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CONTENTS

VOLUME 1

2-9-82

WEED CONTROL IN RICE

VOLUME 2

WEED CONTROL IN RICE

WEED CONTROL IN SUGARCANE AND MAIZE

GENERAL WEED CONTROL TOPICS

COMMON NAMES AND CHEMICAL ABBREVIATIONS

Name	*Chemical Name*
A-820	*N*-sec-butyl-4-tert-butyl-2,6-dinitro aniline
alachlor	2-chloro-2,6-diethyl-*N*-methoxymethylacetanilide triazine
amitrole	3-amino-1,2,4-triazole
atraton	2-ethylamino-4-isopropylamino-6-methoxy-1,3,5-triazine
atrazine	2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine
B-3015	*S*-(2-chlorobenzyl)-*N*,*N*-diethylthiol carbamate
barban	4-chlorobut-2-ynyl-3-chlorophenyl carbamate
benfluralin	*N*-butyl-*N*-ethyl-2,6-dinitro-4-trifluoromethyl aniline
bensulide	di-isopropyl *S*-(2-phenylsulphonyl = aminoethyl) phosphorothiolothionate
benthiocarb	*S*-(4-chlorobenzyl)-*N*,*N*-diethylthiol carbamate
bioxone	2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidene-3,5-dione
bromacil	5-bromo-6-methyl-3-(1-methyl-*n*-propyl) uracil
bromoxynil	3,5-dibromo-4-hydroxybenzonitrile
butachlor	2-chloro-*N*-(isobutoxymethyl)-2′,6′-acetoxylidide
chlonidine	*N*,*N*-bis (2-chloroethyl)-2,6-dinitro-*p*-toluidine
chloramben	3-amino-2,5-dichlorobenzoic acid
chlorbromuron	*N*′-(4-bromo-3-chlorophenyl)-*N*′ methoxy-*N*-methylurea
chlornitrofen	4-nitro-2,4,6-trichlorophenyl ether
chloroxuron	*N*′-4-(*p*-chlorophenoxy) phenyl-*NN*-dimethylurea
chlorproham	isopropyl 3-chlorophenyl-carbamate
chlorthal	2,3,5,6-tetrachloroterephthalic acid
credazine	3 (2-methylphenoxy) pyridazine
cyanazine	2-chloro-4-(1-cyano-1-methylethyl = amino)-6-ethylamine-1,3,5-triazine
cyprazine	2-chloro-4-cyclopropylamino-6-isopropylamino-1,3,5-triazine
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DB	4-(2,4-dichlorophenoxy) butyric acid
dalapon	2,2-dichloropropionic acid
delachlor	*N*-butoxymethyl-2-chloro-2,6′-diethylacetanilide
di-allate	S-(2,3-dichloroallyl) di-isopropylthiocarbamate
dicamba	3,6-dichloro-2-methoxybenzoic acid
dichlobenil	2,6-dichlorobenzonitrile
dichlorprop	2-(2,4-dichlorophenoxy) proprionic acid
dinoseb	2,4-dinitro-6-*s*-butylphenol
diquat	9,10-dihydro-8a,10a-diazoniaphenanthrene
disul	2-(2,4-dichlorophenoxy) ethyl hydrogen sulphate
diuron	*N*′-(3,4-dichlorophenyl)-*NN*-dimethylurea
Dowco 221 — see TCE-styrene	
DSMA	disodium methane-arsonate
EPTC	*S*-ethyl dipropylthiocarbamate
fenoprop	2-(2,4,5-trichlorophenoxy) propionic acid
fluometuron	1,1-dimethyl-3-(3-trifluoromethylphenyl) urea

Name	Chemical Name
fluorodifen	4-nitrophenyl 2-nitro-4-trifluoromethylphenyl ether
"Frenock"	sodium salt of 2,2,3,3-tetrafluoropropionate
HE-314	metatolyl-4-nitrophenylether
ioxynil	4-hydroxy-3,5-di-iodobenzonitrile
isonoruron	*N'*-(hexahydro-4,7-methanoindan-1-yl)-*NN*-dimethylurea and *N'*-(hexahydro-4,7-methanoindan-2-yl)-*NN*-dimethylurea
karbutilate	*m*-(3,3-dimethylureido) phenyl *t*-butylcarbamate
linuron	*N'*-(3,4-dichlorophenyl)-*N*-methoxy-*N*-methylurea
MCPA	4-chloro-2-methylphenoxyacetic acid
MCPB	4-(4-chloro-2-methylphenoxy) butyric acid
mecoprop	(±)-2-(4-chloro-2-methyl phenoxy) propionic acid
methabenthiazuron	1,2'-benzothiazolyl-1,3-dimethylurea
metobromuron	*N'*-4-bromophenyl-*N'*-methoxy-*N'*-methylurea
molinate	*S*-ethylhexahydro-1*H*-azepine-1-carbothiolate
monuron	*N'*-(4-chlorophenyl)-*NN*-dimethylurea
MO 500	2,4-dichloro 6-fluoro 4'-nitro-diphenylether
MSMA	monosodium methane-arsonate
neburon	*N*-butyl-*N'*-(3,4-dichlorophenyl)-*N*-methylurea
nitralin	4-methylsulphonyl-2,6-dinitro-*NN*-dipropylaniline
nitrofen	2,4-dichlorophenyl-4'-nitrodiphenyl ether
noruron	*N'*-(hexahydro-4,7-methanoindan-5-yl) -*NN*-dimethylurea
NTN 5006	*O*-ethyl-*O*-(2-nitro,4-methylphenyl) *N*-isopropyl thiono-phosphoro amidate
OCS 21693	methyl 2,3,5,6-tetrachloro-*N*-methoxy-*N*-methylterephthalamate
OCS 21799	2-(4-chloro-O-tolyl) oxy-*N*-methoxy acetamide
oxadiazon — see RP 17623	
paraquat	1,1-dimethyl-4,4'bipyridilium
pebulate	*S*-propyl butylethylthiocarbamate
picloram	4-amino-3,5,6-trichloropicolinic acid
PP 493	2,5-dichloro-3,6-difluoro-4-hydroxypyridine
prometryn	2,4-bisisopropylamino-6-methylthio-1,3,5-triazine
pronamide	3,5-dichloro-*N*-(1,1-dimethylpropynyl) benzamide
propachlor	2'-chloro-*N*-isopropylacetanilide
propanil	*N*-(3,4-dichlorophenyl) propionamide
propazine	2-chloro-4,6-bisisopropylamino-1,3,5-triazine
propham	isopropyl phenylcarbamate
prynachlor	2'-chloro-*N*-(1-methylprop-2-ynyl) acetanilide
R-7465	2-(α-naphthoxy)-*N,N*-diethylpropionamide
RP 17623 (G-315)	2-tert butyl-4-(2,4-dichloro-5-isopropyl (oxyphenyl)-1,3,4-oxadiazoline-5-one
simazine	2-chloro-4,6-bisethylamino-1,3,5-triazine
simetryn	2,4-bisethylamino-6-methylthio-1,3,5-triazine
swep	methyl *N*-(3,4-dichlorophenyl) carbamate
S-45865	2,4-dichlorophenoxy cyclo hexylester
sulfallate	2-chloroallyl diethyldithiocarbamate
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,3,6-TBA	2,3,6-trichlorobenzoic acid
TCA	trichloroacetic acid
TCE-styrene	α-2,2,2-trichloroethyl styrene
TDW-6643	benzyl-*N,N*-diisopropyl dithiocarbamate
terbacil	5-chloro-6-methyl-3-*t*-butyluracil
terbutryn	4-ethylamino-2-methylthio-6-*t*-butylamino-1,3,5-triazine
Tope	metatolyl-4-nitrophenylether
tri-allate	*S*-2,3,3-trichloroallyl diisopropylthiocarbamate
trietazine	2-chloro-4-(diethylamino)-6-(ethylamino)-*s*-triazine
trifluralin	2,6-dinitro-*NN*-dipropyl-4-trifluoromethylaniline
VCS-438	2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione
vernolate	*S*-propyl *NN*-dipropyl thialcarbamate
X-52	2,4-dichloro-3'-methoxy-4'-nitro-diphenylether

METRIC CONVERSION

1 lb = 0.454 kg	1 kg = 2.20 lb
1 yd = 0.914 m	1 m = 1.09 yd
1 ac = 0.405 ha	1 ha = 2.47 ac
1 gal = 4.55 l	1 l = 0.22 gal
1 lb/ac = 1.12 kg/ha	1 kg/ha = 0.89 lb/ac
1 gal/ac = 11.25 l/ha	1 l/ha = 0.089 gal/ac
1 lb/sq.in. = 6.89 kN/m^2	1 kN/m^2 = 0.145 lb/sq.in.

N.B. N = Newton
N/m^2 has special name of the pascal (Pa).

CONFERENCE SUMMARY

WILLIAM R. FURTICK
International Weed Science Council

It is difficult to summarize the nearly sixty excellent papers which covered such a wide range of topics.

The conference was opened by President Neil Van der Schans who reviewed the history and current status of the Asian-Pacific Weed Science Society. He indicated that 200 delegates had pre-registered.

The final registration indicated the pre-registration figure was very close to the actual attendance. In addition, a number of students from the university and other local people attended some sessions without being included in the registration figures.

The delegates attending were almost evenly divided between the private sector and the government and university sector. This makes a very desirable union of the two components important for the future of weed science.

Dr A. H. Moseman, in his key address to the Society, indicated that, in the United States, industry made more than half the total investment in agricultural research and their investment was increasing, while the expenditure by government was decreasing in relation to actual purchasing power of the dollars spent.

