st application (stem girth means = cm)				Stem girth increase
		0	3	6	9	
1. Control	-	3.6a*)	5.9a*)	7.9a*)	10.4a*)	189%
2. Basta 15 (150 g/l)	500	3.3a	5.9a	8.5a	11.1a	236%
3. Roundup (360 g/l)	540	3.4a	5.4a	7.4a	10.1a	197%
4. Paraquat (200 g/l)	560	3.3a	6.5a	9.1a	11.6a	252%

*) Means followed by the same letter are not significantly different.

Table 5b, Treatment effects on stem girth development of guava (strip spraying and leaf painting method)

Treatments	Rate g a.i./ha	Months after 1st application (stem girth means = cm)				Stem girth increase
		0	3	6	9	
1. Control	-	63a*)	103a*)	144b*)	194a*)	208%
2. Basta 15 (150 g/l)	500	63a	134a	180a	210a	233%
3. Roundup (360 g/l)	540	65a	116a	154ab	180a	177%
4. Paraquat (200 g/l)	560	67a	138a	181a	212a	216%

*) Means followed by the same letter are not significantly different.

3. Efficacy

Figure 3 shows the efficacy of the treatments applied in the planting strips at four weeks after application. All three herbicide treatments show similar control of total weed at this stage. Glufosinate at 500 g a.i./ha, glyphosate at 540 g a.i./ha each recorded 72%, 82% and 70% total weed control respectively. Major weeds in sequence of importance consists of *Paspalum conjugatum, Borreria latifolia, Cleome rutidospora, Pueraria phaseoloides* and *M. cordata.* After subsequent applications, it was found that *Paspalum conjugatum* eventually became the dominant weed species in the glufosinate and paraquat plots while *Borreria latifolia* remained as the major weed species in the glyphosate plot followed by *Paspalum* sp.

CONCLUSSION

This experiment has revealed several interesting points for discussion. The following are the indications:

1. Guava and starfruit show different levels of tolerance to the herbicide used in the field if drift is not avoided.
2. Glufosinate at 500 g a.i./ha does not interfere with the development of stem girth and plant length of guava and starfruits.
3. Glufosinate at 500 g a.i./ha pose lowest risk when application is carried out in the field where poorly supervised spraying is common.
4. Glufosinate at 500 g a.i./ha gives equal weed control to glyphosate at 540 g a.i./ha and paraquat at 560 g a.i./ha in this trial.

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PROTEIN PATTERNS OF RICE CULTIVARS AFFECTED BY THIOBENCARB HERBICIDE

H.Y. KIM, K.U. KIM, AND D.H. SHIN[1]

ABSTRACT

This study was conducted to evaluate the susceptibility of rice cultivars to thiobencarb herbicide through determination of protein patterns using SDS-PAGE. In both greenhouse and laboratory screening tests, IR 10198-66-2 and IR 9660-50-3-1 showed relatively tolerant response to thiobencarb while IR 22, IR 31802-48-2-2-2 and IR 20656-R-R-R-6-1 were susceptible to it. The total protein content of susceptible cultivars markedly decreased as the concentrations of thiobencarb increased, but tolerant cultivars such as IR 10198-66-2 and IR 9660-50-3-1 showed very slight changes suggesting that protein synthesis of susceptible cultivars may be inhibited by thiobencarb. The protein profiles of the tolerant cultivars were not much affected by thiobencarb treatment. However, the bands with molecular weights between 94kD and 30kD and of about 14.4kD were not observed in the susceptible cultivars, indicating that varied susceptibility of rice cultivars against thiobencarb can be attributed it difference in protein metabolism affected by thiobencarb herbicide.

INTRODUCTION

Thiobencarb [S-(4-chlorobenzyl)-N,N-diethylthiolcarbamate] is a carbamate herbicide known to be selective for preemergence control of grasses and broadleaved weeds in paddy fields. Mechanism of thiobencarb is not clear yet although it has been known to inhibit protein synthesis and biosynthesis of gibberellin-induced α-amylase in aleurone layer of germinating seeds (Kunikazu *et al.*, 1970; Mazur *et al.*, 1970). In rice (*Oryza sativa* L.) thiobencarb is absorbed rapidly and translocated to the upper part of the plant (Ishikawa *et al.*, 1976). The absorption of this herbicide was higher in the upper part of the plant than in the root and dissipation of it was rapid in the upper part compared to that in the root (Ichiro *et al.*, 1971). Differential cultivar response can be attributed to differences in ecogeographic race (Shin, 1987).

In addition, Ichizen (1976) reported that Japonica type cultivars had higher tolerance to thiobencarb than those of Indica type and their hybrid cultivars. Kim *et al.* (1975) made the similar report that phytotoxicity of the mixture of thiobencarb and simetryne was higher in Indica x Japonica type cultivars than in Japonica. Shin *et al.* (1988) reported that there was differential cultivar response of rice among Indica type against thiobencarb herbicide.

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Many herbicide-resistant plants have been identified either in weeds or in crops (Amrhein *et al.*, 1980; Anderson *et al.*, 1986; Barbara *et al.*, 1989; Beversdorf *et al.*, 1985; Chaleff *et al.*, 1987; Darmency *et al.*, 1985; Hassan *et al.*, 1986; Ichiro *et al.*, 1971). Genetic variation in herbicide tolerance of plant can be used to modify the crop genotype to tolerate herbicides or raise their level of tolerance to herbicides, so that it should be possible to improve herbicide selectivity (Comai *et al.*, 1985; Smith *et al.*, 1988).

Many works have been done to identify differential cultivar response of rice to thiobencarb herbicide (Ichizen, 1976; Kim *et al.*, 1975; Shin, 1987). However, mechanism of differential cultivar responses has not been precisely understood, especially those based on biochemical aspects. The mechanism of differential response of rice cultivar to the specific herbicide is necessary to improve herbicide selectivity or develop a herbicide-tolerance cultivar by introducing genetic variation in herbicide tolerance of plants.

This experiment was conducted to determine any possibility of difference in protein patterns between thiobencarb-resistant and susceptible rice cultivars recommended by Shin *et al.* (1987) and further confirmed by the preliminary study.

MATERIALS AND METHODS

Experiment 1a. Greenhouse screening for rice cultivar tolerance to thiobencarb

The seeds of five rice cultivars i.e. IR 22, IR 9660-50-3-1, IR 10198-66-2, IR 31082-44-2-2-2, and IR 20656-R-R-R-6-1 obtained from the International Rice Research Institute (IRRI) were soaked for 24 h and incubated for 48 h before seeding. Germinated seeds of each rice cultivar were planted in pots and allowed to grow for 3 days. Four plants having similar height and appearance were transplanted in 5 rows in each plastic trays filled with a clay loam soil which was sieved through a 3 mm sieve. Water was maintained at a depth of 2 cm just before herbicide application.

The commercial formulations of thiobencarb (7% G) were applied at rates of 3.0, 4.5, 9.0, and 12.5 kg/10a at 4 days after transplanting. Treatments were replicated three times and untreated controls were provided for comparison.

Plant height, root length, and dry weight of whole plant were determined to evaluate the responses of the cultivars to the herbicide. Plant height and root length were taken from the base of the culm to the top of the longest leaf or root at 15 days after treatment (DAT). Dry weight was measured after oven-drying for 48 at 80°C. Data were analysed using Duncan's Multiple Range Test (DMRT).

Experiment 1b. Laboratory screening for rice cultivar tolerance to thiobencarb

This experiment was conducted to compare varietal responses of rice to thiobencarb with laboratory screening method.

Five rice cultivars used in Experiment 1a were again evaluated in this experiment. Ten seeds sterilized for 15 min. with 1% sodium hypochlorite were germinated on filter paper in petridishes of 9 cm diameter. Ten ml of thiobencarb solution of 3.0, 4.5, 9.0, and 12.5 kg/10a thiobencarb were applied to the petridishes which were then placed in a chamber maintained at constant temperature of 25°C under dark condition. Each treatment was replicated three times. Data on shoot and root length were taken at 2 DAT.

Experiment 2. Protein patterns of rice cultivars

Plant materials

Rice seeds sterilized with % sodium hypochlorite were germinated at 25°C in an incubator under dark condition. Ten ml of thiobencarb solution having 1.0, 3.0 and 5.0 ppm were added to the petridishes.

Protein assay

One hundred mg of fresh shoots were ground into powder in a mortar and resuspended in 1 ml of extraction buffer (0.0625 M Tris-HCl, pH 6.8, 5% mercaptoethanol, 4% glycerol, 3% SDS). The homogenate was centrifuged for 10 min. at 12,000 rpm. The supernatant was taken in order to measure protein content. Protein content was assayed by the Bradford method (Bradford, 1976). Lypophilized bovine gamma globulin was used as a standard for determining protein content.

Gell electrophoresis

One hundred mg of etiolated shoots in each rice cultivar treated with various concentrations of thiobencarb for 3 days was ground into powder and resuspended in 1 ml of sample buffer (0.0625 M Tris-HCl, pH 6.8, 5% mercaptoethanol, 4% glycerol, and 3% SDS). The homogenate was heated in a water bath at 95°C for 4 min., allowed to cool at room temperature and centrifuged at 15,000 rpm for 15 min. The supernatant was then stored at 4°C until electrophoresis.

To separate proteins in one dimensional gel electrophoresis, the SDS-polyacrylamide gel system (Laemmli, 1970) was employed using slab gels.

The separating gel was prepared by adding 6.5 ml of 30% acrylamide/0.8% bisacrylamide, 3.75 ml of 4 x 1.5 M Tris-HCl/0.4% SDS (pH 8.8), 4.75 ml of distilled water, 50 ul of 10% ammonium persulfate, and 10 ul of TEMED.

The stacking gel was prepared 0.65 ml of 30% acrylamide/ 0.8% bisacrylamide, 1.25 ml of 4 x 0.5 M Tris-HCl/0.4% SDS (pH 6.8), 3.05 ml of distilled water, 25 ul of 10% ammonium persulfate, and 5 ul of TEMED. Electrode buffer concentrations were 0.025 M Tris-HCl (pH 8.3), 0.195 M glycine, and 0.1% SDS. Fifteen ul of extracted proteins were loaded onto the slab gels. Electrophoresis was carried out at 25 mA for the stacking gel and then at 40 mA for the separating gel. After electrophoresis, the gels were fixed in the solution [50% (v/v) methanol, 10% (v/v) acetic acid, and 40% (v/v) distilled water] and then stained with Coomassie brilliant blue [50% (v/v) methanol, 0.05% (w/v) Coomassie brilliant blue R, 10% (v/v) acetic acid, and 40% (v/v) distilled water]. The stained gel were subjected to destaining in the solution [5% (v/v) methanol, 7% (v/v) acetic acid, and 88% (v/v) distilled water].

RESULTS AND DISCUSSION

Rice Cultivar Response to Thiobencarb under Greenhouse and Laboratory Conditions

Plant height and root length were decreased as the thiobencarb concentration increased irrespective of the cultivars used in greenhouse conditions. The greater decrease in plant height and root length was observed in IR 22, IR 31802-48-2-2-2, and IR 20656-R-R-R-6-1 than those of IR 10198-66-2 and IR 9660-50-3-1 (Table 1). A similar trend was observed in dry weight of rice cultivar treated with thiobencarb (Fig. 1). In fact, there are no definite basis to classify tolerant and susceptible cultivars against herbicide. However, in many herbicide screening experiments, the cultivars screened have been categorized for convinience into the two groups, i.e. tolerant and susceptible cultivar. Shin *et al.* (1987) reported that some cultivars which when treated with 2 x 10^{-5} M thiobencarb, had plant heights and dry weight equal to or greater than 60% of the untreated check were regarded to be tolerant to the herbicide. According to this criteria, IR 10198-66-2 and IR 9660-50-3-1 can be classified as the tolerant cultivars to thiobencarb while IR 22, IR 31802-48-2-2-2, and IR 20656-R-R-R-6-1 were the susceptible ones to thiobencarb.

In this study, regardless of the herbicide rates used, two varieties namely IR 10198-66-2 and IR 9660-50-3-1 showed more than 80% of untreated control in both plant height and dry weight, showing relatively torelant to thiobencarb herbicide. The results obtained in this experiment showed a similar trend to those of Shin *et al.* (1987) although different screening systems were employed.

Table 1. Effect of different concentrations of thiobencarb on the growth of several rice cultivars treated in pot under greenhouse condition [1)]

Cultivars	Herbicide application rates (kg/10a)	Shoot length				Root length			
		3.0	4.5	9.0	12.5	3.0	4.5	9.0	12.5
		% of control							
IR 10198-66-2		99.7	98.3	91.3	86.2	99.3	89.2	92.5	88.7
IR 9660-50-3-1		98.8	97.5	89.5	84.9	98.4	94.7	89.3	86.5
IR 22		87.3	83.7	71.6	63.9	89.9	86.7	75.1	70.3
IR 31802-48-2-2-2		91.3	87.6	80.6	68.8	92.1	88.3	74.8	69.3
IR 20656-R-R-R-6-1		87.4	85.2	69.2	60.8	88.3	82.7	78.5	69.5

1) Average of 5 plants with 3 replications, determined at 15 days after treatment.

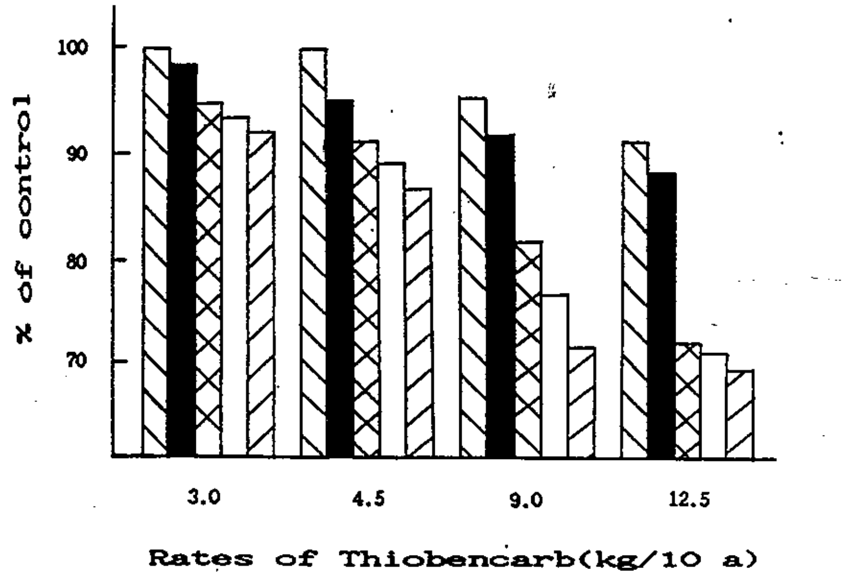

Figure 1. Dry weight of rice cultivars as affacted by various rates of thiobencarb.

- IR 10198-66-2
- IR 9660-50-3-1
- IR 22
- IR 31802-48-2-2-2
- IR 20656-R-R-R-6-1

Under laboratory screening, shoot and root length of rice cultivars as affected by different concentrations of thiobencarb are shown Table 2. In general, shoot and root length of IR22, IR31802-48-2-2-2 and IR20656-R-R-R-6-1 decreased significantly as the thiobencarb concentration increased.

Table 2. Effect of different concentrations of thiobencarb on the growth of several rice cultivars treated in petri dish.[1)]

Cultivars	Thiobencarb conc. (ppm)	Shoot length 0	Shoot length 1	Shoot length 3	Shoot length 5	Root length 0	Root length 1	Root length 3	Root length 5
		cm							
IR 10198-66-2		3.7[2)]	3.9	3.1	2.8	5.6	6.1	5.2	4.3
IR 9660-50-3-1		3.5	3.6	2.6	2.2	4.8	5.2	4.4	4.2
IR 22		3.6	1.8	1.1	1.0	5.5	3.9	3.2	3.2
IR 31802-48-2-2-2		3.9	2.3	1.8	0.9	6.7	6.3	5.4	3.3
IR 20656-R-R-R-6-1		4.0	2.1	0.9	0.8	5.5	4.3	3.9	3.7

1) Herbicide treated at 3 days after germination in petri dish and ditermined at 48 hours after treatment.
2) Average of 10 seedlings with 3 replications in petri dish.