Several important points relative to issues that must be faced by weed science in the future were made by Dr Moseman. This Society must be concerned with these matters, which included:

(1) Co-ordinated national research programmes that include research on the problems of the primary production regions of each country must be developed. Sound research must be done before starting large promotional programmes.

(2) The agricultural scientist must meet the needs of safeguarding the quality of the environment as it relates to his field. When new programmes such as pesticides are backed by adequate research for safeguarding the environment, the government scientist needs to help dispel false information in the mind of the public.

(3) The socio-economic factors need to be more thoroughly taken into consideration. This is particularly true of weed science where there is widespread fear that introduction of modern technology may lead to mass unemployment and social unrest.

Several excellent papers were given which reviewed the current status of weed science and outlined weed problems in several countries. These included Indonesia, Korea, Australia, New Zealand, South Vietnam, India, and Kenya.

These papers pointed up the rapid development of weed science in these countries but also the small size of the effort relative to older disciplines such as entomology and plant pathology.

These review papers also indicated a heavy emphasis on research with herbicides. In Dr Iven's paper on Kenya he pointed up the fact that, with smallholders who cannot afford herbicides, major improvements can be made by introducing improved implements such as lighter and more efficient hoes.

It is my hope that, as weed science gains strength in the Asia-Pacific area, it can expand into a more multi-disciplinary approach and give greater emphasis to such things as:

(1) *Ecological factors* such as illustrated in the papers by Dr Noda and others presented at the conference on the differences in germination patterns of important weeds, factors affecting weed establishment, etc. The future programmes of SEAMEB BIOTROP outlined by Dr Soerjani should be supported as an important step in this direction.

(2) *Changes and improvement in cropping systems* as illustrated by several papers on potentials of minimum tillage, use of higher plant populations, crop dessication to aid burning of cane, or conversion of bushland to pasture, etc.

(3) *Economic implication.* Unfortunately very little work was reported that was based on studies of economic factors determining alternative choices, national priorities or social implications.

(4) *Equipment and application problems.* This was another important area with very little work reported.

The same could be said for many other important areas with only very few papers dealing with aquatics, persistence in the environment, etc.

Work on Estate Crops

Usually herbicides are used first on estate crops because they have the ability to pay the purchase price.

There were a number of papers presented on weeding estate crops. They indicated satisfactory herbicide programmes are

available for these crops for most weed species. There were still a number of unanswered questions indicated, such as control measures for certain species, and the best programme for maximum economy. These crops have been used in the development of various practices such as sequential applications and other methods of programmed weed control. Papers were presented on weed control in sugarcane, rubber, tea, oil palm, coffee and cotton.

Rice

Eighteen of the papers related directly to weed control in rice. A majority dealt with the use of herbicides, which indicates a wide interest in chemical weeding. Although the largest number of papers were from Japan where herbicide use is highly developed, the wide geographic distribution of the authors indicated widespread interest.

The large number of new herbicides indicated a variety of future products will be available for rice. In addition, several papers dealt with new uses for older herbicides such as 2,4-D, MCPA and chloramben.

Several excellent papers dealt with germination habits of important species, the reproduction characteristics of certain perennial weeds, and the effects of water management and temperature on herbicide performance.

Some of the differences in herbicide performance in rice appeared to be due to differing responses between the Japonica and Indica species, between varieties, or as a result of various water management systems or temperatures.

Studies of Specific Weed Species

Several papers detailed work on important weed species.

Weed Control in Corn, Soya Bean and Peanuts

The work reported in several papers indicated effective herbicides are available and also pointed up the importance of early weeding whether by hand or with chemicals.

New Herbicides

The properties of a number of new herbicides were presented by company representatives or were discussed in papers by government workers. This indicates a continuing introduction in the future of highly efficient new products.

Aquatic Weed Control

The extensive interest shown in the few papers that dealt with aquatic weeds would indicate that this is an area of more importance than the small amount of work reported would signify. Much more effort appears to be needed in this area.

Residue Studies

The limited amount of work reported would also indicate deficiencies in this important work.

Purpose of a Professional Society

The excellent attendance and interest shown in the 3rd Asian-Pacific Weed Science Society meeting were heartening. I am going to list a few purposes of professional societies so that each delegate can consider how well our Society is meeting the goals.

(1) Bring people together for the exchange of ideas through the papers presented and personal contact. It is important to re-read the papers of interest to gain the most benefit.

(2) Stimulate an improved status and gain attention for the discipline.

(3) Improve professional competence through expanded knowledge.

(4) Develop enthusiasm through a feeling of being part of a team rather than isolated among colleagues of other specialties.

(5) Arrange continuing exchanges of information through newsletters, journals, and other publications.

(6) Improve the discipline by setting standards such as standardized terminology and research techniques.

It would appear that the Asian-Pacific Weed Science Society is well on the road to maturity. The Society is deeply indebted to the private sector for the financial support and the large amount of time and effort of their staff to help the new Society gain the success shown at this meeting. The Society particularly needs to show its appreciation to the unusually capable and hard-working officers, President Neil Van der Schans, Treasurer Roger Billman, Secretary Don Plucknett, and Programme Chairman David Barnes.

RESEARCH AS RELATED TO AGRICULTURAL DEVELOPMENT

A. H. Moseman

Director, Malaysian Agricultural Research and Development Institute

An invitation to speak at a professional meeting where the programme is sharply focussed on a specific subject such as weed control presents a problem for those of us who are research administrators. Since we are on the sidelines of science, rather than full participants in the game, we can seldom contribute directly to advances in new experimental knowledge. Our task, therefore, is to address a subject of related but more general mutual concern.

I do feel a certain kinship with those involved in this conference because of a close association with development of research on weed control in the United States over more than thirty years. This covered the early period of only casual concern about weed problems, through the pre-World War 2 period when special research and control programmes were set up for serious noxious weeds that were infesting vast areas of agricultural lands, and the post-war period when the mechanization and chemicalization of agriculture brought weed control into full partnership with other advanced techniques in the new technology "packages of practices" concepts of advancing modern agriculture.

THE SCIENTIFIC BASIS FOR MODERN WEED CONTROL

There are few areas of agricultural research which have been more stimulating, challenging and exciting during the past three decades than research on weed control. Plant physiologists charted new courses in studies with plant growth regulators — in identifying chemicals with ever-increasing selectivity. Today the selective chemical control of grassy weed species in rice, maize, wheat and other monocotyledons is accepted as commonplace. Plant ecologists and agronomists have found new challenges in designing cultural practices for weed control and engineers have long since perfected equipment and application patterns to subdue the once critical problems of droplet size, spray patterns and drift of herbicide sprays and dusts to susceptible crops. Entomologists and plant pathologists have made new contributions in biological control of a number of stubborn weed species. Soil scientists and economists also play their part.

Other disciplines or specialties could be enumerated as prime participants in the evolution of current weed control practices. The key point is that modern weed control is *solidly science-based* and the constant improvements in effectiveness and efficiency depend upon a well-supported and well-organized agricultural research system.

TEMPERATE ZONE TECHNOLOGY

Most of the significant advances in modern weed control practices have been evolved under temperate zone conditions. Aside from empirical observation trials, there was limited research on weed control in the developing nations of Latin America, Asia and Africa prior to 1960. The major regional effort in Latin America was initiated in 1966 when the U.S. Agency for International Development supported a project directed by Oregon State University co-operative with a number of Latin American countries. The intensive wheat and rice production schemes in South Asia — India and Pakistan — since 1966 also stimulated attention to weed control research, particularly because the short-strawed "Mexican wheats" and IRRI rice varieties were less able to compete with weeds than the taller indigenous varieties.

This is the Third Conference of the Asian-Pacific Weed Science Society and it may be safe to assume that there are few intensive, sustained research programmes that extend back prior to the research set up at the International Rice Research Institute in the early 1960s.

THE NEED FOR NATIONAL AGRICULTURAL RESEARCH SYSTEMS IN ASIA

The modernization of agriculture can be expected to proceed at an accelerated pace in Asian countries in the years ahead. Demands for food will increase as populations grow at the rate of 3% or more per year in many countries in the region. Adjustments in crop and livestock production are an immediate problem, as higher productivity of rice from new technology and from new irrigation systems provides for national self-sufficiency for rice in many countries and for changes in both domestic and international rice market patterns.

Increased populations and increased technology in farming present new concerns about employment in rural areas. We appreciate a growing world-wide concern about the quality of the environment — a factor relevant to use of herbicides and other agricultural chemicals. Intensified agricultural production, whether double cropping of rice or rotation cropping — or involving expanded production of new crops — will require greater efforts and new knowledge about control of pests, diseases, and weeds.

The list of problems or inhibitors in future agricultural development is formidable. And these problems are distinct, recognizable, *and specific to local farming areas.* If agricultural and economic development is to proceed through sustained growth in dependable and efficient productivity, there must be precise answers to precise problems. A few specific issues may be assessed.

1. Food Production

The remarkably productive new rice varieties and related technology from the IRRI which triggered the "green revolution" in Asia during the past 5 years have made a broad impact in boosting rice yields. But in most cases the new varieties IR-8 and IR-5 have had a brief production life as they have been attacked by local forms of fungus, bacterial and virus diseases. There is a continuing major task for each country to carry on the breeding and selection programmes and related research to combine present high-yield capabilities with the disease and pest control and quality factors suited to local conditions and local consumers.

2. Cropping Adjustments — Diversification

During the past fifteen years, Thailand has changed from essentially a rice mono-culture to an increasingly diversified agriculture. Malaysia's hard core of agriculture is rubber and oil palm. A serious limitation to the diversification of agriculture in this country is the lack of dependable information on alternative crop or livestock enterprises.

The consultant team concerned with the Johore-Tenggara land development project, in their Fifth Progress Report of June, 1970, pointed out:

> Owing to the past, almost exclusive, attention to rubber and oil palm, little information is available about the commercial feasibility of other activities. There are also great gaps in the technical information intended for developing many of them.

The study team considering possibilities for future agricultural development in Pahang-Tenggara also has recognized the handicap of

> a limited amount of basic and applied research data and documented commercial experience with respect to the way in which many of the crops being considered perform under Malaysian conditions, and more specifically, under conditions prevailing in the Study Region. This has made it necessary to attempt to modify data and experience from elsewhere in making an assessment of the potential of certain crops.

The study team concludes that, before embarking on any general scale planting of crops in the study region other than rubber and oil palm, it will be necessary to establish a well-organized comprehensive programme of basic and applied research.

The planning and implementation of new cropping and land use systems, whether to adjust agriculture in old areas or for new land development schemes, must be guided by the new knowledge and new technology that fit the precise conditions.

3. Quality of the Environment

There has been a growing popular concern about human health hazards from chemical additives, including agricultural chemicals, since Rachel Carson's book *Silent Spring* made its impact almost a decade ago. Atmospheric and water pollution have come in for more recent attention.

While these problems are world-wide, with Los Angeles, New York City, Mexico City and Tokyo sharing pollution prominence, it is essential to determine the specific nature of the problems and the solutions, as related to agricultural practices, for local areas. Knowledge is the antidote to the fear stemming from uncertainty about health hazards from agricultural chemicals. The sophistication of instrumentation — the ability to detect minute quantities of man-added chemicals in food products — has outdistanced understanding of the relevance of such presence.

The answer-finding and decision-making on these issues cannot be left entirely to the Western World. Political and administrative leaders in the United States have been accused, with some justification, of "panic decisions" in response to public pressure to withdraw approval for use of certain pesticides and herbicides. I share the concern of the official of the U.S. chemical company who deplores the "efforts by 'instant ecologists' to portray manufacturers as 'uncaring polluters'." In the close association with

the agricultural chemicals industry during my years with the U.S. Department of Agriculture research programme, through 1956, I developed a deep appreciation of the efforts by scientists in industry to achieve meaningful understanding of the significance of pesticide residues.

The greater danger in the *emotion-charged* environmental quality issue is the backlash against science and technology generally. It has been estimated that in the U.S. total federal expenditures on research and development have declined in real dollars by more than 20% in the last 4 years. The accompanying withdrawal from research and development work on pesticides by private companies because of uncertain decisions on residues may have a serious potential effect on agricultural production around the world in the years ahead. In this regard the views of Dr Philip Handler, President of the U.S. National Academy of Sciences, have special relevance:

> If we forswear more science and technology, there can be no cleaning up our cities, no progress in mass transportation, no salvage of our once beautiful landscape and no control of overpopulation. Those who scoff at technological solutions to these problems have no alternative solutions.

Research on herbicides must proceed to improve specificity and selectivity as well as to determine the behaviour of various compounds under cropping conditions in Asia. In this connection the experience of the International Rice Research Institute with insecticides is relevant. Certain chemicals such as diazinon were highly effective for control of stem borers, green leaf hoppers and brown plant hoppers for a number of years. However, after four years of use on the same experimental fields, diazinon became ineffective in the control of the brown plant hopper, *Nilaparvata lugens*. This was apparently due to genetic selection of resistant forms of the insect, together with the build up in the soil of types of micro-organisms that readily degraded diazinon and rendered it ineffective a few days after its application. The microbiologists at IRRI have shown that several of the organochlorine insecticides such as DDT, BHC and heptachlor are degraded rather rapidly in flooded padi soils, although the same materials are persistent in well-drained soils.

4. Rural Socio-Economic Factors

One of the prominent "second generation" concerns about Asia's Green Revolution is the prospective unemployment of rural people — especially young people — and increased migration to urban areas. Some will argue that efforts to modernize agricultural production, by mechanization, the use of herbicides, etc., should be restrained in order to perpetuate labour-intensive agricultural practices.

We cannot ignore the need to develop and apply modern techniques to the upgrading of agricultural productivity in Asia. And we must reject the notion that we can anchor youth to the land with the roots of weeds. Present and future generations in Asia will not be content to squat in the fields for endless hours pulling weeds. Perpetuation of drudge labour on the land is not an answer to the rural employment problem. Job opportunities must be expanded elsewhere through the steady commercialization of agriculture. These opportunities will vary in different countries and between regions of a given country.

5. Crop Protection

Perhaps the major justification for national agricultural research capability is the need for a continuous alert to crop disease and pest hazards. Even with highly organized research systems, outbreaks of destructive diseases, of epidemic proportions, may occur. The heavy losses of the 1953 and 1954 wheat crops in the United States to a new race of stem rust is a prime example. The widespread damage to the U.S. corn crop in 1970 from *Helminthosporium* blight is another.

Asian countries face a continuing hazard from virulent forms of bacterial, fungus and virus diseases in rice and other economic crops. At the moment there is concern in Malaysia, in Sarawak, about the damage to pepper from *Phytophthora*. This is not a new hazard — the organism is a continuing limiting factor to pepper growers and has great versatility in destroying other crops around the world. The *Phytophthora* fungus causes stem canker and the black-pod disease of cocoa in Africa and has been found recently in cocoa plantings in Malaysia.

Crop pests and diseases cause losses annually in many countries ranging to 20% or more, in production, handling and storage. The alternatives are either to accept this magnitude of loss as a production cost function or to establish and maintain a research capability to control or at least minimize such losses. Since the physiologic races or forms of disease vary in different agricultural regions of the world, and soil and climate factors influence disease spread, it is necessary to have the research resource at the national level.

AGRICULTURAL RESEARCH CAPABILITIES IN ASIA

My first review of agricultural research programmes in countries of Asia was made in 1950, prior to the activation of the U.S. Point IV programme of technical co-operation. As we assess the present status of national research capabilities, it is evident that far too little progress has been made during these 20 years of substantial technical assistance from many national and international, private and public organizations.

India is one exception. The review of agricultural research and education by a joint team of Indian and American scientists in 1955 resulted in the reshaping and strengthening of the Indian Council of Agricultural Research, the Indian Agricultural Research Institute and other centralized research institutes, and the establishment of strong experiment station capabilities as a part of the emerging agricultural universities. Research on the major crops in India is now supported through All-India Co-ordinated Research schemes rather than through the fractionated project support of the past. Research in soil and water similarly is organized on a national basis.

Detailed reviews of research capabilities have been conducted in Korea in 1967, in Pakistan and Malaysia in 1968 and in Indonesia in 1969. An intensive study of research in the Philippines is now in process and will be completed within this calendar year. These studies have identified the limited scientific staff capabilities in each of the countries, the inadequacy of research facilities, the lack of co-ordination of support and operations in research — in general a common insufficiency of a suitable technological base upon which to build agricultural development.

There are, of course, exceptions and some examples of excellence in organizations and programmes in Asia. The Rubber Research Institute of Malaya and the former research programmes on sugar cane in Java and India stand out.

RESTRAINTS IN STRENGTHENING NATIONAL RESEARCH SYSTEMS

When the slow progress in building national self-reliance in agricultural research over the past two decades is analysed, a number of causal factors can be identified. Some of these, listed without regard to priority significance, follow.

1. *The action-oriented efforts in extension and community or rural development*

The developing nations as well as external assistance agencies have taken the position in past years that development must be accelerated — "we cannot wait, the disadvantaged people of the world are in a hurry". The rate of progress in agricultural development in Asia over the past twenty years furnishes abundant evidence that such "haste makes waste" and the substantial investments which have been made to apply poorly-fitted innovations from temperate climate agriculture to tropical farming regions have generally produced minimal returns.

Dr John W. Mellor, Professor of Agricultural Economics at Cornell University, after a critical analysis of factors in rural progress in India (1968), concluded:

> The most telling criticism of Indian agricultural development policy is that the key deficiency — lack of an effective organisation to produce a flow of highly profitable innovations suited to Indian conditions — was not recognised at the beginning. The error was not in underrating the importance of improved technologies but in overestimating the productivity and applicability of what was at hand. . . .
>
> The research problem came increasingly to be realised in the second and third plan periods. The advantage of hindsight suggests that at least five years and possibly ten could have been saved if this problem had been more fully understood and tackled initially. The obvious lesson is that the first step in an agricultural development program should be initiation of a substantial, highly integrated research program, directly connected to farm problems at one end and to basic research and foreign efforts at the other.

There is still a continuing tendency to stress so-called action programmes or development schemes to stimulate farmers to better efforts or to encourage new or expanded crop production to diversify agriculture. Such efforts, based upon inadequate knowledge of what to grow, where to grow it, and how to grow it, together with uncertainties with respect to market outlets, will continue to be unproductive until national research capabilities have been strengthened to furnish more dependable guidance.

2. *Lack of awareness and understanding of political and administrative leaders of the importance of new technology in agricultural development*

In recognition of the importance of improving food production in Mexico, the Rockefeller Foundation in 1943 initiated an adaptive research programme concentrating on improvement

of wheat and maize production, in co-operation with the Ministry of Agriculture of the Government of Mexico. This programme was subsequently expanded in Latin America with co-operative programmes in Columbia, Chile, Peru, Ecquador and other countries.

In 1954 the Foundation turned attention to the possibility of improving rice production in Asia. Following reviews of research and educational institutions, over a period of about eighteen months, the Foundation endeavoured to strengthen rice research resources through training awards and grants to selected Asian institutions. After about five years, in 1959, it became apparent that this process was relatively ineffective, primarily because political and administrative leaders of the nations involved did not appreciate the importance of a strengthened research capability and were not furnishing the co-operative support necessary to make the external assistance meaningful.