Increased from 1.0 to 5.0 ppm of thiobencarb greatly inhibited the growth of shoot and root in both IR10198-66-2 and IR9660-50-3-1, but the degree of inhibition in both shoot and root length was much lower than that of the three other cultivars.

Based on results obtained in both greenhouse and laboratory experiments, it can be stated that the results observed in the greenhouse condition was well coincided with those of the laboratory screening, indicating that IR 10198-66-2 and IR 9660-50-3-1 can be categorized as the tolerant cultivars to thiobencarb while IR 22, IR 31802-48-2-2-2, and IR 20656-R-R-R-6-1 as the susceptible ones to it. Hassan *et al.* (1986) made the similar observation on evaluating cultivar response to alachlor [2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl) acet-amide] and metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide], that the laboratory screening method was well correlated with results from a greenhouse experiment.

Changes in Protein Content

Figure 2 showed that total protein content of shoots of rice cultivars is affected by various concentrations of thiobencarb. As thiobencarb concentration increased from 1.0 to 5.0 ppm, a very slight decline in the total protein content was observed in tolerant cultivars such as IR 9660-50-3-1 and IR 10198-66-2. However, the total protein content of susceptible cultivars such as IR 22, IR 31802-48-2-2-2 and IR 20656-R-R-R-6-1 was markedly decreased as the concentrations of thiobencarb increased from 1.0 to 5.0 ppm (Fig. 2). These data strongly suggest that protein synthesis of susceptible cultivars may be greatly inhibited by thiobencarb treatment, resulting in the decreased protein content. Actually, thiobencarb is a herbicide known to inhibit protein synthesis

(Kunikazu *et al.*, 1970; Mazur *et al.*, 1987; Nobumasa *et al.*, 1978; Tadaaki *et al.*, 1986). It is assumed that the effect of thiobencarb on protein content was coincident with the influence of it on plant height and dry weight of susceptible and tolerant cultivars.

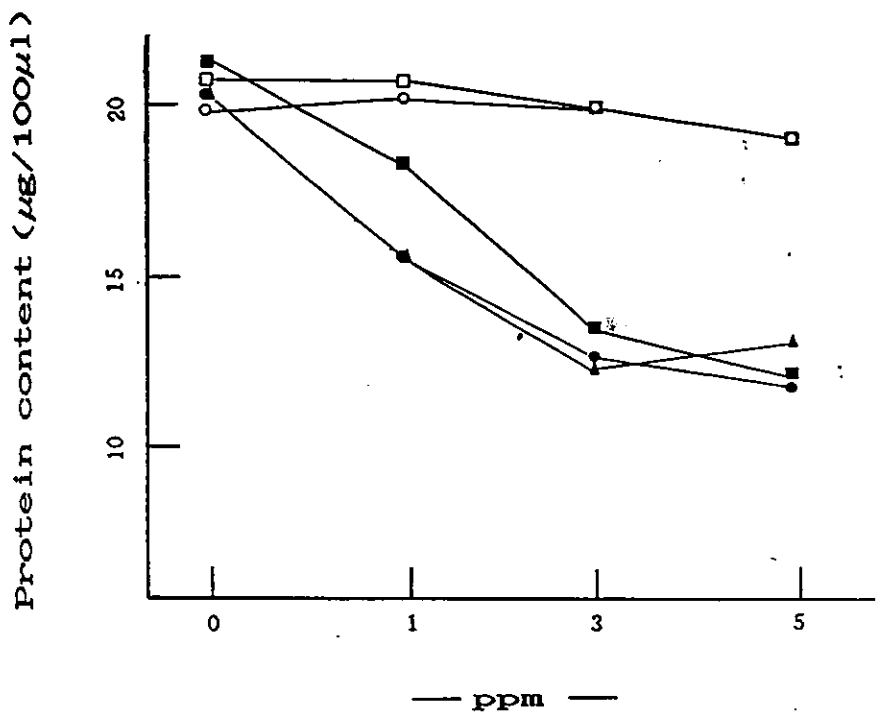

Figure 2. The changes in protein content of rice cultivars as affected by various concentrations of thiobencarb

□ IR 10198-66-2
○ IR 9660-50-3-1
■ IR 22
▲ IR 31802-48-2-2-2
● IR 20656-R-R-R-6-1

Changes in Protein Patterns

When rice leaf of various cultivars treated with 5 ppm thiobencarb was separated on SDS gels and stained with Coomassie blue, banding pattern of protein showed differences depending upon rice cultivars. The protein profiles of tolerant group such as IR 9660-50-3-1 and IR 10198-66-2, and susceptible group such as IR 22, IR 31802-48-2-2-2, and IR 20656-R-R-R-6-1 revealed shifts in protein composition in susceptible group, but no shifts in torelant group (Fig. 3). The bands with molecular weights from about 94 to 30kD and about 14.4kD were not observed in susceptible cultivars (lane 1, 4, and 5). It can be suggested that tolerance of rice cultivar to thiobencarb may be closely related with the protein having molecular weights between 94kD and 30kD, and of about 14.4kD which disappeared in susceptible cultivar.

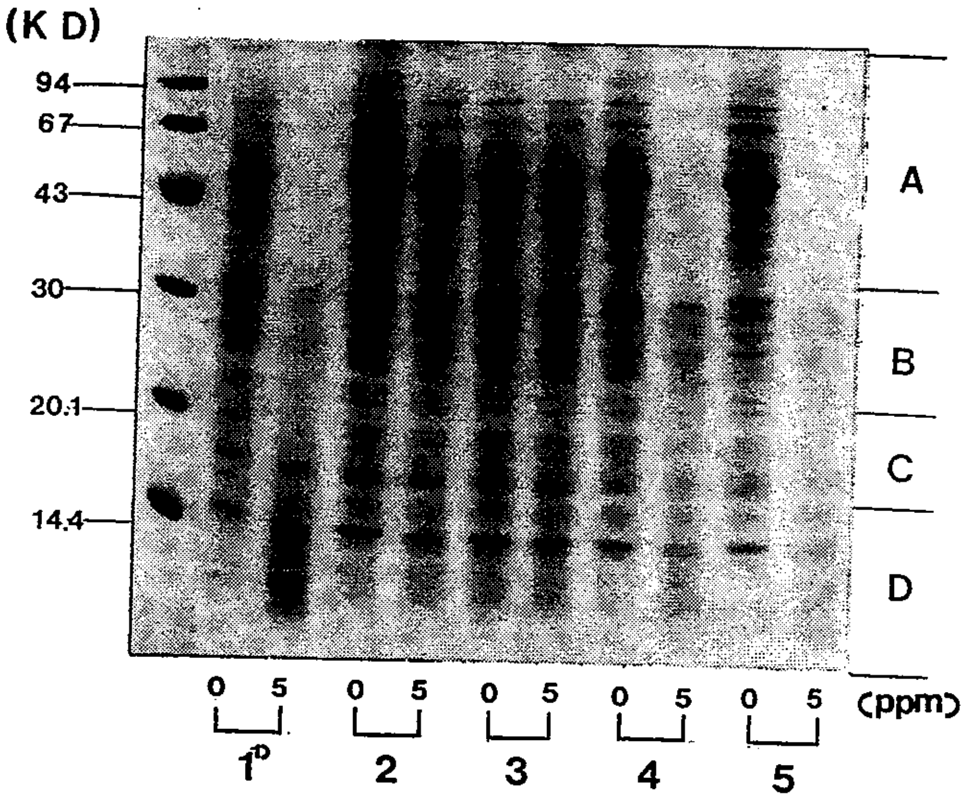

Figure 3. Different in protein handing patterns of SDS-PAGE from several rice cultivars as affected by thiobencarb.

1. IR 22
2. IR 9660-50-3-1
3. IR 10198-66-1
4. IR 31802-48-2-2-2
5. IR 20656-R-R-R-6-1

Figures 4 and 5 showed that the protein profiles of susceptible cultivars are affected by different concentrations of thiobencarb. The bands which were not observed at the 5.0 ppm thiobencarb were detectable at 1.0 ppm concentration.

This confirmed that varied protein content of tolerant and susceptible cultivars might be closely related to thiobencarb's selectivity.

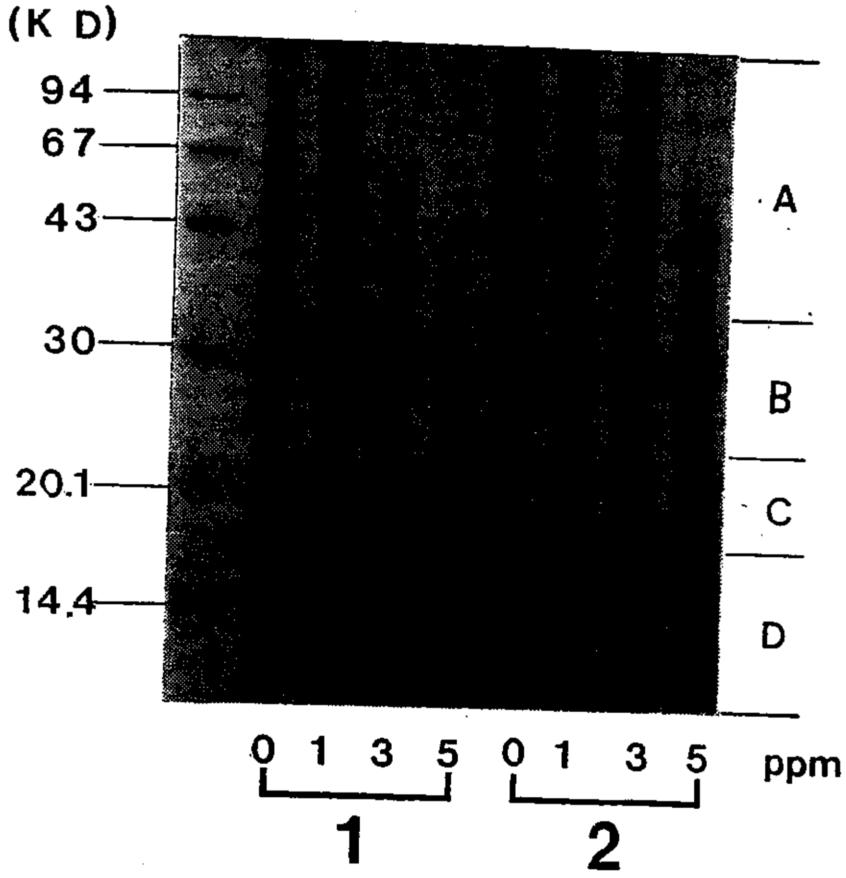

Figure 4. Changes in banding patterns of SDS-PAGE from rice cultivars as affected by various concentrations of thiobencarb.

1 : IR 22

2 : IR 31802-48-2-2-2

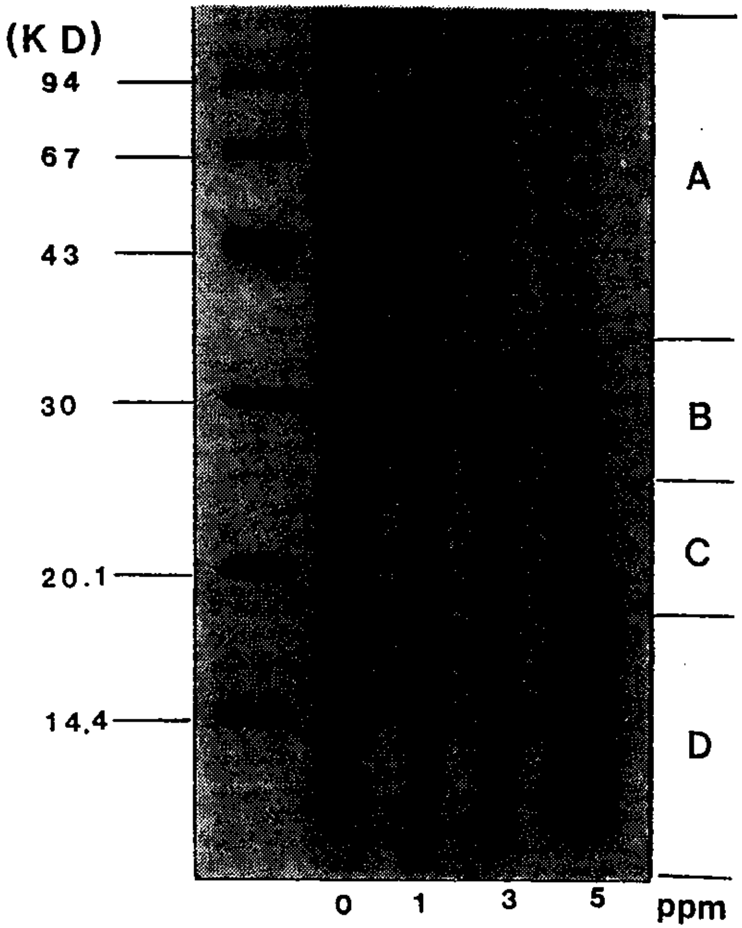

Figure 5. Changes in banding patterns of SDS-PAGE from IR 20656-R-R-R-6-1 as affected by various concentrations of thiobencarb.

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THE USE OF OXYFLUORFEN ON HAWAIIAN GROWN TARO

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ABSTRACT

A preliminary experiment with seven preemergence herbicides identified oxyfluorfen as a promising herbicide for commercial taro (*Colocasia esculenta*) production in Hawaii. Oxyfluorfen was applied twice at 0.38, 0.56 and 1.11 kg/ha to taro grown under wetland flooded and upland conditions. No oxyfluorfen residues were found in plant tissues (limit of detection 0.02 ppm). Oxyfluorfen levels in water from treated lowland plots was determined. Trace levels present in flood waters immediately after treatment dissipated to undetectable levels (limit of detection, 0.001 ppm) within 24 hours.

INTRODUCTION

Taro is a tropical crop grown for the edible corms, leaves and stems. The natural habitat of taro is Southeastern Asia and Malaysia (Allen, 1940). In Hawaii, taro is generally classified into two groups. Dasheen (*Colocasia esculenta*) var. *antiquorum*) is grown for small edible auxiliary corms that are boiled and eaten. Dasheen was promoted by the USDA in 1990 as a promising wetland crop for the southern United States (Barret and Cook, 1910). Chinese taro (*Colocasia esculenta* var. *esculenta*) is grown in Hawaii for consumption of young leaves and edible main corm (derived from seed pieces). Large corms (3 to 4 kg) are the desired commodity for fresh market and chip production (deep fried slices, similar to potato chips). Taro grown under flooded conditions is cooked and ground into a thick paste (poi) and eaten.

In a preliminary experiment (unpublished data) in Hawaii, seven preemergence herbicides were evaluated on Chinese taro and dasheen. All treatments were applied at 0, 69 and 172 days after planting (DAP). All applications made after planting were directed to the base of plants. Metribuzin (0.6 and 1.1 kg ai/ha) caused unacceptable crop injury on Chinese taro which reduced yield. No herbicide treatments adversely affected dasheen yield, which is not in agreements with a previous report (Kasasian, 1967) showing crop injury with diuron. Short term (35-40 days) activity of diethatyl (2.3 kg ai/ha), pronamide (2.3 kg ai/ha) and metolachlor (2.3 kg ai/ha) prevented their inclussion in subsequent studies. Diuron (1.1 and 2.2 kg ai/ha) and

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thiobencarb (4.5 kg ai/ha) provided acceptable weed control with no crop injury. However, they were dropped from further study due to problems in obtaining legal use of this materials in USA. Oxyfluorfen emerged from this study as the most promising herbicide for use in commercial taro production.

The objective of this research was to determine the bio-accumulation of oxyfluorfen in edible taro corms and leaves from plants growing in flooded wetland and upland soils. Oxyfluorfen in wetland flood waters was also determined.