The International Rice Research Institute was conceived in 1959, and established in 1962, in order to provide a multidisciplinary research team approach to study of the various factors limiting rice production and to develop a modern rice production technology for Asian conditions. The IRRI, which produced readily applicable results three years later, demonstrates what can be done when there is a positive commitment to support and develop an effective research capability.

3. *The heritage of colonial emphasis on primary products for international commerce*

The strong past emphasis on plantation or estate crops or products such as rubber, oil palm, sugarcane, cotton, jute, tea, coffee, cocoa, etc., directed attention toward research to insure dependable production of these commodities. This situation prevailed in India, Indonesia, Malaya and other countries of Asia and Africa. Some of these countries have moved away from the strict commodity research institute approach or have built national research capabilities through and around such organizations. Other countries, notably Indonesia, are still trying to consolidate and/or co-ordinate these fractured research resources into effective national systems. Their support through special cesses, with preferred salary levels and operations budgets, encourages those so privileged to perpetuate their autonomous status.

4. *The disruptive effects of World War 2 and subsequent struggles for independence*

The benefits of new agricultural technology developed in the United States and other countries prior to and during World War 2 were delayed in coming to those countries of Asia which were occupied by foreign forces during the war, and immediately or soon thereafter were engaged in efforts to achieve national independence. India, Pakistan, Indonesia and Korea were among the Asian countries where major institutional adjustments were required in the 1950s and the 1960s following a decade or more of disruption of previously established research and educational systems.

5. *The Green Revolution*

The failure of the monsoons in India and Pakistan in 1965 focussed world-wide attention on the increasingly critical shortages of food production in Asia. The availability of the high-yielding varieties of rice together with the improved production practices from the IRRI in 1966 provided the prime resource for boosting the yields of this important crop throughout South Asia and the Far East countries. The growing attitude of despair about world food supplies in 1965 changed abruptly to an attitude of cautious optimism by 1968. In fact, we now face the real risk of *over-optimism* and a sense of complacency about future food resources.

The Green Revolution involved not only the improved technology for rice production but also for wheat production in India and Pakistan, based upon the research initiated by the Rockefeller Foundation in Latin America in 1943. The "Mexican wheats" as well as the "Miracle rices" combined to change our targets and prospects for food production in Asia during the past five years. For his leadership in research in developing the Mexican wheats and their application to South Asia, Dr Norman E. Borlaug of the Rockefeller Foundation was awarded the Nobel Peace Prize for 1970, the first agricultural scientist to achieve this recognition.

The Green Revolution has created a greater awareness of the value of research-adapted technology for agricultural growth and development. Top political and administrative leaders in India, Pakistan, the Philippines and other Asian nations have recognized the contributions of the adaptive research programmes in wheat and rice production. The intensive agricultural programme to accelerate the extensive use of the new varieties and related

technology received top government support during the past five years.

There is still the unanswered question as to whether those Asian government leaders who identified the benefits or fruits of research — from the IRRI and from Mexico — have developed any firm priority commitments to the building of national capabilities to generate such new technology. Because of the outstanding performance of the IRRI, the International centers including the International Rice Research Institute, the International Center for Maize and Wheat Improvement in Mexico, the International Institute for Tropical Agriculture in Nigeria, and the centre for International Agricultural Research in Columbia are in the forefront at the present time, as the potential generators of new agricultural technology. Leaders of economic and technical assistance organizations, including private foundations, international organizations and national agencies, are providing increasing amounts of support to such centres.

The 1970s may well be another decade of dependence on external agricultural technology for the developing nations unless there is greater awareness of the need for building national capabilities for research. This awareness must emerge primarily within the developing countries themselves, by political and administrative leaders at the highest levels of government.

The Government of Malaysia is taking steps to establish a more effective research base through the Malaysian Agricultural Research and Development Institute. There is, unfortunately, no ready formula for instant institutional development and the evolution of MARDI into a productive and effective national research system will take five to ten years. Results from high priority research projects will, of course, be forthcoming prior to that time but it must be recognized that an effective institutional base for research and education requires a strong commitment, including effective financial support, for a continuing period of years.

THE ROLE OF PRIVATE INDUSTRY IN AGRICULTURAL RESEARCH

The private industries concerned with agriculture are a most important factor in agricultural research in the more advanced as well as in the developing nations. In the United States, in 1965, the private industries spent $460 million or 53.9% of the funds supporting agricultural research. The balance was provided through federal appropriations or grants and from state resources.

The agricultural industries which provide fertilizers, pesticides, herbicides and machines have a prime concern that their products meet farm requirements and that they are used properly. The heavy investments by farmers in modern agricultural inputs require maximum efficiency and suitability of these inputs.

The support by industry is an important dimension in cost-sharing in agricultural research. It would be most unfortunate if private companies were to reduce or eliminate research and development work on herbicides and pest control chemicals because of uncertainties about government decisions on use of agricultural chemicals. If the full burden for development of crop protection materials and methods is shifted to government agencies in the future, less effective pest control practices, including weed control measures, can be expected in the years ahead. With present tendencies to de-emphasize support for science and technology it is very doubtful whether federal and state government will pick up the added research tab of the magnitude provided by private industry in recent years.

SUMMARY

I have emphasized the form rather than the substance of research in these remarks. Your programme has a full measure of reports on specific experimental results for the remaining sessions of the Conference. Many of these are project-orientated, on individual chemicals, by scientists from industrial or public organizations.

Weed control research is multi-disciplinary; it requires the type of broad organizational and financial base that will support essential basic and background research as well as the more applied and observational trials.

As agriculture in Asia is modernized, with greater dependence on new technology, the research resource base in this region of the world must be strengthened. It can be developed on a broadly-participating *national* basis only if national administrative and political leaders develop a greater awareness of and a deeper commitment to improved technology for agricultural growth. If this does not occur, we can expect a continued emphasis by technical assistance "donor" organizations on the establishment of more specialized *international* agricultural institutes as sources of new agricultural technology. This could well defer the building of *national* self-sufficiency in agricultural science and technology for another decade or more.

The advances in weed control practice over the past 25 years are marked by ever-increasing specificity — of selected chemicals to control given weeds in certain crops under prescribed growing conditions. If agricultural growth and development, and diversification of agriculture, are to proceed at the pace necessary to meet targets for economic and social progress in Asia, there must be equal precision in fitting solutions to location-specific problems in crop and livestock production. This will require more positive efforts to strengthen *national* research capabilities.

PROSPECTS FOR CHEMICAL WEED CONTROL IN INDONESIA

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Summary

Weed science in Indonesia — and in particular weed control methods — is still in its infancy. In many crops, weeding still depends mainly on manual labour. However, it was recently felt that, in particular plantation crops, manual weeding is becoming difficult, especially during certain periods of time and in particular thinly populated areas.

Since 1966 the use of herbicides in agriculture, especially in plantation crops — *e.g.* rubber, tea and oil-palm — has been becoming more economically important. It is also expected that the use of herbicides will be increasingly needed in other crops, such as sugarcane, in mechanized rice farming, in irrigation system or water reservoirs, in vegetables and other horticultural crops.

A co-ordinated screening programme is needed to achieve optimum results and efficient practical implementation of chemical weed control, directed not only toward the crop system, but also toward the weed species. In this respect, an inventory of noxious and troublesome weeds found in various agricultural conditions will be very valuable.

There is a general lack of knowledge of the principles and practice of chemical weed control. Therefore, a training programme is urgently needed, if the limited effort available is to be as productive as possible.

INTRODUCTION

Weeds interfere with every aspect of human welfare, and particularly with crop production. Their importance in Indonesian agriculture is undoubtedly great, as Indonesia is part of the tropical belt with favourable climate throughout the year, adequate daylight, warm and humid for the prolific growth of various weed species.

Chemical weed control has been one of the significant advancements in world agriculture during the past thirty years and many works have been conducted in Indonesia since 1950 to study the possibilities of replacing conventional manual weed control with herbicides. However, as in many other developing countries, the

progress in this field has been rather slow owing to the presence of abundant cheap labour. Large-scale use of herbicides in practice has started more recently during the past few years in North Sumatra and Java.

It is anticipated that the future development of herbicide usage in Indonesia will greatly depend on the projected Five-year Development Plan, 1969-1974, which stresses the agricultural sector as the central point of its development.

The aim of this paper is to analyse the prospects for chemical weed control based on the current situation and factors that might affect the future development of weed control programmes in Indonesia.

Because of the limited opportunity and limited time available, the information was compiled from some of the current users of herbicides — *e.g.*, State Estate Enterprises (P.N.P.). It is hoped that further study will be made to complete the information, including material from industrial sectors.

THE FIVE-YEAR PLAN

The Five-year Plan is directed toward raising the standard of living of the people and creating new foundations, which will enable planning and implementation of the Second Five-year Plan.

For long, agriculture has been the backbone of the economic structure of Indonesia. The majority of manpower (approximately 80% of the 115 million people) is employed in agriculture, while during the past years, approximately 70% of foreign exchange earnings came from exported agricultural commodities (Department of Information, 1969).

Development in agriculture means a widening of employment and increase in the income of the greater part of the Indonesian people. This will increase demand and develop new markets for industrial production. Subsequently, this will bring price stability and stability of wages, and the emergence of industry which will be directed toward supporting agricultural sectors, and of industries producing substitute articles which are otherwise imported. In this way a wider field of employment will be opened and there will be changes in the proportion of manpower available for the agricultural sector. By the end of the Five-year Plan it may fairly be assumed that the available agricultural manpower, including that used for manual weeding, will be reduced.

FOOD PRODUCTION

The aim of food production increase is that, by 1974, Indonesia will be self-supporting in rice, and that the nutritive value of the diet (containing animal and vegetable proteins) will be improved.

The target of rice production in 1974 is 15.4 million tonnes, which is an increase of 50% within 5 years — compared with the 1968 production figure. In order to reach this target, efforts are being made through intensification — *i.e.,* through the improvement of the "five efforts" system (irrigation, superior seed, fertilizers, pesticides and information) — and expansion of agricultural areas outside Java.

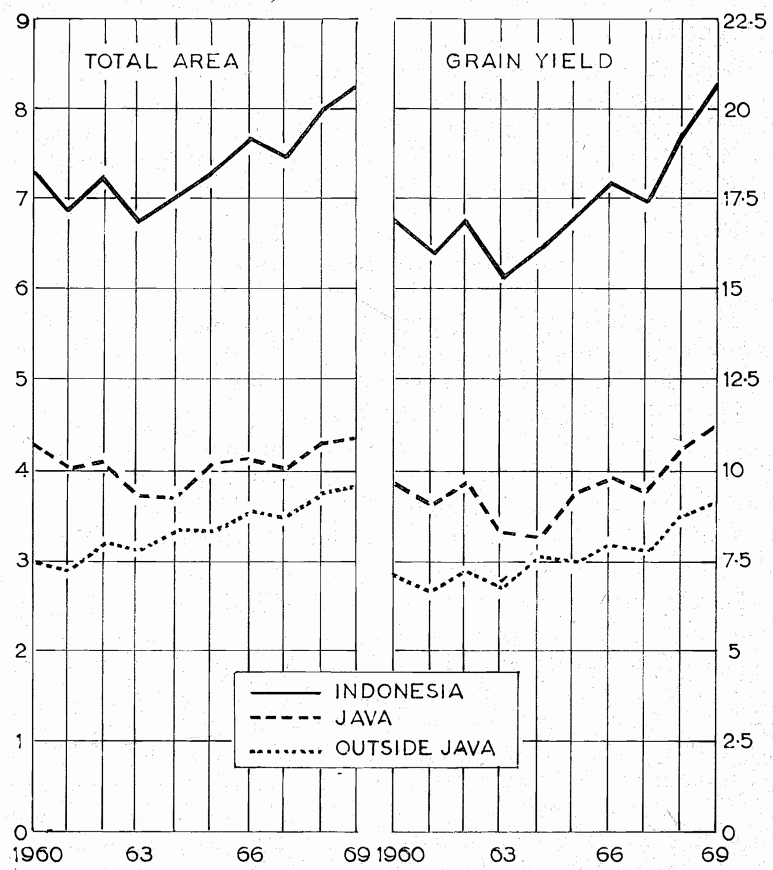

Fig. 1: Rice production in Indonesia, 1960-69. (Central Bureau of Statistics, Djakarta.)

Figure 1 shows the increase of rice production in Indonesia during the past 10 years (1960-69) and the total area of rice-fields inside and outside Java. It is to be noted here that the increase of production is partly caused by the success of the intensification efforts in Java, but there is also a considerable increase of producing areas outside Java, where labour is relatively scarce.

Forest land covers an area of 120 million ha, of which 18 million ha could be converted into more productive farmland. Almost all of these areas (97%) are located outside Java. This will certainly affect the emphasis of weed control practices; a logical consequence of new expansion of rice culture outside Java is that it will be mainly in the form of mechanized or semi-mechanized rice production units.

Several good examples of this semi-mechanized rice-field operation are clearly demonstrated by several rice projects conducted by the Estate Enterprises, namely, P.N.P. V at Sungei Karang (approximately 550 ha), Uniroyal at Kisaran (approximately 400 ha) and P.N.P. XVIII at Subah (approximately 100 ha). Non-productive rubber areas were converted into irrigated and upland rice-field, depending upon the availability of irrigation water.

In this semi-mechanized culture, rotovators are being used for land preparation, while combine harvesters are available for harvesting the crop. Transplanting and weeding are still being done manually. However, the use of herbicides to replace manual weeding seems promising. Paraquat at minimum rates and zero-tillage followed by MCPA, or propanil combined with manual weeding seems promising as regards yield per unit area. Important problems still occur regarding the price of herbicides as compared with labour cost. To some extent, propanil is already being used on upland rice to replace manual weeding.

Table 1 lists a selection of promising herbicides for weed control in food crops (rice and corn) prepared from various reports to the First Indonesian Weed Science Conference (Mangunsukardjo and Kadnan, 1971a, b; Sutidjo and Sjarifullah, 1971; Sundaru, 1971; Ronoprawiro, 1971).

To assist in the improvement of the nutritive value of the diet of the people, it was recently planned to carry out intensification efforts in the so-called "mass guidance system" in developing poultry and animal husbandry. How much these new activities in food production will affect the availability of manpower for agriculture, and further influence the use of pesticides in general and herbicides in particular, is as yet unpredictable. However, every success in this campaign (as any success in other developmental efforts, in industry, etc.) will inevitably absorb a certain part of manpower resources and increase the costs of manual weeding accordingly.

TABLE 1: HERBICIDES WITH POTENTIAL USE IN RICE AND CORN

Crops and Treatment (kg/ha)	*Time of Application** *D.B.P.(S)*	*D.A.P.(S)*
Upland rice:		
propanil 4	—	12
2,4-D amine 1.4	—	20
MCPA 0.5-1.0	—	25
metobromuron 3.0 + 2,4-D amine 1.4	21	22
MSMA 2.64 . . . 2,4-D amine 1.4	7	22
paraquat 0.6 . . . 2,4-D amine 1.4	7	22
propanil 4 . . . MCPA 0.5 . . . MCPA 0.5	—	14 . . . 28 . . . 42
Lowland rice:		
propanil 3.3 . . . handweeding	—	24 . . . 30
nitrofen (granular) 2.0	—	3
2,4-D IPE (granular) 0.8	—	4
benthiocarbamate (granular) 3.0	—	4
delachlor 1.0 + 2,4-D BE (granular) 0.5	—	4
delachlor (granular) 1.0	—	4
Corn:		
chlorthal 0.55	—	3
2,4-D amine 0.80	—	32
2,4,5-T + 2,4-D amine 0.45	—	3
2,4-D amine + MCPA 0.80	—	32
nitrofen 2.50	—	3

*D.B.P.(S) = Days before planting (sowing). D.A.P.(S) = days after planting (sowing).
. . . = followed by.
+ = mixture.

EXPORT COMMODITIES

Rubber, palm-oil, tea, coffee, sugar, pepper, tobacco, copra, etc., are the main export commodities from estates and smallholder plantations. Efforts have been made to increase the volume and quality of export products through new investments in the form of rejuvenation and new planting, high yielding clones, reduced cost per unit, the use of improved technology, etc.

Estate Enterprises are mainly located in North Sumatra, Java and to some extent in South Sumatra and South Sulawesi (see Fig. 2). It is also interesting to note that most estates are located in areas with a population density of 90 to 769 per km². A number of small estates, however, are found in less densely populated areas, namely 20 to 99 per km² (see Table 2).

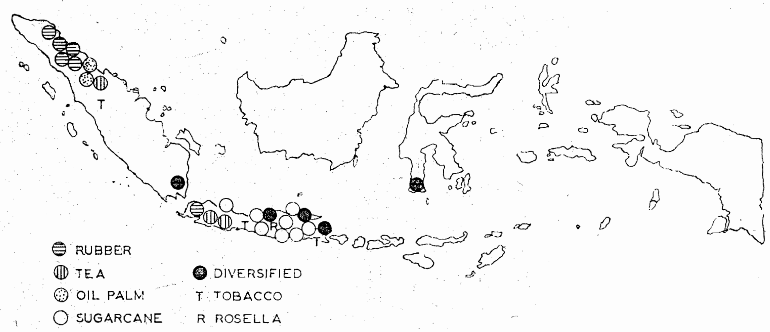

Fig. 2: The location of state estates.

TABLE 2: POPULATION DENSITY OF INDONESIA IN 1970
(Central Bureau of Statistics, Djakarta)

Province	*Total Population*	*Area (km²)*	*Population Density (per km²)*
1. Djakarta-Raya	4,303,768	577	7,458.8
2. Jogjakarta	2,438,489	3,169	769.5*
3. Central Java	21,262,165	34,206	621.6*
4. East Java	24,812,305	47,922	517.8*
5. West Java	20,682,781	46,300	446.7*
6. Bali	2,064,997	5,570	370.7
7. West Nusa-Tenggara	2,154,335	20,177	106.8
8. South Sulawesi	5,009,968	50.233	99.7†
9. North Sumatra	6,399,687	70,787	90.4*
10. Lampung	2,662,695	33,342	79.9†
11. West Sumatra	2,704,247	41,778	64.7†
12. South Kalimantan	1,646,938	37,660	43.7
13. East Nusa-Tenggara	2,234,515	52,876	42.3
14. North Sulawesi	1,646,747	44,239	37.2
15. Atjeh	1,923,885	55,392	34.7†
16. Djambi	978,312	44,924	21.8†
17. South Sumatra	3,338,581	158,163	21.1†
18. Central Sulawesi	896,521	44,239	20.3
19. South-East Sulawesi	897,921	50,233	17.9
20. Riau	1,538,932	94,562	16.3
21. Maluku	1,061,407	74,505	14.2
22. West Kalimantan	1,758,414	146,760	12.0
23. Bengkulu	544,946	124,821	4.4
24. Central Kalimantan	719,505	152,600	4.2
25. East Kalimantan	673,142	202,440	3.3
26. West Irian	933,000	421,981	2.2
Indonesia	115,288,203	2,059,557	55.97

*Areas where most of the estates are found.
†Areas where some estates are found.