MATERIALS AND METHODS

Upland Taro Study

The experiment was conducted in Oahu at the University of Hawaii Waimanalo Research Farm on a Waialua stony silty clay (vertic haplustoll, 2% organic matter and pH 6.3). The experiment began on May 21, 1987. Taro (cv. 'Niue') planting material consisted of an axial corm with a 25-30 cm petiole attached. The experimental unit was 2 m wide, 4.6 m long with a double row of taro (within row spacing was 0.5 m and between row spacing was 0.6 m). Oxyfluorfen was applied (7 and 98 DAP) at three rates: 0.38, 0.58, and 1.11 kg ai/ha. The control treatment consisted of hand weeding 25, 48 and 70 DAP. Taro leaves and corms were sampled 186 days after the final herbicide application.

In all experiments, herbicides were applied in a spray volume of 350 l/ha at 125 kPa using flat fan spray tips (Spraying System Co. Wheaton, IL 61820, USA). Herbicide treatments applied after planting were directed to the base of plants on plots that were weed free. Fertilizers, irrigation and other pesticides were applied as needed for commercial crop production (Mitchell and Maddison, 1983). Treatments were replicated four times using a randomized complete block design. Standard procedures (Adler and Hofmann, 1980; Adler *et al.*, 1978; Food and Drug Administration, 1983) were used for quantifying oxyfluorfen in edible taro leaves, corms and water.

Wetland Taro

Oxyfluorfen in corms. The experiments were initiated in the Kauai Rice Experimental Field on the island of Kauai. The soil type was Hanalei silty clay (tropic fluvaquent, 6.6% organic matter at pH 4.6). Weeds in control plots were removed by hand to avoid competitive effects on the crop. On May 12, 1987, oxyfluorfen was applied to the soil of drained wetland plots (0 and 95 DAP) at three rates: 0.38, 0.56 and 1.11 kg/ha. An experimental unit consisted of enclosed plots (1.8 m wide and 6.1 m long) with a double row of taro (cv. 'Lehua maole') spaced 0.3 m within the row and 0.6 m between rows. Plots were formed so that water could continuosly flow through each plot without cross treatment contamination. Taro corms were sampled for residue analysis 282 days after the final herbicide application.

Oxyfluorfen in existing paddy flood waters. On September 30, 1988, oxyfluorfen was applied (0 and 81 DAP) at 0.56, and 1.11 kg/ha. an experimental unit was 1.8 m wide and 6.1 m long and contained a double row of taro (cv. 'Maui Lehua'). Immediatelly after the second herbicide application flood waters entered treated plots. Water flooding the treated plots was sampled 0 and 24 hours after herbicide application. At collection time, samples were passed through a clean sheet of filter paper (D.B. Eaton-Dikeman co. Filter Paper, 533 cm grade 615) supported by a stainless steel funnel into glass bottles wrapped with aluminium foil.

RESULTS AND DISCUSSION

Two applications of oxyfluorfen on taro grown under upland and flooded wetland cultivation did not result in detectable bioaccumulattion in edible leaves (dryland only) or main corms. These data will support the legal use of oxyfluorfen for upland taro production in Hawaii. Oxyfluorfen applied to lowland soil caused trace levels in water flooding the plots 0 hours after application (Table 1.), at 24 hours none were detected. Due to the strict rules governing pesticides in moving water, trace levels of oxyfluorfen in flood water will preclude legal (in USA) use on lowland taro in the manner documented here. Research will be initiated to develop a wetland cultural practice which will prevent detectable levels of oxyfluorfen in waters leaving treated lowland soils.

Table 1. Oxyfluorfen concentration in flood waters exiting treated lowland flooded taro plots at 0 and 24 hours after application[1]

Treatment	Rate (kg ai/ha)	Oxyfluorfen conc.[2] (ppm)	
		0 hours	24 hours
Untreated control	-	ND *	ND
Oxyfluorfen	0.38	0.008	ND
Oxyfluorfen	0.56	0.009	ND

[1] Mean of four replications
[2] Limit of detection in flood water was 0.001 ppm.
* ND - not detectable.

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AN OVERVIEW OF HERBICIDE FORMULATION

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ABSTRACT

Formulation is an essential component of the herbicide product. It facilitates the safe and efficient application of the herbicide to its target site. There are many types of formulation which can be selected according to the physical properties of the active ingredient, the needs of the user, operator's safety and biological efficacy. Until recently, the major solid formulations were granules, wettable powders, dustable powders on soluble powders, and the liquid formulations were mostly emulsion or suspension concentrates. Owing to increasing user and environment demands, more modern formulations such as water dispersible granules, water soluble bags, capsule suspensions and aqueous emulsions have been recently introduced. The characteristics, advantages and disadvantages of these formulation types are discussed.

INTRODUCTION

A herbicide product comprises of four components, i.e. herbicidal chemicals, formulation ingredients, packaging and use recommendation.

Each of these components is essential to ensure that the herbicide can be used safely and effectively to manage weed problems.

The formulation ensures that the active ingredient is maintained in a form whereby it can be easily and uniformly applied by the farmer to the site where it is needed. The demands placed on a formulation are very stringent. It must be stable after storage for more than one year under fluctuating temperature conditions. For spray application, it must usually disperse quickly in water without foaming or clumping. The resulting spray mixture must be sufficiently stable to allow trouble-free application.

Since the quantities of active ingredient applied per hectare can now be very low (5-20 g a.i./ha^{-1} for sulfonylureas), the formulation must also facilitate the precise application of these tiny amounts over large areas. Application rates of 0.1 g a.i./cm^{-2} are now common. Finally, the formulation must ensure that the maximum biological potential of the herbicidally active component is fully achieved.

In order to fulfil these very demanding and diverse requirements, the science of formulation technology has reached a high level of knowledge and

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innovation. As a background to the further discussion of this subject, a review of the current status of formulation technology will be given in this paper.

FORMULATION

Formulation Type

Some twenty years ago pesticides were formulated either as
- wettable powders (WP)
- emulsifiable concentrates (EC)
- dustable powders (DS)
- granules (GR),

or if the active ingredient was soluble in water as
- soluble powders (SP)
- soluble liquids (SL).

These formulations can be considered the classical or conventional types. They are still widely used with the exception of dusts. Later on, special formulations were developed for ultra low volume application, and suspension concentrates, also known as flowables, became a favorite alternative to wettable powders :
- ultra low volume liquid (UL)
- suspension concentrates (SC).

The more recent formulation types, developed to improve user safety or biological performance are :
- water dispersible granules (WG)
- products in water soluble bags
- capsule suspensions (CS)
- aqueous emulsions (EW).

Classification of Formulation

Formulation can be classified according to their

- Method of application : – formulations which must be diluted before application
  – ready to use formulations
- Physical state : – solid formulations
  – liquid formulations
- Water solubility : – water insoluble formulations
  – water soluble formulations.

Description of Conventional Formulations

The characteristics of the most important conventional herbicide formulation types are as follows :

Wettable powder usually consists of a solid active ingredient, a solid filler such as clay or silica and surfactants to ensure dispersion in water. A liquid active ingredient can be adapted for use in this type of formulation by adsorption onto a solid carrier. The active ingredient and the filler are ground together in a mill to ensure a fine particle size (the medium size is in the range of 5-15 microns). Wettable powders must also be free flowing Z (for easy measurement) and should disperse quickly without clumping or excessive foaming when mixed with water.

An emulsifiable concentrate is a solution of the active ingredient which can form an emulsion in water. To produce this kind of formulation, the active ingredient is dissolved in an organic solvent to which various emulsifiers, surfactants and stabilizers are added. Stability of the spray emulsion is critical since there is always a tendency for phase separation. Therefore an optimal choice of emulsifiers as well as the empirical determination of their most effective concentrations is essential. The choice of solvent is often limited on toxicological or environmental grounds, or because of low flash points or high prices.

A suspension concentrate is a stable suspension of a finely divided solid active ingredient, normally in water. The active ingredient is wet-milled together with surfactants, thickeners and anti-freezing agents (if appropriate). These additives ensure the stability of the suspension concentrate which otherwise has a tendency to sediment during storage. The active ingredient in the suspension concentrate has a small particle size, normally below that of wettable powders. In some cases this may result in higher biological activity of S.C.'s compared to the equivalent wettable powder.

Granules are ready to use formulations for direct application to soil or into water. There are various types of granules named according to the production method: coated, adsorbed, extruded, compacted and spray-dried granules. To produce coated granules, a carrier such as sand, gypsum or clay is treated with the active ingredient or a premix thereof. Adsorption granules are made by adsorbing a liquid active ingredient or a solution on a porous carrier such as pumice. Extrusion, compaction and spray- drying processes are used to produce the other types.

Description of Modern Formulations

The ideal herbicides should be highly and specifically active against the target weeds, be well tolerated by the crops, have minimum impact on the environment and be safe to the operator. Since in reality the inherent properties of most active ingredients are not so universally favourable, significant improvements can be achieved by special formulations.

A water dispersible granule is essentially a granulated wettable powder manufactured by various technologies. WG's are less voluminous then powders, show good flow properties and form almost no dust. They are therefore easier to handle and the exposure risk of the operator due to inhalation of dust or contamination of clothes and skin with dust is reduced. However, WG's are only acceptable if the dispersion can be sprayed without difficulties. This means that the granules must quickly disintegrate in the spray tank and not leave any sediment that could clog sieves or nozzles. Good dispersibility on one side and low dust and good resistance to abrasion on the other side could be contradictory requirements. Depending on the properties of the active ingredient, it may be rather difficult to find a good technical solution.

Water soluble bags have been known for quite a long time, but until recently no satisfactory technical solution was available. The older foils used for making soluble bags were very susceptible to humidity and often the seals did not completely dissolve in water, thus causing troubles during application. In the last few years foils have become available that do not show this disadvantage any more. The water soluble bag is a viable possibility to protect the operator from direct contact with the product during mixing. The bag was first used for solid formulations, but now also liquids can be packed in soluble bags. The water soluble bag represents one dose; the bag losses its purpose if the contents are divided into smaller portions.

Capsule suspensions are aqueous suspensions of finely dispersed droplets of active ingredient surrounded by a polymer wall. Encapsulation is a kind of packaging on a microscopic scale. The polymer wall which is formed around the a.i. droplets is not soluble in water, but since it is very thin, the a.i. is released by diffusion across the wall. Microcapsules are controlled release systems, which normally exhibit a different biological performance from a conventional formulation. Release characteristics have to be optimized by varying wall thickness and particle size. If compared to corresponding EC's, most capsule suspensions show a significant reduction of the oral and dermal toxicity and are therefore much safer to the operator.

Aqueous emulsion are concentrated emulsions of a liquid active ingredient in water. If, in a formal consideration, we reduce the wall thickness of the just mentioned microcapsules to zero, we obtain the formulation type EW. When comparing recipes of EW's to those of EC's the most important difference is that organic solvents are replaced by water. This is very desirable because many solvents are no longer allowed in formulations due to unfavourable toxicity. Not every EC can be replaced by an equivalent EW. A prerequisite is that the active ingredient is liquid and sufficiently stable in an aqueous medium.

CHOICE OF FORMULATION

There is no universally optimal formulation type. The choice is decided by a compromise between: physical characteristics of the a.i., needs of the user and operator safety, effects on biological activity.

Physical Properties of the a.i.

The choice of formulation type is highly influenced by the melting point and the solubility of the active ingredient in acceptable solvents. For active ingredients with high melting points the preferred formulation is a wettable powder, a water dispersible powder or a suspension concentrate. Liquid active ingredients are preferably formulated into emulsifiable concentrates or, if possible, into aqueous emulsions. Solid a.i.'s may also be formulated as an EC, but there may be some danger of crystallization during storage, dependent upon the solubility of the a.i. and the concentration of the EC. On the other hand liquid a.i.'s may also be formulated as WP's or WG's, but the maximum a.i. contents will then be lower than in the case of a solid active ingredient. Ready to use granules normally have a low a.i. content and can therefore be made with both solid or liquid a.i.'s. The chemical stability of the a.i. on the granular carrier may be critical. Optimization of formulations involves a standard set of tests to define their physical properties, the application behaviour, the chemical and physical stability as well as phytotoxicity.

Needs of the User

Each formulation type is characterized by certain advantages and disadvantages for the potential user. Their importance depends on the objectives of the user and the kind of application equipment that he has. A comparison of formulation types is shown in Table 1.

Effect on Biological Activity

Three areas of formulation technology can influence the activity of the herbicidal component of the product: particle size, formulation additives, and controlled release technology.

Particle size influences the uptake of an a.i. into the plant. Very logically, the smaller the particle the more quickly it can penetrate into the plant or the more uniform it will be distributed in the soil. Also a smaller particle size can improve adhesion to a leaf surface and avoid washing off by rain.

Table 1. A comparison of the major formulation types with regard to user needs

	Advantages	Disadvantages
EC	- easy to measure - bio-efficacy high - no dusting	- uses organic solvents - solid a.i.'s may crystallize
SC	- no solvents - no dusting - higher efficacy than WP	- a.i. restricted - stability in storage may be limited - viscous
EW	- no solvents - no dusting - high efficacy	- a.i.'s restricted - hydrolisis
CS	- low toxicity - persistent	- sedimentation - efficacy - expensive
WP	- stable in storage	- dust - dispersibility
WG	- stable in storage - no dust - free flowing	- dispersibility - expensive
WSB	- no dust - less exposure	- bag strength - dispersibility - one dose

Formulation additives such as surfactants can also improve uptake of the a.i., for example the addition of ammonium sulfate or other surfactants to glyphosate clearly improves its uptake and performance.

Controlled release technology reduces the rate at which the herbicide enter the environment. It can increase the duration of activity of a product and reduce its toxicity. Microencapsulation has already been described for the spray application of products. For granule applications, herbicides can be incorporated into various polymer systems which allow slow release into the soil.

FUTURE TRENDS

The agrochemical industry aims to provide herbicides which will continue to solve farmer's problems with minimal risk to health or the environment. Formulation technology has an important role to play in this area since it can influence the behaviour of the active ingredient and the kind of packaging that can be used. The behaviour of herbicides in the soil is causing much concern, especially in countries where groundwater contamination has been detected.

It can be expected that formulation research can help alleviate such problems in different ways :

- additives can improve bio-efficacy and reduce rates of a.i. needed for effective weed control,
- additives may also speed up the rate of degradation of herbicides that are rather stable in the soil, and
- slow release may reduce the amount of a.i. leached into the soil.

The disposal of used containers which may still be contaminated with herbicide is a current challenge for the agrochemical industry. Contamination may be reduced by selecting a formulation which leaves little residual herbicide in its container. Water dispersible granules may be particularly appropriate here. A double-container approach is also used for some products. An outer container which is not contaminated, holds a water soluble bag which in turn contains a high concentration of WP formulation. Such innovative combinations of formulation plus packaging concept will need much more research effort in the future.

CONCLUSIONS

- The formulation is an essential component of the complete weed control product.
- Efficacy, selectivity, environmental behaviour and toxicology are all influenced by formulation.
- The choice of formulation is a compromise between the characteristics of the active ingredient, the needs of the user and the effect on biological activity.
- Modern formulations attempt to maximize efficacy and minimize risks to the user, the environment and the public.

ACTION MECHANISM OF TOPE (3-METHYL, 4'-NITRODIPHENYLETHER), A PHOTO-INDEPENDENT HERBICIDE

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ABSTRACT

Unlike photo-dependent diphenylethers, herbicidal activity of TOPE appeared slowly and its symptoms were burning of leaf blade in grasses, growth inhibition, abnormal division of meristem, and expanding of roots and stems under upland condition in greenhouse. Biosynthesis of chlorophyll in etiolated cucumber cotyledon was not inhibited by treatment of TOPE at low light intensity (5.7 $\mu E\ m^{-2} sec^{-1}$PAR) and protoporphyrin IX was also not accumulated by TOPE application. However, the contents of phytoene, phytofluene and ß-carotene increased. Mitochondrial respiration from soybean hypocotyl significantly increased at 10 μM of TOPE. But the effect of TOPE on electrolyte leakage from cucumber cotyledon was not alleviated by antimycin-A and DCP, and olygomycin had rather synergistic effect, which indicates that respiration was not involved in the primary action of TOPE. In the interaction of several chemicals with TOPE using cucumber cotyledon, electrolyte leakage was inhibited by chloramphenicol and actinomycin-D but not by cycloheximide, and the curling of cotyledon margin was inhibited by cycloheximide and actinomycin-D but not by chloramphenicol, suggesting that nucleic acid metabolism was related to the mode of action of TOPE. Increase of DNA, RNA and protein contents was induced in both cucumber cotyledon and rice root treated with TOPE, and DNA of them increased at first. These results suggest that TOPE, at first, increase DNA directly or indirectly, which disturb various metabolic pathway to cause abnormal physiological and morphological effects and then final death.

INTRODUCTION

Diphenylether herbicides (DPEs) could be classified into two groups depending on the light requirement for activity. One group, such as nitrofen and oxyfluorfen having 2,4,6-substituent(s) on one benzene ring, is a photo-dependent type, and the other group, such as TOPE (3-methyl,4'-nitrodiphenylether) and DMNP (3,5-dimethyl 4-nitrodiphenylether) having 3,5-substituent(s) on one benzene ring, is a photo-independent type (Matsunaka, 1969).

Recently a number of laboratories have reported dramatic accumulation of tetrapyrroles (PPIX) (Matringe and Scalla, 1988; Witkowski and Halling,

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1988; Lydon and Duke, 1988; Kouji *et al.*, 1989; Kim *et al.*, 1990) by protoporphyrinogen oxidase inhibition (Matringe *et al.*, 1989; Witkowski and Halling, 1989) in plant tissues treated with the photo-dependent DPEs. The accumulated tetrapyrroles generate activated oxygen in light (Orr and Hess 1982, Upham and Hatzios, 1987), which initiate membrane peroxidation and finally cell disruption. But the action mechanism of photo- independent DPEs has not been understood.

This study, therefore, was conducted to find out the action mechanism of TOPE and to compare with that of photo-dependent DPEs.

MATERIALS AND METHODS

Herbicidal characteristics in greenhouse. Barnyardgrass (*Echinochloa crus-galli* var. *ferruginea*) and large crabgrass (*Digitaria sanguinalis*) were seeded in plastic pots (350 cm^2) filled with sterilized sandy loam. They were kept in greenhouse for 2 weeks at day temperature 30-35°C and night temperature of 20-25°C, under upland condition before treatment. TOPE was foliar-applied at 4 kg a.i. ha^{-1} in a spray volume of 14 ml pot^{-1} (50% acetone, 0.1% Tween-20) and the treated pots were placed in continuous dark or natural condition in greenhouse for 2 days. Herbicidal activity was visually rated by percent scale from zero to one hundred based on the severity of injury.

Extraction and determination of pigments. Etiolated cucumber cotyledons grown for 5 day at 25°C were incubated for 14 hr in darkness followed by 24 hr in light (14 µE $m^{-2}sec^{-1}$ PAR) in various concentrations of TOPE. Afterfresh weight checked, total chlorophyll and carotenoids were extracted with absolute methanol and determined according to the method of Lichtenthaler (1987).

Protoporphyrin IX (PPIX) was extracted with acetone + 0.1 NH_4OH (9;1 v/v) according to the modified method of Duggan and Gassman (1974) from the samples treated as above except light exposure (36 µE $m^{-2}sec^{-1}$ PAR) for 2 hr, and determined with fluorescence spectrophotometer (Ex 400, Em 630) by comparison with standard PPIX.

Carotenoid intermediates were extracted with methanol from cucumber cotyledon incubated in test solution for 1.5 day at 25 °C. The methanol extract was fractionated to n-hexane. Absorbance at 287 nm, 347 nm and 453 nm of the supernatant was measured spectrophotometrically for determining phytoene, phytofluene and ß-carotene, respectively.

Respiration rate. O_2-consumption rate using mitochondria from etiolated soybean hypocotyl was measured by oxygen electrode (Rank Brothers, Bottishan Co.) as described by Moreland (1986).

Electrolyte leakage experiment. To investigate the site of action, the interaction of TOPE and inhibitors having known sites was studied. Five pairs of etiolated cucumber cotyledon were placed on the mixture of TOPE and 5 inhibitors including antimycin-A. After incubation for 5 days in darkness at 25 °C, the degree of electrolyte leakage in the solution was measured with conductivity meter (DOC-10, DKK Co.).

Analysis of protein, RNA and DNA. Etiolated cucumber cotyledons or rice roots (cv. Dongjinbyeo) treated with TOPE were homogenated in 0.1 M potassium phosphate (pH 7.5) buffer and centrifuged. The supernatant was used for protein analysis and the residue for nucleic acid. Protein was determined by Bradford's method. DNA and RNA were extracted according to the modified method of Chen (1972) and determined by diphenylamine and orcinol reaction (Gruenhagen and Moreland, 1977), respectively.

Petiole curvature test. To determine the auxin-like activity, velvetleaf (*Abutilon theophrasti*) grown for 7 day in greenhouse was treated with 100 ppm 2,4-D and TOPE solution. The degree of cotyledonary petiole curvature was checked after one day.

Chemicals. TOPE was synthesized in our lab. Oxyfluorfen and norflurazon was 70.3% and 80.3% technical, respectively. PPIX, antymycin-A, olygomycin, DCP, cycloheximide, chloramphenicol, DNA and RNA were purchased from Sigma or Aldrich and actinomycin-D from Merk Co.

RESULTS AND DISCUSSION

In order to observe herbicidal characteristics of TOPE, test compound was foliar-applied to barnyardgrass and large crabgrass in greenhouse (Fig. 1).

The weed control value was about 10% in dark and 60% in light at the first day after treatment. At the 4th day, 65% was obtained against barnyardgrass and 40% large crabgrass under dark condition but 70% and 60% under light condition (natural day), respectively. It indicates that the activity of TOPE appear slowly in dark than in light, and is photo-independent. We also observed that the growth of untreated plant was more rapid under light condition. Therefore, it is assumed that the low activity in dark can be attributed to the slow absorption and growth.

Chlorosis, wilting and desiccation of leaf blade appeared in grasses at 1 to 2 days after foliar treatment. At 1 to 2 weeks after treatment, growth inhibition, abnormal division of meristem and expanding of roots and shoots were observed. After all, leaf blade desiccation and abnormal growth were typical symptoms of TOPE under upland condition.

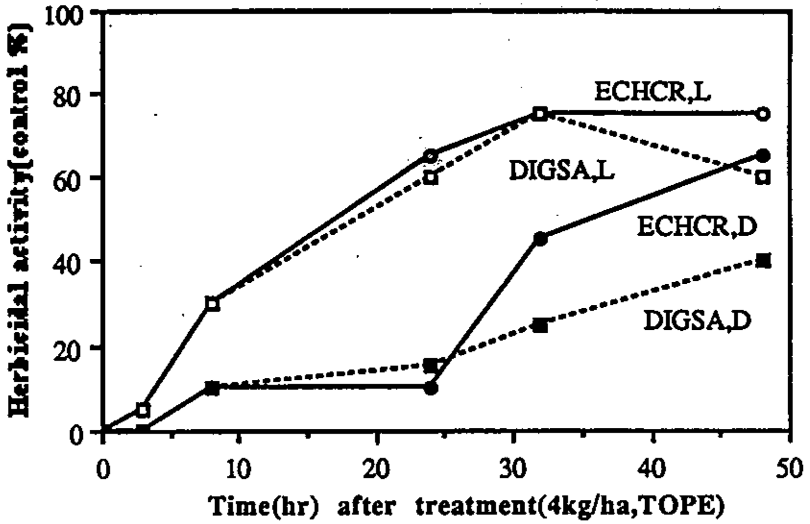

Figure 1. Herbicidal activity of TOPE against to barnyardgrass (ECHCR) and large crabgrass (DIGSA) in light or dark. TOPE was foliar-treated at 4 kg a.i./ha 9 day after seeding in greenhouse, and then immediately incubated in continuous dark (D) or light (natural day, L)

To investigate whether the leaf blade desiccation was caused by chlorophyll biosynthesis inhibition as shown in treatment of photo-dependent DPEs, the contents of chlorophyll and carotenoids were determined using etiolated cucumber cotyledons. The etiolated cotyledons treated with various concentrations of TOPE for 14 hr in darkness were exposed to light for 24 hr. The contents of chlorophyll and carotenoids were reduced to about 40% of the control at 2 mM, whereas the fresh weight was increased with concentrations (Fig. 2). On the other hand, the inhibition of chlorophyll biosynthesis was not found at low light intensity (5.7 $\mu E\ m^{-2} sec^{-1}$ PAR) (data not shown) in preliminary experiment. PPIX accumulation was significantly induced by oxyfluorfen but not by TOPE (Fig. 3). These results suggest that its primary action site is not on the chlorophyll pathway and the pigment inhibition in high light intensity may be secondary effect induced by other causes.

The effect of TOPE on carotenoid biosynthesis was investigated. To distinguish exactly which pathway of chlorophyll and carotenoids is inhibited, the experiment needs to be conducted at low light intensity in which photooxidation do not occur, or in darkness.

Thus, the intermediates of carotenoid biosynthesis were extracted and analyzed with etiolated cucumber cotyledons treated with TOPE for 1.5 day in darkness (Table 1). Norflurazon, phytoene and/or phytofluene dehydrogenese inhibitor, induced phytoene accumulation accompanied by reduction of ß-carotene, whereas TOPE treamnent accumulated phytoene, phytofluene and

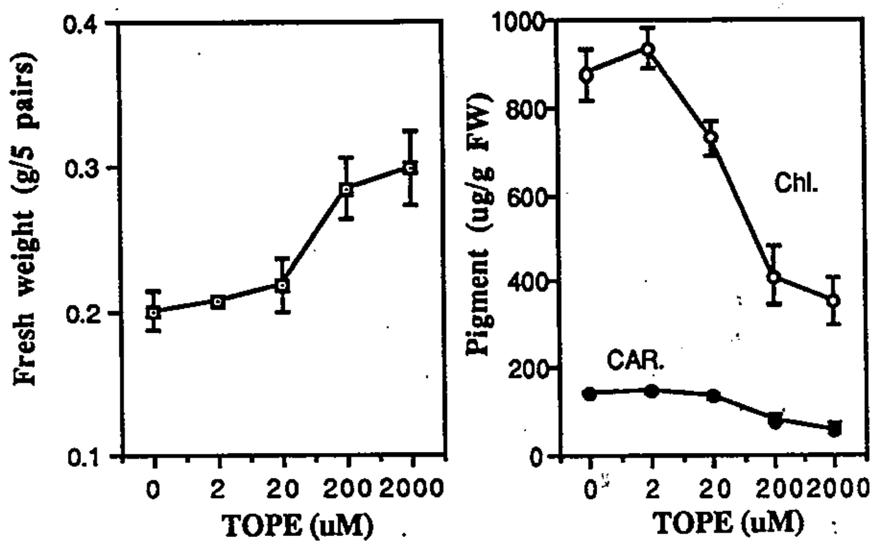

Figure 2. Effect of TOPE on the fresh weight and pigments biosynthesis of etiolated cucumber cotyledon.

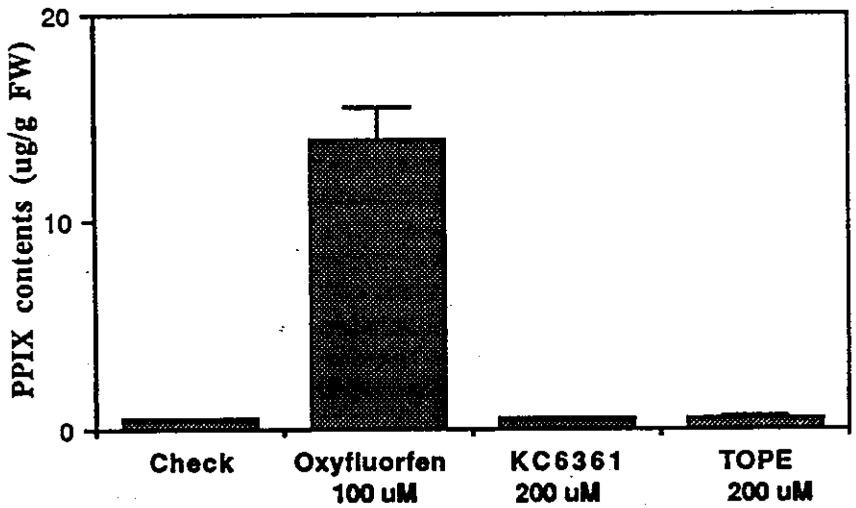

Figure 3. Effect of TOPE on the protoporphyrin IX contents of cucumber cotyledon.

ß-carotene by 2.6, 2.8 and 1.1 times, respectively. The stimulated carotenoid biosynthesis might be induced by increased respiration that could be indirectly detected by TTC test.

Table 1. Effect of KC6361 and TOPE on the carotenoid biosynthesis of cucumber cotyledon.

Herbicides	Phytoene A287	%	Phytofluene A347	%	ß-Carotene A453	%
Untreated check	1.476	100.0	0.081	100.0	0.279	100.0
Norflurazon 50 µM	1.875	127.0	0.081	100.0	0.180	64.5
TOPE 1.0 µM	3.777	255.9	0.225	277.8	0.306	109.1

Methanol extraction followed by separation with n-hexane

In the preliminary experiments using TTC, the dehydrogenase activity increased (data not shown). The effect of TOPE on respiration was, thus, investigated using mitochondria from soybean hypocotyl. The rate of O_2 consumption was slightly inhibited at 100 µM TOPE, but rather accelerated at 10 µM by 2.13 times (Table 2). The above results, i.e. the increase of fresh weight (Fig. 1), the accumulation of all carotenoid intermediates (Table 1) and the increase of dehydrogenase and respiration activities (Table 2) indicate that the action of TOPE may be connected to the abnormal metabolic stimulation rather than inhibition.

Table 2. Effect of oxyfluorfen, KC6361 and TOPE on the O_2 comsumption rate of mitocondria from soybean hypocotyl

Herbicide	Conc. (µM)	O_2 consumption rate (nmoles O_2/mg protein/min)	
Oxyfluorfen	0	18.00	100.0%
	100	11.48	63.8
TOPE	0	16.52	100.0
	0.01	18.46	111.7
	0.1	16.96	102.7
	1	19.01	115.1
	10	35.12	212.6
	100	9.15	55.4

Here we can assume that if the abnormal metabolic stimulation was primarily caused by the acceleration of respiration, the effect of TOPE will be reduced by respiration inhibitors. When the interaction of TOPE and respiration inhibitors was investigated on the basis of the electrolyte leakage which

is one of the typical symptoms including curling of cucumber cotyledon margin, the electrolyte leakage induced by TOPE was not alleviated by antimycin-A and DCP, and increased synergistically by oligomycin. It indicates the primary action site is not likely to be present on the pathway of respiration (Table 3).

Table 3. Effect of respiration inhibitors and TOPE on the electrolyte leakage of cucumber cotyledon under dark condition.

Compounds	Conc.	TOPE 0 µM	TOPE 200 µM
		uS/cm	uS/cm
Antimycin A	0 µM	7.7 ± 1.17	143.0 ± 24.25
	1	9.2 ± 0.77	137.7 ± 3.21
	10	14.9 ± 1.32	151.0 ± 32.42
	100	17.5 ± 2.12	140.0 ± 24.52
DPC	0 mM	14.1 ± 3.32	145.0 ± 17.09
	0.02	14.9 ± 3.17	127.3 ± 11.02
	0.2	11.5 ± 0.12	124.3 ± 12.34
	2.0	482.0 ± 37.00	444.3 ± 48.00
Oligymycin	0 ppm	5.2 ± 0.25	152.0 ± 12.17
	0.1	6.4 ± 0.36	211.3 ± 12.50
	1.0	12.2 ± 1.50	261.3 ± 4.04
	10.0	21.0 ± 3.18	447.3 ± 11.72
	100.0	22.6 ± 3.51	544.7 ± 19.43

On the other hand, in the same experiment using inhibitors of protein and RNA synthesis, we obtained the results that electrolyte leakage was inhibited by chloramphenicol or actinomycin-D, but not by cycloheximide, and that curling of cotyledon margin was alleviated by cycloheximide or actinomycin-D, but not by chloramphenicol (Figs. 4 and 5). Cycloheximide and chloramphenicol affected only one of these two symptoms but actinomycin-D did both. This data indicate that TOPE may be related to nucleic acid metabolism.