TABLE 3: TOTAL AREA, AVERAGE ANNUAL PRODUCT AND EXPORTED VOLUME OF IMPORTANT COMMODITIES (1965-1969, Central Bureau of Statistics, Djakarta)

Commodities	*Total area (000 ha)*	*Av. Annual Product (000 tonnes)*	*Exported Vol. (% of Annual Product)*
Rubber	1,900	730	95
Palm-oil	72	140	80
Coffee	350	120	71
Tea	115	75	46
Sugar	104	700	34
Cacao	10	1	32
Tobacco	152	50	18

The figures in Table 3 illustrate the total areas of rubber, oil-palm, tea, coffee, sugar and other important estates and their respective average annual product during the five years 1965 to 1969. They also show the average percentage of the annual product exported.

The use of herbicides for weed control in the various plantations greatly depends on the manpower resources and scale of wages. Comparing the four estate areas in North Sumatra, West, Central and East Java, in terms of their order of population density, it could be logically explained that the problem of manpower resources diminishes in the order North Sumatra > West Java > East Java > Central Java. This coincides with the fact that North Sumatra was the first to introduce the use of herbicides on a commercial scale as from 1966. West Java has started to use herbicides more recently, commencing 1968, while East and Central Java might be expected to follow shortly. Furthermore, West Java is the most vulnerable province in respect to urbanization into the growing city of Djakarta.

Almost all tea and oil-palm plantations, as well as most rubber estates, are located in North Sumatra and West Java, which explains why the most important herbicide requirements are for use in those crops.

TABLE 4: CHEMICAL WEEDING IN STATE ESTATES (As % of the total weeded area)

Crop	*North Sumatra*	*West Java*	*Others*
Rubber	15	5	—
Tea	25	20	—
Oil-palm	<0.1	—	—

Calculated from the preliminary figures of 1970, the approximate percentage areas of State Estate Enterprises using herbicides are shown in Table 4.

Sugarcane may be considered as the next crop in East and Central Java where chemical weeding will become more important. The main reason for this attitude is the need to avoid crucial problems in employing too many labourers for manual weeding at acceptable wages from a managerial point of view. Secondly, in other cases there are indications of less labour being available during the early stage of cane growth (Kuntohartono, 1971) owing to social duties in rural communities during rice harvesting, etc.

From a psychological and sociological point of view, this change of emphasis in weeding methods should be co-ordinated with other efforts to create other fields of employment within the framework of the Five-year Development Plan.

Tobacco plantations, which are widespread in North Sumatra, which is known as the producer of Deli tobacco, have a special cultural system — *i.e.,* a shifting cultivation method in order to obtain a high organic soil content. Weed problems in this system are in practice simple. Other tobacco plantations are located in Central and East Java.

The most used herbicides at present are dalapon, paraquat, MSMA, 2,4-D amine and sodium chlorate in rubber, oil-palm and tea. More details of the herbicides used in plantations are presented in Table 5.

TABLE 5: HERBICIDES WIDELY USED IN PLANTATIONS

Crops and Treatments (kg/ha)	*No. Applications per year*
Rubber:	
dalapon 5-8.5	3
paraquat 0.4-0.8	4
dalapon 5* . . . paraquat 0.3	†
Tea	
MSMA 2.7 + 2,4-D amine 1.3 + sodium chlorate 2.8	4
dalapon 4 + 2,4-D amine 0.7	3
paraquat 0.3	6
Oil-palm	
dalapon 5 . . . paraquat 0.3	†
pentachlorophenol 0.8-1.4	†

. . . = followed by.
+ = mixture.
*4 weeks later.
†Depends on the weed condition.

TABLE 6: A PRELIMINARY LIST OF INSTITUTIONS ENGAGED IN WEED RESEARCH WORK AND DEVELOPMENT IN INDONESIA

Location: Institution and Address	*No. of Staff*	*Name of Principal in Weed Problems*	*Field of Interest*
Medan:			
1. Research Institute of the Sumatra Planters' Assoc. (RISPA), P.O. Box 14, Medan	4	S. Mangunsukardjo	Weed control in rice and plantation.
2. Marihat Research Station, P.O. Box 37, Pematang-siantar	4	K. Sutedjo	Weed control in tea and oil-palm.
3. Rubber Research Center, Tandjung Morawa	1	R. Basuki	Weed control in rubber and other plantations.
4. P.N.P. V, Sei Karang	2	J. Pais	Weed control in rice.
5. P.N.P. VI, Pabatu, Tebing-tinggi	6	A. J. L. Purba	Weed control in oil-palm and rubber.
6. P.N.P. VIII, Dj. Pemuda 10, Medan	2	S. Arifin	Weed control in tea.
Djakarta:			
7. I.C.I. Plant Protection, Dj. Kertosono 10, Djakarta	?	J. E. Varley	Weed control in rice and plantation.
8. Ciba-Geigy, Dj. Birah I/1, Djakarta	?	?	Weed control in plantation.
9. Shell Int. Chem. Co., Djl. Malaka 50, Djakarta	?	M. S. Eversdijk	Weed control in rice (?).
10. Pertamina Oil Co., Djl. Perwira 10, Djakarta	?	?	Weed control in agriculture.
11. Far East Chemical Services Inc., affiliate Rohm & Haas, Djl. M.H. Thamrin 10, Djakarta	3	P. Tirtarahardja	Weed control in rice and plantation.
12. BASF, Djl. Basuki 12, Djakarta	?	U. Hinrichsen	Weed control in plantation.
Bandung:			
13. Bandung Institute of Technology	?	?	Weed biology.
14. Padjadjaran University, Bandung	?	O. Ramelan	Weed control in agriculture.
15. P.N.P. XII	?	K. Hutomo	Weed control in tea.
16. P.N.P. XIII	?	I. Santosa	Weed control in tea.
Bogor:			
17. Central Research Inst. for Agriculture, Djl Merdeka 99, Bogor	2	M. Sundaru	Weed control in rice, corn, and other food crops.
18. Research Institute for Estate Crops, Taman Ade Irma Nasution 1, Bogor	2	A. Sudarsan	Weed control in rubber and tea.
19. Research Institute for Industrial Crops, Djl. Tjimanggu Ketjil 1, Bogor	1	H. Azis	Weed control in industrial crops, particularly in rosella.
20. Research Institute for Inland Fisheries, Djl. Sempur 1, Bogor	2	N. Suweta	Weed control in open waters.
21. Research Institute for Animal Husbandry, Djl. Gunung Gede, Bogor	1	M. S. Siregar	Weed competition in pasture.
22. Research Institute for Forestry, Djl. Gunung Batu, Bogor	1	R. Surjono	Weed problems in forestry.
23. National Biological Inst., Regional Center for Tropical Biology, P.O. Box 17, Bogor	4	M. Soerjani	Weed biology.
24. Bogor Agricultural University, Djl. Otto Iskandardinata, Bogor	4	K. Sukartaatmadja	Weed control in rice and plantation, inventory of weeds.
Jogjakarta:			
25. Gadjah-Mada University, Fac. of Agriculture/Biology, Jogjakarta	3	S. Ronoprawiro	Weed control in rice, corn, and peanuts, inventory of weeds
Salatiga:			
26. Satya-watjana University, Salatiga	1	N. Adam	Inventory of weeds in Rawa Pening lake.
27. Rubber Research Center, Getas, Salatiga	2	I. Darmawidjaja	Weed control in rubber.
Pasuruan:			
28. Research Institute for Sugarcane Industry, Djl. Pahlawan 25, Pasuruan.	1	T. Kuntohartono	Weed control in sugarcane.
Malang:			
29. University of Brawidjaja, Fac. of Agriculture, Djl. Dinojo, Malang	3	Sutono	Weed problems in rice, particularly of *Salvinia*.

There are differences in the cost of weeding from place to place, and from one crop to the other. Cost of weeding, particularly of manual weeding, has increased markedly during the past few years. The order of higher to lower cost are North Sumatra > West Java > Central Java $\simeq$ East Java.

OTHER POSSIBILITIES

Because of local consumption, the export of vegetables and fruits should be considered as negligible at present. The role of horticulture, especially in the vegetable growing areas, is of extreme importance owing to the large number of people involved in land preparation, planting, pest control, and harvesting.

Certain technical factors might be present so that chemical weed control is desirable, for instance in onion and similar crops, where disturbance of the soil by manual weeding might cause injurious effects to the root. Furthermore, labour is also becoming more expensive in these particular areas (including weeding costs). Introduction of the use of herbicides in horticulture might be very successful in the very near future. So far, field testing of herbicides on an experimental scale has shown promising results. In spite of this, more investigational work is still needed.

Another very limited use of herbicides has been demonstrated at Rawa Pening lake in Central Java using 2,4-D amine, and by the Brantas River authority in East Java using paraquat, to prevent the spread of *Salvinia* and *Pistia.*

FUTURE DEVELOPMENT PLANS IN WEED CONTROL

To achieve more efficient weed control methods with respect to planning, selection of proper herbicides, logistic support, import regulations, distribution, etc., it is vitally important to give priority and encouragement to weed research activities in Indonesia.

A list of institutions actively engaged in weed research work and development is given in Table 6.

As suggested during the First Indonesian Weed Science Conference in 1971 in Bogor (Soerjani *et al.,* 1971), it is the first priority in considering future weed research in Indonesia to make an inventory of weeds commonly found in Indonesia. A list of important weed species compiled from available literature, combined with preliminary surveys done in several places, is given as Appendix 1. More surveys have to be made to collect additional information on the current distribution of weeds in important agro-ecological conditions. It is also necessary to record important biological shifts resulting from cultural methods in general and weed control methods in particular.