So, DNA, RNA and protein were extracted from etiolated cucumber cotyledon incubated in TOPE solution for 1 and 3 day under darkness and their contents were determined. As shown in Fig. 6, at the first day after treatment, only DNA was increased by 18%, and at the third day DNA and RNA increased by 27% and 20%, respectively.

The same results as above were obtained in the rice roots dipped in 10 M TOPE solution. Increased rate of DNA and RNA were 46% and 7.8% at 6 hr, respectively, and at 24 hr after treatment DNA, RNA and protein contents increased 33.2%, 67.2%, and 14.9%, respectively (Fig. 7). More rapid increase of DNA in the tissues means that TOPE may act on nucleic acid metabolism rather than other physiological pathways.

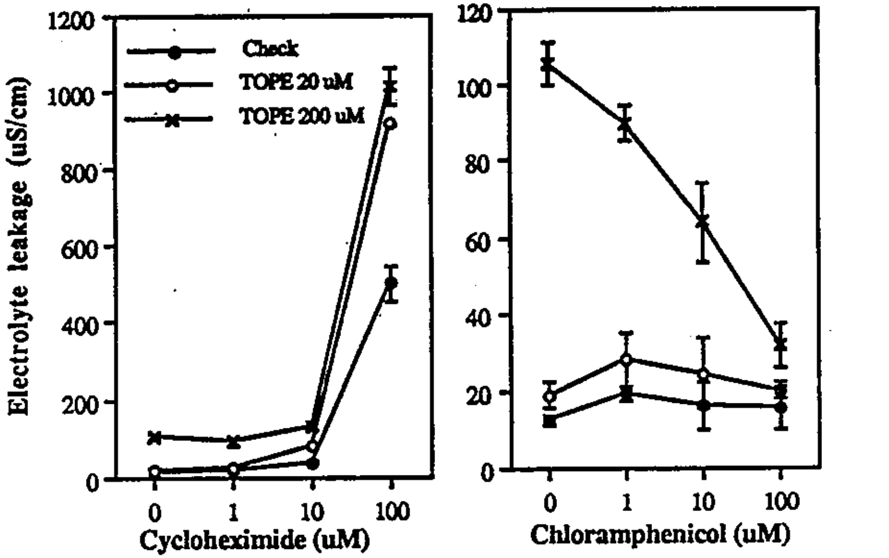

Figure 4. Effect of cycloheximide and chloramphenicol added to TOPE on the electrolyte leakage of cucumber cotyledon in darkness.

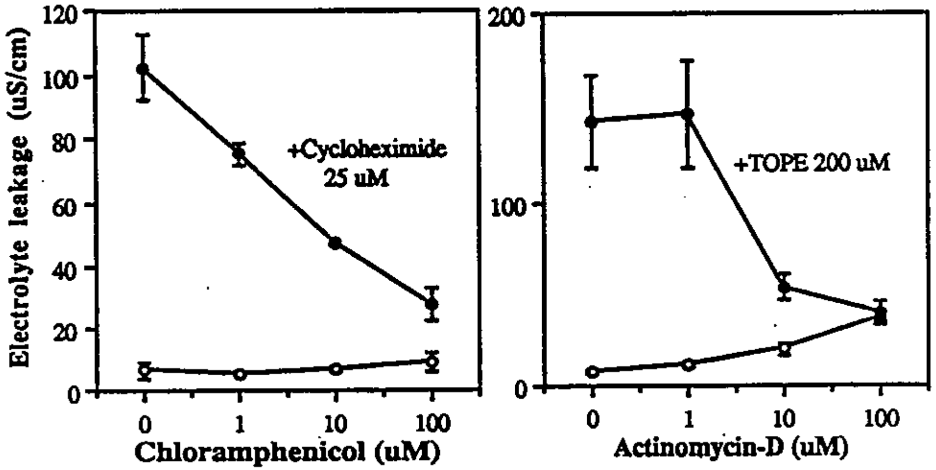

Figure 5. Effects of cycloheximide and TOPE added to chloramphenicol and actiomycin-D on the electrolyte leakage of cucumber cotyledon in darkness.

Such an increasing tendency of DNA, RNA and protein by 2,4-D was reported (Chen *et al.*, 1972). But it was not suggested that TOPE have the same action mechanism with 2,4-D, because petiole curvature, a typical symptom of auxin-like substances, did not occur in TOPE treated velvetleaf at all (Fig. 8).

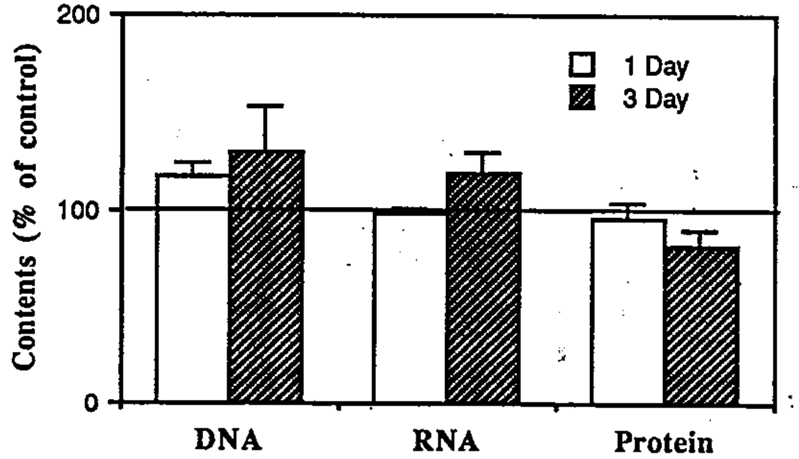

Figure 6. Effect of TOPE on the DNA, RNA and protein contents per fresh weight in cucumber cotyledon under dark incubation.

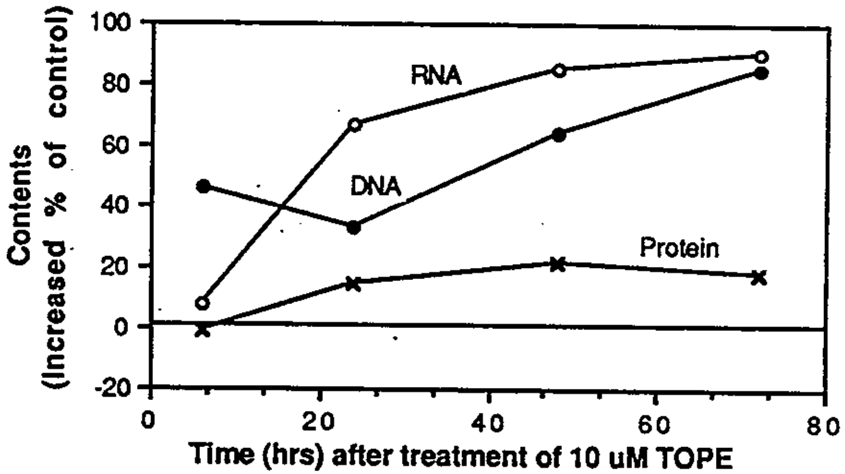

Figure 7. Changes of DNA, RNA and protein contents per fresh weight in rice roots treated 10 M TOPE.

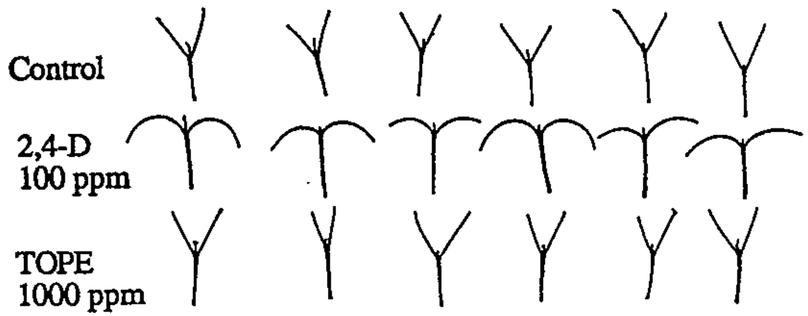

Figure 8. Effect of 2,4-D and TOPE on the cotyledonary petiole curvature response of velvetleaf.

Based on the results shown in the above experiments, we suggest that the treatment of TOPE, at first, increase DNA contents directly or indirectly, which might radically disturb balances of various metabolic pathway containing protein synthesis to cause abnormal physiological and morphological effects and then final death. Further studies are necessary to determine whether the rapid increase of DNA is a direct effect of TOPE or indirect one due to the regulation of other factors.

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SELECTED RESULTS OF RESEARCH ON *IMPERATA CYLINDRICA* (L.) RAEUSCHEL BY THE GOI/ODA IMPERATA PROJECT, 1982-1991

T.I. COX[1], P.J. TERRY[2] AND D.E. JOHNSON[1]

ABSTRACT

Methods for improving the management of *Imperata* were sought which would be appropriate for small-scale farmers in Southeast Asia. Research was carried out both in the United Kingdom and Indonesia. Work on modified cultural practices, evaluation of herbicides, application equipment and herbicide additives is described. Techniques are suggested to optimize the efficiency of the two most useful herbicides, glyphosate and imazapyr.

INTRODUCTION

The *Imperata* Project was funded by the United Kingdom Overseas Development Administration (ODA) in collaboration with the Government of Indonesia, (a) the SEAMEO Regional Centre for Tropical Biology (BIOTROP), Bogor and (b) the Research Institute for Estate Crops, Sembawa (Puslitbun Sembawa), Palembang. A component of the research was done at the University of Bristol, AFRC Institute of Arable Crops Research, Long Ashton Research Station. Eleven graduate scientist, five from Indonesia and six from the UK, worked on the Project during its nine year duration and most of their published works, plus reviews by Brook (1989) and Townson (in press), are cited.

The overall objective of the Project was to identify methods for improving the management of *Imperata cylindrica* (hereafter referred to as *Imperata*) appropriate for small-scale farmers in South East Asia. Techniques were sought which would enable these farmers to convert land which has been abandoned to *Imperata* into areas that would support sustainable cropping systems.

On a large scale, *Imperata* can be controlled with tractor cultivations and herbicides often followed by the establishment of a legume cover crop before young trees are planted. This has proved to be cost-effective for small-scale farmers whose initial aim is to grow food crops on newly cleared land.

In transmigration settlements especially, cultivation is still the only option. This is only feasible on a small-scale and never results in complete

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rhizome removal. Consequently, many farmers give up the unequal struggle and abandon their land.

Successful long-term control of *Imperata* can be achieved by initial suppression measures followed by a programme of management aimed at prevention of its re-establishment. The biology of *Imperata* has been well investigated and described and much research has been done in Indonesia to identify cropping systems which sustain control of *Imperata*. Modified cultural practices and new herbicides, spray additives and spraying equipment have been included in the research of this project and this paper selects and describes some of the more applied aspects of its research.

COMPARISON OF HUSBANDRY PRACTICES

Fire is the conventional method of clearing land infested with *Imperata*. After burning, the application of a herbicide may be preferable to cultivation as a means of controlling *Imperata* regrowth. Herbicides may also be applied to mature *Imperata* prior to clearing the trash, or chopping it and leaving it as a mulch on the soil surface. These options were tested in field experiments by Cox and Johnson (1990a). Glyphosate was effective when applied to *Imperata* regrowth after previous burning but less so when applied to mature, standing *Imperata*. Thus, clearance of *Imperata* before spraying, allowing treatment of young regrowth, may enable more effective use of the herbicide. Despite the fact that considerable effort was expended in removing rhizomes whilst cultivating, there was little difference after five months between this treatment and one where rhizomes were left *in situ*. This demonstrated the impracticality of controlling *Imperata* by removing rhizomes.

Field trials evaluating various combinations of herbicides and tillage showed that better control of *Imperata* may be achieved with combinations of glyphosate or imazapyr with tillage rather than herbicides or tillage alone.

Herbicides combined with strip cultivation rather than overall ploughing could provide suitable seedbed conditions for crop establishment with minimal energy expended on tillage.

On-farms trials to investigate the efficiency of imazapyr and glyphosate for *Imperata* control in the rows of young rubber trees showed that the herbicides were more effective when applied to the regrowth of *Imperata*, after cutting, than when applied before cutting.

Recent work with a rolling technique is promising (Cox and Johnson, 1990c). Strips were sprayed and cultivated in areas of *Imperata* and a legume ground cover mixture sown with a starter dose of triple superphosphate. The *Imperata* each side of some of the strips was rolled by hand using an empty 200 l oil drum with angle iron welded across its width to form ridges. Best establishment of the ground cover was obtained when the strips were sprayed

with either glyphosate 2.0 kg a.e./ha or imazapyr 0.6 kg a.e./ha before cultivation and the areas alongside were rolled at six or 12 week intervals. A further development of the roller was to attach wooden shafts so it could be drawn by a "Bali" cow. Thus, one pass could be accomplished at a rate of 6 hours/ha - a considerable improvement on handwork.

The shrub legume *Codariocalyx gyroides*, planted after "sheet" *Imperata* had been sprayed with glyphosate, grew rapidly to form a closed canopy. The ingression of *Imperata* was almost completely prevented during the first year.

HERBICIDE EVALUATION

Glyphosate became available in the 1970s and was shown to give good control of *Imperata* but at 2.16 kg a.e./ha, the usual dose rate recommended, the economics of use for small-scale farmers was suspect especially as lack of rainfastness presents risks which may be unacceptable. Two new herbicides became available for the control of *Imperata* in the early 1980s, imazapyr and glufosinate-ammonium.

Bacon (1984a, 1984b, 1985) described field evaluations of imazapyr (AC252925) and glufosinate-ammonium where these products were compared with glyphosate, dalapon and asulam. Although glufosinate-ammonium produced leaf necrosis on *Imperata* at 2.5 kg a.e./ha within two days, it failed to kill rhizomes and regrowth occurred through the dead stubble.

By contrast, it took up to 120 days for imazapyr at 1 kg a.e./ha to produce complete necrosis of *Imperata* shoots but the control was sustained for up to 250 days after treatment and there was no secondary weed infestation during that time. Further work confirmed the efficacy of imazapyr against *Imperata* at doses of 0.5 to 1.0 kg a.e./ha.

Imperata infested land contains a range of other species (Bacon 1984a; Townson 1990) which may become more prolific and problematical when *Imperata* is suppressed. Bacon noted the abundance of 54 species of plants on plots where the *Imperata* had been treated with glyphosate and imazapyr. He concluded that the only herbaceous species which might be regarded as resistant to imazapyr was *Ceropteris calomelanos* (L.) Underw. (Filicales : Adiantaceae). Several species quickly invaded areas treated with glyphosate especially members of the families Rubiaceae and Gramineae, and it was suspected that the rubiaceous species had physiological resistance to glyphosate.

With the availability of glyphosate and imazapyr for controlling *Imperata*, the project sought ways in which these products could be utilized by small-scale farmers. This meant minimizing their costs, determining appropriate methods of application, reducing risks (particularly soil residues of imazapyr and lack of rainfastness in glyphosate) and incorporating them into the farming, systems.

HERBICIDE MIXTURES

Early field work showed the potential of herbicide mixtures, for example glufosinate-ammonium plus imazapyr, to control *Imperata* (Bacon 1984b).

Suryaningtyas (1990a,b) examined the possibility of using mixtures of glyphosate and imazapyr to control perennial weeds. Mixtures of five rates of glyphosate up to 0.5 kg a.e./ha were applied to four-week-old *Cyperus rotundus*, either alone or in combination as a tank mix, with five rates of imazapyr up to 0.25 kg a.e./ha. The herbicides were applied in 356 l/ha of water using a laboratory track sprayer. One week after treatment, the *Cyperus* shoots were harvested and the tubers were extracted from the treated pots and sown into fresh soil.

Sprouting of the tubers was observed for one month and the viability of tubers that did not sprout was assessed with triphenyl tetrazolium chloride. Imazapyr, when applied singly, significantly reduced the number of sprouting tubers and viable non-sprouting tubers at doses of 0.125 and 0.25 kg a.e./ha, but glyphosate did not. The number of dead *Cyperus* tubers was significantly increased by imazapyr but not by glyphosate.

The use of imazapyr in combination with glyphosate generally improved the control of *Cyperus* and/or did not reduce the efficacy of the two herbicides. It could not be determined if the improved efficiency was due to additive or synergistic effects but synergism between glyphosate and imidazolinone herbicides has been reported elsewhere.

This work demonstrated the possibility of using glyphosate in mixtures with imazapyr. If the effects could be obtained with *Imperata*, it may be possible to reduce the dose rates of imazapyr with consequent reductions in soil residues and risk to subsequent crops.

APPLICATION EQUIPMENT

Several types of equipment were evaluated for appliying glyphosate and imazapyr to *Imperata*. Conventional hydraulic knapsack sprayers were used to compare with weed wipers and spinning disc applicators and also to study a range of different nozzles and spray volumes rates.

In the laboratory there was evidence of a parabolic relationship between spray volume rate and glyphosate activity. The optimum volume rate depended on surfactant concentration but, in general, was observed to be *c.* 200 l/ha. The performance of imazapyr against *Imperata* in the field was also affected by an interaction between volume rate and surfactant concentration. In general, the activity of imazapyr and glyphosate decreased as the volume rate decreased in the range 400 to 50 l/ha and 500 to 50 l/ha, respectively.

Drift spraying of glyphosate was tried by applying undiluted "Roundup" through a "Micron Ulva" sprayer to a dense sward of *Imperata*. The results were disappointing and no further work was done.

Two conventional spinning disc sprayers (known also as controlled droplet applicators, CDA), a battery-powered "Herbi" (Micron Sprayers Ltd.) and manually-powered "Birky" (Ciba-Geigy) (Bacon, 1988) were evaluated. Glyphosate and a imazapyr were applied in 20 l/ha at a range of doses.

Applications of glyphosate with the "Herbi" worked consistently well when applied to *Imperata* with an average height of 130 cm; the level of control obtained with 1.08 and 2.16 kg a.e./ha in the CDA sprayer was as good as 2.16 kg a.e./ha applied with a knapsack sprayer at a volume rate of 400 l/ha.

Glyphosate was less effective when applied with CDA equipment to *Imperata* regenerating from newly burned stubble. Bacon concluded that this was probably because the erect leaves with small leaf areas did not present a good target for droplet impaction and retention, unlike leaves in more mature *Imperata* swards. Using imazapyr at doses of 0.5, 0.75 and 1.0 kg a.e./ha in a "Herbi", Bacon showed that good control of *Imperata* was possible using the lowest dose but that the susceptibilities of two other plants associated with *Imperata*, *Cheilanthes tenuifolia* and *Aphaenandra uniflora*, varied according to whether imazapyr was applied at 20 or 350 l/ha.

Townson (1990) concluded that there are no real advantages and several disadvantages of introducing spinning discs in preference to knapsack sprayers for use by small-scale farmers in Indonesia, *viz* (a) small-scale farmers are generally less familiar with the operation and maintenance of spinning discs than knapsack sprayers, (b) calibration of spinning disc may be inaccurate if the herbicide formulation is more viscous than water and if, as often occurs, farmers remove the batteries for use in other electrical applicances, and (c) spinning discs are more uncomfortable to operate than knapsack sprayers in tall stands of *Imperata*.

Weed-wiping with a herbicide-soaked cloth has been a common practice in plantations in South East Asia for many years. Recently, equipment has been developed for wiping concentrated solutions of herbicide, primarily glyphosate, onto target weeds. Rope wicks or sponge pads are connected to a reservoir of the concentrated herbicide. Hand-held wipers are swung or pushed through the weed foliage, directly applying a smear of herbicide to the target plants.

Weed-wiping was evaluated using glyphosate and imazapyr in two commercial applicators. Two field trials were done on a site where *Imperata* was about 120 cm high and a third was done where *Imperata* was about 30 cm high and regrowing after being burnt. One part "Roundup" was mixed with two parts water and applied at rates equivalent to 0.36 kg a.e./ha in 3.0 l/ha of solution. Comparisons were made with knapsack and spinning disc sprayers.

Preliminary results were encouraging (Bacon and Kusnanto, 1984). In the first trial, weed wiping was as good as knapsack and spinning disc applications but used only one fifth the glyphosate dose of the latter two sprayers. The weed wipers were less effective in the second trial but control of *Imperata* was almost as good as hand-hoeing. They were easier to use when the *Imperata* sward was in the regrowth stage than when it was mature.

In a subsequent trial (Bacon, 1988), where a rope-wick wiper was used to apply glyphosate prior to the establishment of a small- holder rubber plantation, it was concluded that the wiper was not very suitable because of the need for repeated applications and reliability depended on the density of the *Imperata* sward.

In detailed studies of volume rates and herbicide concentrations, Townson (1989, 1990) found that a rope-wick wiper was more effective than a herbicide-saturated cloth for applying imazapyr and glyphosate to *Imperata* in the field, provided that the concentration of imazapyr did not exceed 10 g a.e./1.

Although weed-wipers can be used to apply these two herbicides and have much to commend them for use by small-scale farmers, their practicality for clearing large areas is still questionable. Townson concluded that weed-wipers have limited potential because (a) the herbicide activity is likely to be reduced by high concentrations, (b) weed-wiping is more time- consuming than spraying, and (c) weed-wiping is often more uncomfortable for the operator than spraying; the sharp leaf blades of *Imperata* cut the skin and eye injury can occur when the operator bends down to wipe the base of shoots. Weed- wipers can be useful for spot-applications to sporadic shoot regrowth and also have the advantage that they can be used to selectively apply herbicides to tall weeds without damaging the crops with which these weeds are growing.

HERBICIDE ADDITIVES

Imazapyr and glyphosate are formulated for application with standard equipment. At dose rates of 1-2 kg a.e./ha for glyphosate and 0.5-1.0 kg a.e./ha for imazapyr, effective control is possible when applied in the approved and recommended way. By improving herbicide activity, lower doses may be applied to achieve the same levels of control, thereby reducing costs and, in the case of imazapyr, minimizing soil residues.

Several products have been marketed as additives to enhance the performance of glyphosate, a typical claim being that the additive would halve the herbicide dose required to control *Imperata*, thereby reducing application costs. Field trials in 1983 and 1984 evaluated four of these products, "Frigate", "Ethokem", "Ethokem-t" and "Hyspray" (Bacon & Terry, 1984; Bacon, 1984b, 1985, 1988).

Mixtures of glyphosate at 0.36 and 1.08 kg a.e./ha and each of the additives at 3 l/ha were applied in 350 l/ha of water to *Imperata* up to 90 cm high and the effects were measured for up to 130 days after treatment. None of the additives significantly improved the activity of glyphosate in suppressing *Imperata* growth.

A further range of nonionic and cationic surfactants were tested as additives to glyphosate and imazapyr. Townson (1990) reports effects on spray retention and other events at the leaf surface, foliar uptake and translocation of herbicides, cell permeability and photosynthesis. In the glasshouse, the relative efficiency of surfactant types for activation of glyphosate was amine ethoxylate (AM) > linear alcohol ethoxylate (LA), nonylphenol ethoxylate (NP) > organo silicone (OS), phenol ethoxylate (PH). In the field, the order was OS, AM > LA, NP > PH.

In both glasshouse and field, the relative order of imazapyr activations was LA > NP, AM, OS > PH. Imazapyr activity was less affected by variation in surfactant type than was glyphosate.

It was concluded that the chemical type of surfactant added to solutions of glyphosate and imazapyr significantly influences the performance of these herbicides in *Imperata*; AM surfactants promote glyphosate activity more than LA and NP surfactants, whereas the reverse is true for imazapyr.

In terms of field practice, the most important finding of this work is that it is possible to achieve long-term (4-6 months) suppression of growth of *Imperata* using half the recommended doses of glyphosate and imazapyr, provided that an optimum herbicide formulation and carrier volume are used.

Excellent control of *Imperata* may be obtained by applying a solution of glyphosate (e.g. a concentration of 5.4 g a.e./l in a spray volume of 200 l/ha) containing a hydrophilic cationic amine ethoxylate surfactant at 0.5% w/v, to shoots which have regrown two months after slashing the foliage. This is equivalent to a glyphosate dose of 1.08 kg a.e./ha (=3 l/ha "Roundup"). The addition of organosilicone surfactant L77 to solutions of glyphosate has potential for reducing the critical rainfall period of this herbicide, a useful attribute in the wet tropical climates of South East Asia.

In field work at Sembawa this surfactant, marketed as "Pulse" significantly improved rainfastness of "Roundup" when applied at 0.2% of the spray solution thirty minutes or more before watering to simulate rainfall on *Imperata* foliage (Cox and Johnson, 1990b).

The activity of imazapyr may be optimized by applying a solution (e.g. a concentration of 1.25 g a.e./l in a spray volume of 200 l/ha) containing a nonionic surfactant at slashing. This is equivalent to an imazapyr dose of 0.25 kg a.e./ha (= 1 l/ha "Assault 25OA").

In order to apply a lethal herbicide dose per unit area in very low carrier volumes (e.g. 20-50 l/ha), high herbicide concentrations (e.g. 50 g a.e./l) must be present in the formulation. High surfactant concentrations (e.g. 1-5% w/v) are also associated with a decrease in carrier volume. If the concentrations of herbicide and surfactant exceed 10 g a.e./l and 1% w/v, respectively, a reduction in the performance of glyphosate and imazapyr is likely to occur. In general, a greater decrease in activity of imazapyr compared with glyphosate in *Imperata* is observed at high herbicide concentrations. It is concluded that very low carrier volumes (20-50 l/ha) are unsuitable for application of glyphosate and imazapyr to mature *Imperata*, as adequate spray coverage of the foliage is necessary for maximum herbicide efficiency.

IMAZAPYR RESIDUES

Since oil palm and rubber are often grown after clearance of *Imperata*, the effect of imazapyr residues on the establishment of these crops was studied. Bacon (1985) found no significant reduction in vigour of one-year-old newly budded grafts of rubber treated with 0.5 kg a.e./ha imazapyr applied to the weeding circle. Similar results have been reported from elsewhere but there are also reports that rubber and oil palm can be damaged by imazapyr. A trial was done at Sembawa where imazapyr was applied at 0.5, 0.75, 1.0 and 2.0 kg a.e./ha to *Imperata*-dominated land 30 and 60 days before planting rubber seedlings (one year old) and oil palm (six months old) (Subagyo, 1989b). Glyphosate at 2.16 kg a.e./ha and hand hoeing were used as comparisons.

The leaves of rubber seedlings in plots treated with imazapyr had chlorotic symptoms for 2-3 weeks after planting but they disappeared later. No significant height differences were observed on rubber seedlings planted 60 days after imazapyr applications but the crop was stunted by planting it only 30 days after application, especially by 2.0 kg a.e./ha imazapyr.

However, after one year no differences between treatments were observed. None of the treatments affected oil palm. Caution is therefore advised on the use of imazapyr in young rubber but it appears likely to be a practical treatment where doses do not exceed 1.0 kg a.e./ha and there is an interval of at least two months between application and planting.

Bacon (1988) noted that there was little residual activity after imazapyr was applied in the field to moist soil but growth of upland rice was suppressed when sown 40 days after the herbicide had been applied to dry soil. Cox and Johnson (1989) studied the effects of imazapyr dose and the intervals between applying imazapyr and sowing upland rice on the subsequent growth of the crop. They concluded that imazapyr at 0.6 kg a.e./ha had no effect on the crop if it was sown four weeks after the herbicide was applied.

In further work, Cox and Johnson (1990c) applied 0.6 kg a.e./ha imazapyr in the field and extracted soil cores 2, 4, 6, and 8 weeks after treatment to determine herbicide residues in the 0- 20, 20-40 and 40-60 cm depths by means of a rice bioassay. The largest growth reductions occurred in the 0-20 cm layer of soil and effects were obtained for up to eight weeks.

In the 20-40 cm layer there was a reduction in growth when sprayed two weeks before sampling but there was little or no effect at longer intervals or in the 40-60 cm layer.

Subagyo (1988, 1989a, 1989b) made detailed studies of the relationship between the persistence of imazapyr and various soil factors. Using a batch equilibrium technique for studying soil adsorption of herbicide, he showed that in the presence of excess water, especially in soils with low organic matter and high pH, imazapyr can be very mobile. These conditions are only likely to be found in inundated paddy fields or swamps, not where *Imperata* is usually found.

Subagyo also studied the relationships between imazapyr and variations in soil moisture using maize as a test species. He found that the toxicity of imazapyr increased as the soil moisture at application time increased. Drying of wet soil after application tended to increase adsorption, especially in soil which started at field capacity, and hence maize growth was less inhibited in these conditions.

Suryaningtyas (1990a) tested rice cultivars for their susceptibility to imazapyr residues and found that rice growth suffered less from imazapyr toxicity when the herbicide was applied to dry soils (moisture content 10%) than to soils containing 15-25% moisture. Imazapyr was less toxic to rice on soils containing high organic matter (6-12%) than low (3%) probably because it is less available for plant uptake due to its higher adsorption on drier soil particles and in soils with higher organic matter.

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IMAZAPYR CONTROLS *IMPERATA CYLINDRICA* IN ARABLE CROPS

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ABSTRACT

Field studies were carried out in 1989 and 1990 to assess the efficacy of imazapyr, for control of cogongrass [*Imperata cylindrica* (L.) Raeuschel]. Glyphosate, glufosinate-ammonium, and fluazipop-butyl were included for comparison. In the first year of this study, the effects of these herbicides were evaluated over time with the last sampling taken at 24 weeks after treatment. Imazapyr was more effective than all of the other herbicides tested. It caused more rhizome mortality and was more effective in preventing production of new shoots than glyphosate and fluazifop-butyl. Imazapyr at 0.5 kg ae/ha was more effective than glyphosate at 1.8 kg ae/ha but imazapyr at 1.25 kg ae/ha was as good as glyphosate at 3.6 kg ae/ha. Glufosinate- ammonium had no lasting effect on cogongrass even when it was applied at 3.6 kg ae/ha. The residual effects of these herbicides were assessed a year later. Plots treated with imazapyr at 1 .25 kg/ha, fluazifop at 2.0 kg/ha, or glyphosate at 3 .6 kg/ha in 1989, required two weedings to minimize corn yield reduction associated with cogongrass infestation. Plots treated with glufosinate-ammonium were weeded three times. An untreated control plot had to be weeded four times to get comparable level of cogongrass control in maize. There appeared to be no advantage in applying imazapyr at 1 .5 kg/ha. These results were further confirmed when the study was repeated in 1990.

INTRODUCTION

Cogongrass [*Imperata cylindrica* (L.) Raeuschel] is an extremely aggressive rhizomatous perennial grass which has become a serious problem in all tropical crops grown in the savanna agro-ecological zone. It is ranked as the seventh worst weed in the world (Holm *et al.*, 1977). Plantation crops such as coconut, rubber, oil palm are particularly susceptible to cogongrass competition because they do not develop sufficient canopy to adequately shade the weed. In root and tuber crops such as cassava, yams and sweet potato, loss is not only from yield reduction caused by direct competition, but also from secondary infection from fungi which gain entry into the tubers when they are pierced by growing rhizomes of cogongrass.

While a precise estimate of the total loss in crop production is hard to come by, the fact that millions of hectares of good farmland are being abandoned to this weed each year in most part part of Africa is an increasing source

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of concern to everybody in the affected region. In the past, peasant farmers in the tropics solved cogongrass problem by allowing land to revert to bush. The long periods of bush fallow suppressed the weed and guaranteed farmers 2-4 years of continuos cropping before cogongrass re-infestation and poor soil fertility forced them to return the land to bush fallow again. The importance of cogongrass as a weed in the humid and sub-humid tropics of Africa has increased with the increasing pressure on land caused by high human population. Farmers are being forced to abandon good arable land to cogongrass and to cultivate marginal or submarginal lands which are free of this weed (Anoka *et al.*, 1991). Therefore, there is a pressing need to find a solution to this weed problem if food production is to be sustained in the humid and sub-humid tropics.