At present among the most important weeds, from the point of view of their abundance and difficulty in control, are *Imperata cylindrica, Cyperus rotundus, Mikania cordata, Salvinia* spp., and *Eichhornia crassipes.*

Except for *Cyperus rotundus,* many of these weeds are not really difficult to control (mechanically, chemically or with combined methods). However, problems might exist as regards economic feasibility and the continuous supply of herbicides. The first problem might arise from managerial factors which create uncertainty in developing feasible planning. This is an important point, as the use and cost of herbicides might be relatively high during the first years; the cost might subsequently decrease, provided the plan was consistently followed. The second problem must be overcome by having as many alternatives as possible. This policy has further advantages, among others minimizing the hazardous effect of certain herbicides being used continuously, and also preventing the establishment of resistant weed species against particular control methods.

The next priority is to assess losses due to weeds so that weed control programmes can be based on more accurate estimates of feasibility.

The biology of important weed species should be studied to achieve better understanding of their growth habits, life-cycles and reproduction to obtain satisfactory results in weed control. This study should include possible utilization of certain abundant weed species, such as *Imperata cylindrica* which was surveyed for possible use of paper production and *Eichhornia crassipes* for possible use as compost and mulching.

Planned and co-ordinated studies to improve control methods should be initiated to achieve optimum results and efficient practical implementation of weed control. The study should not only be directed toward the crop system but also toward the variation of the phyto-sociology of the weeds in various important environmental conditions (as regards soil type, rainfall, temperature, humidity, light intensity, etc.). In this respect, it is suggested that a so-called data centre for information about weeds in Indonesia is needed. These data would be available and communicable to every interested party. The official communication of the Weed Science Society of Indonesia, *Weeds in Indonesia,* could perform part of this task.

There is a general lack of knowledge of the principles and practice of chemical weed control. Therefore an advanced training programme in weed science either abroad or at home for key persons from official as well as commercial institutions is urgently needed. There are only limited manpower and efforts in weed science in Indonesia. Training courses in weed science will inevitably improve the existing efforts and make them as productive as possible.

Summarizing, we may conclude that the future of chemical weed control in Indonesia in a diversity of crops still remains open, with unlimited potential and possibilities for further development.

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APPENDIX 1

A Preliminary List of Weeds Commonly Found in Indonesian Agriculture

Prepared by: R. E. Nasution and M. Soerjani, Regional Center for Tropical Biology and National Biological Institute, Bogor

I. = Indonesian. J. = Javanese. S. = Sundanese.

Family: Species	*Vernacular Names*	*Rubber*	*Tea*	*Oil-palm*	*Sugarcane*	*Lowland rice*	*Upland rice*	*Irrigation system*	*Lakes*
AMARANTHACEAE									
Alternanthera sessilis (L), R.Br.	keremak (I); kremeh (J.)	—	x	x	x	—	x	—	—
A. philoxeroides (Mart.) Griseb.	—	—	—	—	x	x	—	—	—
Amaranthus spinosus L.	bajem duri (I.J.S.); bajem radja (J.)	x	x	x	x	—	x	—	—
ARACEAE									
Pistia stratiotes L.	kaju-apu (I.J.); ki-apu (S.)	—	—	—	—	x	—	x	x
BORAGINACEAE									
Heliotropium indicum L.	bandotan lombok (I.); gagadjahan (J.)	—	—	—	x	x	—	x	—
BUTOMACEAE									
Limnocharis flava (L.) Buch.	etjeng (I.S.); gendjer (S.J.)	—	—	—	—	x	—	x	x
CARYOPHYLLACEAE									
Drymaria cordata Willd.	djukut-ibun (S.); tjebungan (J.)	—	x	—	—	x	x	—	—
CERATOPHYLLACEAE									
Ceratophyllum demersum L.	—	—	—	—	—	x	—	x	x
COMMELINACEAE									
Commelina nudiflora L.	gewor (S.); brambangan (J.)	—	x	—	—	x	x	—	—

Family: Species	Vernacular Names	Lakes	Irrigation system	Upland rice	Lowland rice	Sugarcane	Oil-palm	Tea	Rubber
COMPOSITAE									
Ageratum conyzoides L.	bandotan (I.J.); babadotan (S.)	x	x	x	x	—	x	—	—
Bidens pilosa L.	ketulan (J.); hareunga (S.)	x	x	—	—	—	x	—	—
Blumea balsamifera DC.	sembung (I.J.S.)	x	x	—	—	—	—	—	—
Eclipta alba Hassk.	urang-aring (I.J.S.)	—	x	—	x	—	x	—	—
Erechtites valerianifolia Raf.	belostrok (S.); sintrong (S.); anjaran (J.); djombret (J.)	x	x	—	—	x	x	—	—
Erigeron linifolius Willd.	djalantir (S.); djabungan (J.)	x	x	—	—	x	x	—	—
Eupatorium pallescens DC.	kirinjuh (S.)	x	x	—	—	—	x	—	—
Mikania cordata Rob.	areuj tajaputuheur (S.); sembung rambat (J.)	x	x	x	—	—	—	—	—
Synedrella nudiflora Gaertn.	djotang (S.); gletangan (J.)	x	x	x	—	—	—	—	—
Tridax procumbens L.	gletang (I.J.); orangaring (J.)	x	x	—	x	—	—	—	—
CYPERACEAE									
Cyperus compressus L.	teki (I.)	—	—	x	x	—	—	—	—
C. difformis L.	teki (I.)	—	—	x	x	—	—	—	—
C. iria L.	teki (I.); djekeng (J.)	—	—	x	x	x	—	—	—
C. rotundus L.	teki (I.J.S.)	x	x	x	x	—	x	—	—
Fimbristylis annua (All.) R. & S.	bulu mata munding (S.)	x	x	x	—	—	—	—	—
F. miliacea (L.) Vahl.	babawangan (S.); adas²an (J.)	—	—	—	x	x	—	—	—
Kyllinga brevifolia Rottb.	djukut pendul (S.)	x	x	—	—	x	—	—	—
K. monocephala Rottb.	teki (I.J.S.); melaran (J.)	x	x	—	—	x	—	—	—
Scirpus laterifolius J.F.Gmel.	mendong (J.); walini (S.)	—	—	—	—	x	—	x	x
EUPHORBIACEAE									
Euphorbia hirta L.	gendong anak (I.); patikan kebo (J.)	—	—	—	x	x	x	—	—
E. geniculata Ortega	—	x	x	—	—	—	x	—	—
Phyllanthus niruri L.	memeniran, meniran (I.J.S.)	x	x	x	x	—	x	—	—
GRAMINEAE									
Axonopus compressus P.B.	rumput pait (I.); papahitan (S.)	x	x	x	—	—	—	—	—
Cynodon dactylon Pers.	djukut kakawatan (S.); suket grinting (J.)	x	x	x	x	—	x	—	—
Echinochloa colonum (L.) Link.	djadjagoan leutik (S.)	—	—	—	—	x	x	—	—
E. crus-galli (L.) Beauv.	djadjagoan (S.)	—	—	—	—	x	x	—	—
Eleusine indica (L.) Gaertn.	rumput belulang (I.); djukut-djampang (S.); godongula (J.)	x	x	x	x	—	x	—	—
Eragrostis amabilis O.K.	djukut-karukuan (S.); emprit²an (J.)	x	x	—	—	—	—	—	—
E. japonica Trin	djampangmerak, merakan S.)	—	x	—	x	—	—	—	—
Imperata cylindrica (L.) Beauv.	alang-alang (I.J.); eurih (S.)	x	x	x	x	—	x	—	—
Ischaemum aristatum L.	blembem (J.)	—	—	x	x	—	—	—	—
Panicum barbatum Lamk.	djambe2an (J.); djamarak (S.)	x	x	—	—	—	—	—	—
P. colonum L.	djadjagoan leutik (S.); tuton (J.)	—	—	—	x	x	—	—	—
P. repens L	lampojangan (I.); pujangan (J.); djadjahean (S.)	x	x	—	x	x	x	x	x
P. reptans L.	brabakan, krekesan (J.)	—	—	—	x	x	—	—	—
Paspalum conjugatum Berg.	rumput pait (I.); pahitan (J.)	x	x	x	x	—	x	—	—
Polytrias amaura Hack.	kekeretian (J.)	—	x	—	x	x	—	—	—
Phragmites karka Trin.	gajonggong (S.); glagah asu (J.)	—	—	—	—	—	—	x	x
Sporobolus berteroanus Hitchc. et Chase	djukut njenjerean (S.); ketjitjing (J.)	x	x	—	x	x	—	—	—
Themeda frondosa Merr.	memerakan (I.J.); kakasangan (S.)	x	x	x	—	—	—	—	—
HALORAGACEAE									
Myriophyllum brasiliensis Cambess.	daun saribu (S.)	—	—	—	—	—	—	x	x
HYDROCHARITACEAE									
Hydrilla verticillata Royle	ganggeng (S.); ganggang (J.)	—	—	—	—	x	—	x	x
LEMNACEAE									
Lemna minor L.	ganggeng (S.)	—	—	—	—	x	—	x	x
Spirodela polyrrhiza Schleid.	mata lele (J.); kakarewoan (S.)	—	—	—	—	x	—	x	x