Hand-weeding is the only option that has been known to small land-holder farmers. Thus control method is laborious and ineffective against this perennial weed because shoots grow back rapidly from rhizomes after each hand-weeding event. Several herbicides have been screened for control of cogongrass. These herbicides include asulam, dalapon, glyphosate, diuron, paraquat, MSMA, and combinations of bromacil or diuron or terbacil with dalapon (Brooks,1989; Kuladilokrat and Suwunnamek, 1983; Moosavinia and Dore, 1979; Panchal, 1977; Seth, 1970). High rates of single application of amitrole, dalapon, and glyphosate; and multiple applications of these herbicides at lower rates have also been investigated (Dickens and Buchanan, 1975; Panchal, 1977). Townson and Butler (1990) studied effect of diffrent methods of applying imazapyr and glyphosate to cogongrass in South East Asia, and concluded that rope-wick wipers were more effective than wiping with a cloth at herbicide concentrations that were less than 10 g ae/l. In arable fields that are heavily infested with cogongrass, rope-wick or cloth application of herbicides can be laborious and of doubtful cost-effectiveness. Moreover, the use of knapsack sprayers for herbicide application is more appealing to small-holder farmers in West Africa than use of either the rope-wick or cloth wipers for applying herbicides. The objective of my study was to assess the efficacy of imazapyr on cogongrass in arable fields when the herbicide is applied with a knapsack sprayer.

MATERIALS AND METHODS

This study was conducted at Ijayi near the International Institute of Tropical Agriculture (IITA), Ibadan (7°29'N, 3°45'E), Nigeria. The site is located in a forest/savanna transition zone on an arable fields that was abandoned because of heavy infestation of cogongrass. The soil type is an Alfisol. The Alfisols have an argillic horizon, a moderate to high base saturation, and neutral to slightly alkaline pH. The experiment was started after the beginning of the rainy season (April) in 1989, as soon as cogongrass had resulted active growth. Various rates of imazapyr were compared with rates of glyphosate, glufosinate-ammonium and fluazifop-butyl. The experiment was set up using a randomized complete block design and the treatments were replicated four times. The treatment plots measured 3m x 8m. Herbicides were applied with a Cooper Pegler knapsack sprayer equipped with a 4-nozzle boom lance, and calibrated to deliver at a volume rate of 200 l/ha. Pressure was set at 2.11 kg/cm^2. The nozzle type was an 8004 fan-jet. The experiment was repeated in 1990 on a site adjacent to the 1989 plot, with changes in some herbicides and rates used.

Data were collected on phytotoxicity of herbicides to cogongrass, biomass of living shoots, rhizome biomass, shoot regrowth, and on the residual effect of the 1989 treatments one year later. Most field studies on herbicide efficacy on cogongrass have been of limited duration. One of the few studies that monitored herbicide effect beyond 12 weeks after treatment is that of Townson and Butler (1990). These workers monitored the effects of imazapyr and glyphosate on cogongrass for up to five months after treatment. In the present study, the efficacy of all herbicides used was assessed by collecting data for more than one year after initial treatment.

Farmers in this agro-ecological zone usually hand-weed their corn fields four to five times in order to minimize yield loss associated with cogongrass. Additional data were therefore collected on weeding frequencies judged to be sufficient to minimize competition with corn in each of the treatments. The weeding frequency necessary to grow a crop of corn successfully was used as an indicator of the success of previous cogongrass control effort. The reliability of this value judgement can be assessed by differences in corn grain yield in the different treatments.

Each plot was divided into two, such that half the plot (3m x 4m) was used for destructive sampling while the other half was used for non-destructive sampling. Shoot density data represent pooled means from three fixed quadrats that were evenly spaced along a diagonal transect within the non-destructive sampling half of the treatment plot. The quadrat measured 25 cm x 50 cm. A metal frame measuring 25 cm x 50 cm was used to ensure that counts were limited to the quadrat. All biomass sampling was taken from means of two quadrat the destructive sampling portion of the treatment plots. A grid was used to demarcate quadrats in the destructive sampling section of each plot and numbers corresponding to sampling dates were randomly assigned to these plots that measured 25 cm x 50 cm. All samples for dry weight determination were oven-dried at 80° C for 48 hours.

RESULTS AND DISCUSSION

Phytotoxicity rating which was started at 4 weeks after treatment (4 WAT) and continued to 24 WAT, show that control of cogongrass using glyphosate was better at 3.6 kg ae/ha than at 1 .8 kg ae/ha (Table 1). Injury was noticeable in plots treated with glyphosate two weeks before it became evident in plots treated with imazapyr. Glufosinate-ammonium at 3.6 kg/ha caused pronounced phytotoxicity to cogongrass at 4 WAT but this effect disappeared at 24 WAT with the production of new leaves by cogongrass. At lower rates, this herbicide did not give acceptable control of cogongrass even at 4 WAT. The effect of these herbicides on biomass of living rhizomes from treatment plots are also shown in Table 1. Imazapyr at 0.5 and 1.25 kg/ha caused more than 50% reduction in biomass of living rhizomes. This herbicide was only comparable to glyphosate at 3.6 kg/ha in this respect.

Table 1. Control rating and effect of herbicide treatment on rhizome biomass at different sampling dates[1]

		Cogongrass control rating[2] WAT			Dry wt. of living rhizome WAT			
Treatment	Herbicide rate	4	16	24	1	4	16	24
	(kg a.e./ha)				(g/m^2)			
Glyphosate	1.8	68	71	70	215	190	245	255
Glyphosate	3.6	91	88	88	178	190	253	169
Fluazifop-butyl	2.0	53	78	83	163	176	214	225
Imazapyr	0.5	52	74	70	233	173	215	185
Imazapyr	1.25	61	88	96	290	206	228	184
Glufosinate	1.0	59	3	0	179	148	240	270
Glufosinate	1.8	69	3	0	167	208	260	196
Glufosinate	3.6	84	12	0	223	178	254	298
Untreated control		0	0	0	204	177	240	398
SE					±27.5	±38.3	±78.6	±41.1
CV %					63.7	40.1	24.1	34.5

[1] WAT = weeks after treatment in 1989.
[2] Rating scale: 0 = no cogongrass control, 70 = acceptable control, 90 = good control, 100 = excellent, all cogongrass killed.

Significant reduction in cogongrass shoot biomass occured only in plots treated with glyphosate at 3.6 kg/ha, fluazifop-butyl at 2.0 kg/ha, and imazapyr at 0.5 and 1.25 kg/ha (Table 2). Cogongrass shoot biomass data in plots treated with all rates of glufosinate-ammonium were similar to biomass from the control plot. As was the case with shoot shoot biomass, imazapyr at 0.5 kg/ha caused more reduction in shoot density than glyphosate at 3.6 kg/ha. Glyphosate at 1.8 kg/ha did not significantly reduce shoot density at 24 WAT (Table 2). Imazapyr at 0.5 kg/ha and 1.25 kg/ha significantly reduced density of living shoots, relative to the untreated control. There were fewer living shoots in plots treated with imazapyr at 0.5 kg/ha than in plots treated with glyphosate at 3.6 kg/ha. After the initial injury by glufosinate-ammonium at 4 WAT, shoot density increased at all rates used in this study, reflecting the effect of shoot regrowth.

Table 2. Efect of herbicide treatment on cogongrass shoot biomass and density at different sampling dates[1]

		Dry wt. of living shoots WAT				Density of living shoots WAT			
Treatment	Herbicide rate	1	4	16	24	1	4	16	24
	(kg/ha)	(g/m^2)				(no/m^2)			
Glyphosate	1.8	297.0	232.0	238.2	376.2	170	122	168	220
Glyphosate	3.6	205.4	181.0	176.0	117.6	126	108	114	82
Fluazifop-butyl	2.0	180.8	204.0	181.0	91.2	120	129	156	118
Imazapyr	0.5	182.6	170.0	212.0	104.8	132	101	122	76
Imazapyr	1.25	261.6	222.0	175.8	66.4	126	136	120	48
Glufosinate	1.0	175.6	270.0	424.0	603.4	100	141	180	312
Glufosinate	1.8	189.0	202.0	571.6	488.0	108	158	222	232
Glufosinate	3.6	283.8	172.0	436.4	509.6	158	107	182	248
Untreated Control		296.0	219.0	454.0	552.4	272	107	214	250
SE		±43.9	±42.3	±71.1	±71.6	±45.8	±25.5	±20.8	±32.1
CV(%)		38.0	39.1	42.2	42.2	63.7	40.1	24.1	34.8

WAT = Weeks after treatment in 1989.

When corn was grown on this site a year later (1990 growing season)plots treated with imazapyr at 1.25 kg/ha glyphosate at 3.6 kg/ha and fluazifop-butyl at 2.0 kg/ha required only two weedings (Table 3). This weeding frequency is the standard practice used in corn fields that are not infested with cogongrass in this agro-ecological zone (Akobundu, 1979). All other herbicide treatments required at least three weedings to minimize yield reduction in maize. Such treatments will not be attractive to farmers if they have to carry out more than the standard hand-weeding for corn. The control plot in which no herbicide was sprayed in 1989 had to be weeded four times before maize harvest. The fact that maize yield was lowest in this control plot in spite of four weedings is an indication that imazapyr at 1.25 kg/ha was effective in reducing cogongrass menace a year after treatment.

Table 3. Residual effect of previous herbicide treatment in 1989 on weeding frequency in maize infested with cogongrass

Previous herbicide treatment	Rate	Time of weeding (WAP)[1] 2	4	6	9	Weeding frequency	Corn yield
	(kg ae/ha)						(kg/ha)
Glyphosate	1.8	+	+		+	3	3284.5
Glyphosate	3.6	+	+			2	3388.8
Fluazifop-butyl	2.0	+	+			2	2085.3
Imazapyr	0.5	+	+		+	3	2338.3
Imazapyr	1.25	+	+			2	2714.0
Glufosinate	1.0	+	+		+	3	2458.5
Glufosinte	1.8	+	+		+	3	2775.3
Glufosinate	3.6	+	+		+	3	3023.8
Hoe weeded control		+	+	+	+	4	3223.5
SE							ns
CV(%)							36.2

[1] WAP = weeks after planting maize in 1990; ns = not significant at P = 0.05.

Glufosinate-ammonium was dropped in the 1990 study because of its poor performance in the earlier study. Results are presented in Table 4. Density of

Table 4. Effect of herbicide rates on shoot density in cogongrass at different sampling dates

Herbicide treatment	Rate	Density of cogongrass living shoots (WAT)[1] 1	4	16	24
	(kg a.e./ha)	(no/m²)			
Glyphosate	1.8	186	141	16	31
Glyphosate	3.6	168	80	0	6
Fluazifop-butyl	2.0	220	161	2	11
Fluazifop-butyl	2.5	188	147	1	1
Imazapyr	0.5	226	206	15	9
Imazapyr	0.75	182	161	8	7
Imazapyr	1.0	204	196	4	2
Imazapyr	1.25	208	195	6	1
Imazapyr	1.5	154	134	0	0
Untreated control		242	271	299	367
SE		±28.6	±23.3	±12.5	±12
CV (%)		83	67	36	35

[1] WAT= Weeks after treatment in 1990.

cogongrass living shoots increased in the control plot with increase in number of weeks after the experiment was set up but declined in the plots treated with herbicides. There were more living shoots of cogongrass at 24 WAT in plots treated with glyphosate at 1.8 kg/ha than in plots treated with imazapyr at 0.5 kg/ha, and imazapyr at 1.0 kg/ha had less cogongrass regrowth than plots treated with glyphosate at 3.6 kg/ha. These results are consistent with those of the 1989 study and with those reported by other workers (Bacon, 1986; Tjitrosemito *et al.*, 1986). Fluazifop-butyl was effective at rates used in this study. Although there were no significant differences in shoot density between glyphosate- and imazapyr-treated plots at 24 WAT in the 1990 study, the fact that some regrowth occuned in plots treated with glyphosate and not in plots treated with imazapyr at 1.5 kg/ha is an indication that this herbicide has potential for possible eradication of cogongrass from arable fields.

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EDUCATION, TRAINING, RESEARCH

THE USE OF VIDEO FOR TECHNOLOGY TRANSFER AND COMPUTER BASED EXPERT SYSTEMS

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ABSTRACT

Advances in electronic technology have brought the use of video cameras, video cassette recorders (VCR) and TV monitors within the economic reach of many colleges, departments and farmers. The University of Hawaii's College of Tropical Agriculture and Human Resources has recently developed a video production facility to utilize new technologies in disseminating information to farmers. Specific examples of enhanced technology transfer include tapes demonstrating the growth of anthuriums under plastic covered greenhouses to control bacterial blight and proper pest disinfestation procedures for exported cut flowers. The videos produced on these subjects were instrumental in helping growers adopt useful production practices. Computers and videos have also been brought together in new ways to enhance the diagnosis of herbicide injury, insect and disease problems as well as other crop disorders. The technologies involved in these applications will be discussed with a focus on agriculturally related topics.

INTRODUCTION

Technical advances in the field of electronic image recording and video tape editing are having a profound affect on technology transfer in agriculture, business and education. As the price of video cameras, editing equipment and VCRB has dropped, more colleges and large departments are acquiring video production capabilities to enable faculty to better serve their clients. The University of Hawaii's College of Tropical Agriculture and Human Resources has developed a full service video production and editing facility. This facility has been producing video tapes to enhance the education of farmers who grow crops such as macadamia, cut flowers such as anthurium and orchids (Bittenbender and Hirae, 1991; Sewake, 1990; Sewake *et al.*, 1990, respectively) and vegetable crops such as taro.

Video production has traditionally been the foundation of specialists trained in mass media communications. The availability of low-cost, high-quality equipment has allowed agricultural professionals to make use of these new communication tools. In this paper, the author will discuss the current uses of video in the delivery of agricultural information to farmers and the recognition of video programs as scholarly works.

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WHY VIDEO FOR FARMER EDUCATION

In the United States and many other parts of the world, television monitors and VCRB are becoming as common as transistor radios and telephones. Traditionally, the flow of information from university researchers to farmers and farm workers has been carried out in the form of slide presentations, workshops and field demonstrations. In an island setting like Hawaii, travel from the main university campus to all six islands of the state becomes expensive and time consuming. Take for example a farm field day to demonstrate the use of a no-tillage mechanical transplanter for vegetable crop production. Several trips to the demonstration site are required for field preparation as well as organizing activities with the cooperating farmer. On the day of the event, a good attendance figure is 45-60 farmers and other interested parties. The professor's time and effort to hold a field day can be greatly magnified if proper plans are made to capture the event on video tape and a comprehensive program on the subject is produced. Once a video program is produced, farmers, students and the general public can have access to this information in a concise, consistent and convenient format. The tape can be played back at farmer workshops, homes and classrooms to enhance the presentations of conventional lectures.

A RANGE OF VIDEO PROGRAM FORMATS FOR TECHNOLOGY TRANSFER

The most common use of video in modern society has been for entertainment. As such, agricultural educators may have been intimidated from producing video programs due to a perceived lack of competence using this media. Most researchers and technology transfer specialists are well versed in slide presentations which incorporate data as well as photographs to convey a specific message. It is easy to capture a slide presentation on video for replay to different audiences. A high quality image can be recorded on video tape of slides projected onto a standard screen. The speaker can make the slide presentation as if an audience was present. With proper editing, slide changing movement can be eliminated and live footage of the speaker or other shots can be incorporated. Thus, a standard slide show can be recorded for distribution to farmers and other agricultural specialist.

Many times, the value of on farm demonstrations and tours is derived from the discussion of farmers participating in a new or improved cultural practice. When video taping these discussions a few good questions can lead a farmer through a detailed discussion of their field operations. Problems arise when the farmer or other non-media specialists are in front of the camera and are unable to speak freely because of fear of mistakes or general shyness. Overcoming this problem is simple and is best illustrated by example.

The anthurium industry in Hawaii has recently been devastated by a bacterial disease spread by cutting tools, rain splash and worker movement through contaminated beds. The agent assigned to this crop worked hard to implement new production procedures like sanitation of harvest tools, roguing infected plants, restricting movement through production beds and rainproof covers above shade cloth materials. This complex set of procedures was difficult to convey in written and oral workshop formats. A video program was planned to capture these production techniques in action (Sewake, 1990) with grower discussions on how effective the new procedures were. A simple technique was used to loosen the tongues of cooperating growers and involved simply asking questions. The growers were not placed in front of the cameras when answering the questions. Rather, questions were asked in an intuitive manner with cameras pointed at the topic of discussion. In this situation, the camera operator needs to know what visual images are to be recorded and somewhat familiar with the topic before starting. Although the entire conversation can be recorded, only relevant sections are used together with footage of the related subject. The video produced in this fashion has made a significant impact on the anthurium industry which is returning to a high level of production and profitability.

It is important for a non-media specialist to understand that visual images and sound do not need to be recorded simultaneously. A good discussion can be recorded with slides or live footage used to illustrate the voices of the agricultural specialist talking with the farmer. For traditional agricultural educators, it is important to understand the power and function of video editing to produce a useful program.

Another important feature of video is the simple way in which a translation of the verbal portion of the tape can be made. Industrial grade editing equipment has two sound tracks: one for voice, the other for music. When a translation of the finished tape is required one track can contain the language of the original speaker and the other can contain the translated version. The translation can be recorded by the new speaker reading a prepared text while viewing the original program. Several attempts are usually required before an acceptable version is recorded. One can see that the verbal translation of a video tape is simpler, faster and more effective than the written translation of a conventional technical publication. Ease of translation is apparent when a letter based text like English is converted to a character based text like Japanese.

Difficulties in producing a useful video tape arise when the traditional media specialist joins forces with the agricultural specialist to produce a program for educating farmers. The agricultural specialist usually has an oversimplified view of what is required for producing effective video. The media specialist is trained to plan and predict as closely as possible the actual visual and sound images to be captured before filming starts. This planning allows for maximum effectiveness of the technology transfer process. Precise planning of shots, timing of transitions and complete preplanned image descriptions are difficult concepts for the agricultural professional to develop. Therefore, projects which attempt to depict specific sequences or legally sensitive messages (like pesticide recommendations) requires several planning sessions with the media specialist and agricultural specialist to make efficient use of both professionals time and effort.

SLIDES, VIDEOS AND COMPUTERS FOR INTERACTIVE LEARNING

Educational video tapes have multiple uses when copied to a laser disc which then can be accessed via computers (Hargadon, 1991). A 30 minute video tape can be copied to a laser disc for less than $300.00 U.S. dollars. Once a video tape is copied to a laser disc, a computer can be used to replay logged sections which can contain voices, music and moving images. The most common union of computer and laser disc in agricultural applications will involve "interactive computer programs which guide users through a series questions leading to a recorded section of a laser disc. Components of such a system have been assembled at our college. In this case there are three parts of the technology transfer system in place. The components include: a printed color bulletin (Bittenbender and Hirae, 1990); a video tape (Bittenbender and Hirae, 1991) and an interactive computer program (Kobayashi *et al.*, 1991) . These materials were developed to serve as diagnostic tools for determining the common problems of macadamia nuts grown in Hawaii. Information includes pest, nutrient and pesticide related production problems in this orchard crop.

Once a video and computer program are produced, an optional step is to transfer the video tape to laser disc. Software can be modified to activate the laser disc at the end of the interactive session and play a sequence of the program which provides a description and solution to the problem which is processed through the computer. Using this example it is easy to imagine applications for video tapes, computers and laser discs in the area of Weed Science. A logical application might be the diagnosis of herbicide injury symptoms. For example, a video tape is produced documenting the onset and final expression of various herbicides on a series of susceptible plants. A computer program is composed to pose leading questions regarding a description of the plant symptoms. As the user works through the program, certain herbicides are eliminated while others become suspect. Ultimately the user is

presented with images from the onset of injury symptoms which can cover 2-6 weeks of plant growth in a 1- 2 minute period. It is clear that the combination of computer programs and laser disc will enhance the effort of crop protection specialists to determine a multitude of plant disorders in a rapid and convenient manner.

NEW SKILLS FOR FUTURE EDUCATORS AND TECHNOLOGY TRANSFER AGENCIES

The field knowledge and experiences of established specialists in crop protection has traditionally been transferred to succeeding generations via written text. The information density available with video can help to capture this knowledge and package it in usable formats for future generations. Computers provide a logical and structured format for locating precise information from a large and complex visual data base. Well produced video tapes offer real usefulness as complete educational packages in everything from pesticide safety to the illustration of multifaceted production techniques associated with modern crop production. As technology improves the resolution and storage capacity of video recording and storage equipment, it will become increasingly useful to educators of agricultural sciences.

Scientists with responsibility in technology transfer must begin to explore and educate themselves in the production and use of video recordings. Agricultural colleges must begin to encourage future crop production specialists to use video to deliver their information with this useful educational tool. To aid in the adoption of this technology, professional scientific societies must begin to accept a composite video/live oral presentation at a recognized mode of knowledge exchange.

Scientific societies can advance the use or video in agricultural "disciplines by developing a format for presenting video programs at their meetings. Once a video section format is developed, authors can submit abstracts for publication and thus receive scholarly credit for their efforts. If video programs become commonly used at scientific meetings, their elevation to a scholarly work can become a reality.

A video session at scientific meetings need not present a logistical problem for viewing and comment by attendees. New projection technology allows for video presentations in large rooms without technical expertise for equipment setup. Video projectors are currently on the market which work in much the same way as slide projectors, thus eliminating the need for video monitors around a meeting room. A structure for video presentations at scientific meetings is now suggested :

1. A call for video presentations is made in the same way as papers and poster session are currently requested.

2. An abstract is submitted summarizing the video. Conference sections can be developed to illustrate research methodology, field cultural practices or educational presentations.
3. Regardless of the length of the completed video work, only 12 minutes or less will be presented at the scientific conference. The remaining time can be used for a question and answer period.
4. The video session will be held concurrently with oral presentations to provide for the conduct of scientific meetings as is currently known.
5. Special evening sessions can be held for viewing and copying completed works.

As video programs become more common in the scientific disciplines, the skill required for their production will be taught at agricultural colleges. The technology transfer experts of tomorrow must be able to communicate orally, in writing and through the media of video. An important step towards this future will be video presentations at scientific meetings and the recognition of their production as a scholarly work.

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INFORMATION NEEDS IN WEED MANAGEMENT

SRI S. TJITROSOEDIRDJO[1]

ABSTRACT

Information concerning weed management is a major requirement for improving weed management practices in farming systems. Information covering scientific, semi-technical, training and motivational materials need to be integrated to support the decision makers at all levels to implement weed management programs.

INTRODUCTION

Information concerning weed management is a major requirement for improving weed management practices in farming systems. To be effective this information must be adopted by farmers. The farmers must be kept informed about the availability of such information. They must learn about the various kinds of information on offer and then learn how to utilize the practices in their farming systems.

Unfortunately this information is diversely scattered in many places, and it requires effective collection, management and distribution before it can be made really useful to society.

Information management is a complex process that consists of many stages and components, starting with the collecting of descriptive data and an assessment of its relevance. It involves various stages of quantitative analysis and validation in which the information is processed into a suitable form to serve as the foundation for intelligent and rational decision-making. The application of this process presupposes that the problem to which it will be applied has been identified. In turn, this leads to identification of the relevant decision-makers and also raises the important question of what kind of information is required. The issues raised are so inter-related that it is impossible to treat them as anything but a whole system that cannot function well if any component is omitted.

INTEGRATED APPROACH

The problems caused by weeds are overcome simultaneously mainly by four groups of decision-makers, farmers, government agencies responsible for research and extension, and those responsible for regulation policy aimed at

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protecting the public interest, and the private sectors which provide services and sales of herbicides and related equipment (Figure 1).

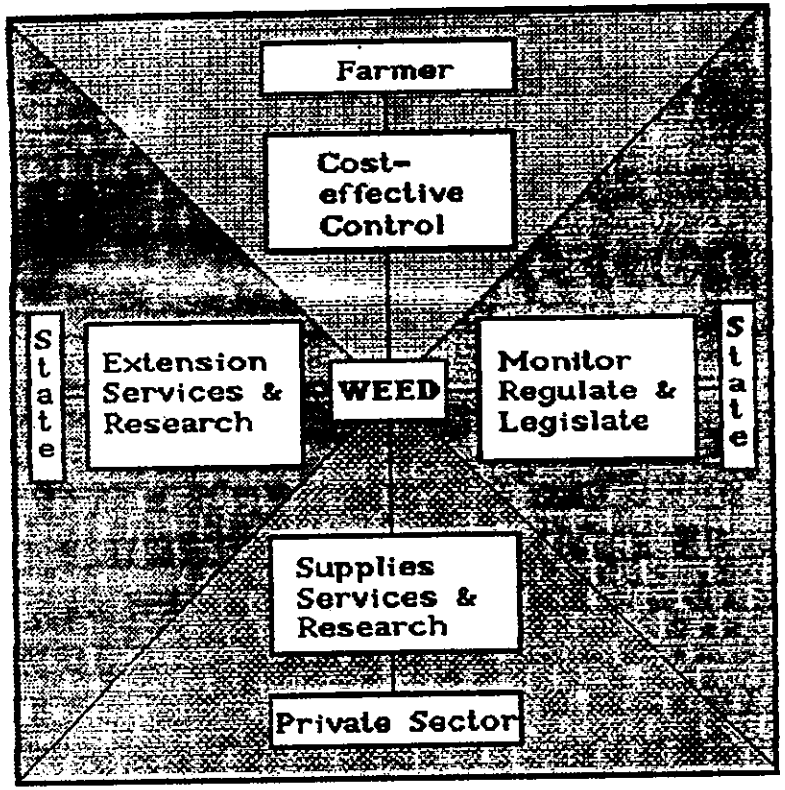

Figure 1. A diagramatic representation of four categories of decision- makers in weed management (modified from Putter and Van der Graaff, 1989).

INFORMATION REQUIREMENT

Farmer's Level

Farmers possess essential indigenous knowledge derived from historical experience in the local farming community. The existence of this basic skill must be recognized and perceived appropriately so that the flow of information can run smoothly. The relationship between indigenous knowledge and research-based knowledge was viewed by Compton (1984) as Figure 2.

Compton (1984) viewed the relationship beween information needs and sources through "a matrix system" network.

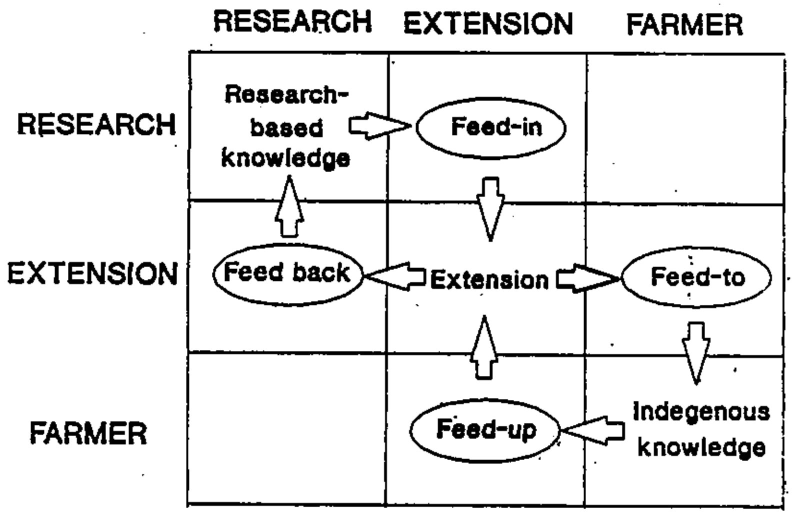

Figure 2. A system matrix for the study of weed management system (modified from Compton 1984).

In this matrix research-based information is derived mainly from scientists. Extension is envisaged as playing a mediator-facilitator role in the exchange of knowledge between scientists and farmers. At key points of interaction (designated as feed-in, feed-to, feed-up and feed-back), sets of relationships and the research needed to answer specific questions are established (Heong, 1989).

These questions include :

What is the appropriate weed management technology ?
How should the technology be communicated?
Who are the "players" and what are their profiles?
What information material is appropriate?
What training modules, materials and programmes are needed?
What motivational messages, materials and campaigns are needed?

Motivational Materials

Traditionally, recommendations targetted at the farmer's level are meant to provide information in simple messages. Common channels used are: (1) mass media such as radio, television, newspaper and leaflets, (2) personal contact with extension workers and representatives of commercial firms, and (3) personal contact with other farmers.

Extension plays an important role in motivating the farmers and their families to learn and understand the knowledge and to be able to solve their problem in a better way.

The information needed by the farmers mostly concerns the following topics: noxious weeds, crop losses due to weeds, management and effective control of weeds, herbicide application in small size farms, and reduction in use of herbicides and the cost of effective weed control methods.

Researchers and Teaching Activities Level

There is a continuous demand for information on the results of current studies on weed control, the evaluation of various crops, Integrated Pest Management, weed biology and ecology, weed identification, herbicide application techniques, activity of herbicides in relation to physio-chemical properties of soils, mode of action of new herbicides, and socio-economic aspects of weed control, with a special need for the latest information on research results.

Research activities are heavily dependent on access to information contained in technical journals, statistical resources, appropriate textbooks and reference materials.

The research workers themselves are expected to be the best resource in the extension of their research results.

Teaching activities in weed science include degree level in universities and non-degree training, for example the courses conducted at BIOTROP (Soedojo and Tjitrosoedirdjo, 1990). Universities in many countries are becoming aware of the problems weeds create in crops, and now include either at least an undergraduate subject in weed science in their curricula or attempt to cover the topic in courses in crop protection. Some have both graduate and undergraduate courses (Saghir, 1982).

The need for weed control specialists is growing very rapidly. Agribusiness which centers around the sale of herbicides or pesticides require many graduates in weed science and crop protection. Weed science is not recognized as a separate dicipline within plant protection in many countries.

The information needs for teaching both undergraduate and non-degree courses in weed science include the biology and ecology of weeds, weed-crop competition, herbicide-soil-plant relationships, principles of herbicide selectivity and herbicide physiology.

Non degree training in which courses are shorter than in degree programs requires the same background information.

Extension Level

Extension services primarily serve as the bridge between the farmers and the sources of potential solution. They are also the first port of call for the farmers, both to have the problem diagnosed and evaluated and as the source of information about potential control measures. To facilitate decisions by farmers, extension agents also need to have access to technical information that they can transfer to their farmer-clients (Putter & van der Graf, 1989).

The target of an extension service in weed management is to stimulate changes in the production system (better farming, better weed management and better business) by improving the existing weed management practices. Such a programme seeks to bring about changes in farmers in their knowledge, ability, attitude and motivation. Changes are needed in what they know concerning weed problems and weed management practices, so that their production systems may be more profitable. Changes are required in their ability to think and to improve weed management practices and in their way of thinking and their feelings concerning weed problems and weed management (Soerjani, 1982).

In their bridging role, extension agents need access to appropriate information on weeds, especially for field use.

Government Monitoring and Regulatory Level

Government agencies and institutions have the function of safeguarding human health and the environment while simultaneuosly ensuring sustainable food supplies by minimizing harmful pest damage. This requires a firm policy on plant protection. Such a policy has to be translated into the foundation of legislation to provide the constitutional basis for the allocation of financial resources to create and maintain plant protection institutions and to provide a legal framework for regulatory activities. These include herbicide registration, plant quarantine and plant health legislation and regulation.

Plant quarantine is a complex government regulatory function that requires information about legislation and regulations, quarantine procedures and facilities, post entry and intermediate quarantine facilities, certification and treatment procedures and lists of noxious weeds that are of quarantine concern (Putter & van der Graaff, 1989).

Private Sector Level

In the private sector herbicide research is the biggest venture. Much of the information about herbicide action, toxicity, environmental effects, dosage levels, application methods and residues is provided by the herbicide industries.

Product marketing (e.g. herbicide sales) requires information about herbicide legislation and registration requirements, statistics about pesticide demand based on estimates of the potential and actual economic significance of weeds, and technical information at the journal level about herbicide issues (Putter & van der Graaff, 1989).

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