Family: Species	Vernacular Names	Rubber	Tea	Oil-palm	Sugarcane	Lowland rice	Upland rice	Irrigation system	Lakes
MALVACEAE									
Sida acuta Burm.f.	sidagori (I.S.)	—	x	—	x	x	—	—	—
S. rhombifolia L.	sidagori (I.J.S.)	x	x	x	—	—	—	—	—
MARSILEACEAE									
Marsilea crenata Presl.	semanggen (J.)	—	—	—	x	x	—	—	—
MIMOSACEAE									
Mimosa invisa Mart.	alimusa (S.); pis kutjing (J.)	x	x	x	x	—	—	—	—
OXALIDACEAE									
Oxalis latifolia H.B.K.	tjalintjing (S.)	x	x	—	x	—	—	—	—
O. corniculata L.	tjalintjing (S.); semanggi (J.)	—	—	—	—	x	x	—	—
POLYGONACEAE									
Polygonum alatum Ham.	bengok (J.); djukut beureum (S.)	—	x	—	—	x	—	x	x
P. barbatum L.	tjatjabean (S.); mengkrengan (J.)	x	—	—	—	—	—	x	—
POLYPODIACEAE									
Drynaria sparsisora Moor	paku langlajangan (S.); sumber lajangan (J.)	x	x	—	—	—	—	—	—
Dryopteris arida O. Kutze	paku kadal (S.)	x	x	—	—	—	—	—	—
PONTEDERIACEAE									
Eichhornia crassipes Solms	etjeng gondok (I.J.); bengok (J.)	—	—	—	—	x	—	x	x
Monochoria vaginalis Presl.	etjeng (I.S.); wewehan (J.)	—	—	—	—	x	—	x	x
PORTULACACEAE									
Portulaca oleracea L.	gelang (I.S.); krokot (J.)	—	x	x	x	—	x	—	—
RUBIACEAE									
Borreria laevis Griseb.	gletak (I.); goletrak (S.)	x	x	—	—	—	—	—	—
B. latifolia Schum.	gletak (I.); djukut minggu (S.)	x	x	—	—	—	—	—	—
B. repens D.C.	—	x	x	x	—	—	—	—	—
Oldendlandia corymbosa Ait.	katepan (I.)	—	—	x	—	—	x	—	—
Richardsonia brasiliensis Gomez.	djemprak, djukut babi (S.)	—	—	—	—	—	x	—	—
SALVINIACEAE									
Azolla pinnata R.Br.	kakarewoan (S.)	—	—	—	—	x	—	x	x
Salvinia auriculata Aubl.	—	—	—	—	—	x	—	x	x
S. cucullata Roxb.	—	—	—	—	—	x	—	x	x
S. natans ALL.	kajambang, mata lele (S.)	—	—	—	—	x	—	x	x
SOLANACEAE									
Physalis angulata L.	tjeplukan (I.J.) tjetjendet (S.)	x	x	—	x	—	x	—	—
P. minima L.	tjeplukan (I.J.); tjetjendet (S.)	x	x	—	x	—	—	—	—
TYPHACEAE									
Typha domingensis Pers.	—	—	—	—	—	—	—	x	x
UMBELLIFERAE									
Centella asiatica Urb.	pegagan (I.); antanan (S.)	x	x	—	—	—	x	—	—
VERBENACEAE									
Lantana camara L.	tahi ajam (I.); tembelek ajam (J.); saliara (S.)	x	x	—	—	—	—	—	—

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RECENT DEVELOPMENTS IN WEED CONTROL IN AUSTRALIA

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INTRODUCTION

Australia comprises an area of 7 686 850 km^2 lying between latitudes 10° 41′ S and 43° 39′ S. Of the total area of Australia nearly 39% lies in the tropics. However, of all the continents (excluding Antarctica), Australia receives the least average rainfall and 39% of the country receives less than 254 mm per annum.

It is obviously impossible in the space of this short paper to review weed problems and weed control methods applying to this large area with its diversity of climate and crops, in any depth. This paper is restricted to a brief review of the more recent developments in the field of weed science in Australia.

CROPS

WHEAT (*Triticum aestivum*)

In spite of the current over-supply situation in the world wheat market, this crop continues to be the most important form of agricultural production in Australia. The area of wheat grown over the last 50 years has ranged between 4 million and 10 million hectares. Obviously weed control in a crop of this size has attracted considerable attention.

Use of phenoxy herbicides provided a solution for the most common weeds of wheat (mainly belonging to the Cruciferae and Compositae). However, the annual treatment of about 20% of the wheat acreage with phenoxy herbicides has resulted in a marked change in the weed flora to species showing considerable tolerance to these chemicals — *e.g., Fumaria* spp., *Amsinckia* spp., *Polygonum* spp., *Emex australis,* and *Lithospermum arvense.* A new range of herbicides has been developed to cope with these problem weeds in wheat including linuron, prometryn, dicamba, bromoxynil, picloram, and most recently methabenzthiazuron.

Concurrently with the increase in broadleaved weeds tolerant to phenoxy herbicides there has been a marked increase in grass weeds, particularly wild oats (*Avena fatua, A. ludoviciana*).

Di-allate and tri-allate used pre-emergence, and barban post-emergence have provided good control under favourable conditions. At present trifluralin is being developed for selective control of wild oats and other weeds in wheat and barley (*Hordeum vulgare*).

Wimmera ryegrass (*Lolium rigidum*) is a problem in southern wheat areas and di-allate and tri-allate are used currently to control this weed. Trifluralin, alachlor, and bioxone, are showing promise for pre-emergence control while diuron and isonoruron show post-emergence activity.

Paradoxa grass (*Phalaris paradoxa*) is a weed of increasing importance in northern cereal areas. Trifluralin is the only herbicide to demonstrate effective control of this weed.

Skeleton weed (*Chondrilla juncea*) remains the major perennial weed of wheat. Kill of seedling rosettes and suppression of mature plants in the crop can be obtained with 2,4-D. Picloram/2,4-D mixtures are also used for this purpose. In southern areas, reduction of skeleton weed population is obtained by use of subterranean clover (*Trifolium subterraneum*) pastures in rotation with wheat, while in drier areas lucerne (*Medicago sativa*) is used for the same purpose. Investigations are currently being conducted in Europe by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in an effort to find biological control agents for skeleton weed.

RICE (*Oryza sativa*)

Although rice is a relatively minor crop in Australia, it is important in that the highest yields in the world are obtained in the Murrumbidgee Irrigation Area (M.I.A.) where some 36 000 ha produces an average yield of 6.27 tonnes of paddy per hectare. Weed control can be a serious problem in this area with barnyard grass (*Echinochloa crus-galli*) being the major problem, causing yield reductions of one-third in severe infestations. Use of propanil has proved effective against barnyard grass, provided temperatures are high enough. Under M.I.A. conditions molinate is proving more reliable than propanil, particularly in cool springs and has the added advantage of residual activity. Rotational pastures are also an important aspect of weed control in rice in the M.I.A.

COTTON (*Gossypium hirsutum*)

The area sown to cotton in Australia is expected to stabilize at about 40 000 ha, almost entirely grown under irrigation. At this time, cotton represents the most intensive application of herbicides for weed control in any crop currently grown in Australia.

Trifluralin, and to a lesser extent nitralin are used pre-plant. Chlornidine also shows promise as a pre-plant treatment under Australian conditions. These three herbicides can provide effective control of most annual grasses as well as some broadleaved weeds. Herbicides applied at planting are fluometuron, diuron, or to a lesser extent noruron. Fluometuron is the preferred post-plant herbicide in the Namoi Valley of New South Wales, but causes severe damage to cotton in the Ord River Valley in Western Australia where diuron has proved the safest of the substituted urea herbicides.

MSMA is used to a limited extent as a post-emergence treatment at present, but its use is likely to increase as nut grass (*Cyperus rotundus*) and Johnson grass (*Sorghum halepense*) infestations spread.

MAIZE (*Zea mays*) AND SORGHUM (*Sorghum bicolor*)

The area planted to maize and sorghum can be expected to increase with the reduction in wheat acreages. At present 2,4-D is the main herbicide used for broadleaved weed control. However, there is a limited use of picloram/2,4-D mixtures where 2,4-D-resistant weeds such as thorn apple (*Datura* spp.) occur.

The use of atrazine is increasing in irrigated crops, but activation in rain-grown crops is erratic. Crop oils have been used to some extent to improve the control of barnyard grass with post-emergence applications of atrazine.

Other herbicides under investigation for use in sorghum and/or maize include propachlor, alachlor and cyprazine.

SOYA BEANS (*Glycine max*)

The area planted in soya beans has shown a rapid increase over the last two years, and there is an increasing interest in weed control in this crop. At present the only herbicides registered for use on soya beans are trifluralin which is applied pre-plant and linuron which is applied post-plant, usually as a band treatment. It is anticipated that all the standard herbicides recommended for soya beans in the United States will ultimately be registered in Australia, including vernolate, chloramben, chloroxuron, nitralin and propachlor.

PEANUTS (*Arachis hypogaea*)

Trifluralin, 2,4-D and 2,4-DB are the standard herbicides currently used on peanuts in Queensland. However, it is expected that nitralin, chlornidine and vernolate will be registered for use on this crop before long.

VEGETABLES

Trifluralin, linuron, chlorthal, sulfallate, nitrofen, prometryn, dichlobenil, benfluralin, chloramben, propachlor and ioxynil, all find application in various vegetable crops. Use of combination treatments such as trifluralin and linuron on carrots and chlorthal and ioxynil on onions is becoming increasingly common.

Of the new herbicides, the 4-amino-1,2,4-triazin-5-one group (BAS 94337) is most interesting, providing selective control of black nightshade (*Solanum nigrum*) as well as barnyard grass in direct-seeded tomatoes (*Lycopersicon esculentum*).

FRUIT

Use of residual herbicides in perennial fruit crops is expanding rapidly. Diuron alone and simazine, either alone or in mixtures with amitrole find application in citrus (*Citrus* spp.), pome fruits and grapes (*Vitis vinifera*). Simazine/atrazine mixtures are used on citrus and restricted areas of grapes only.

In citrus bromacil has largely replaced diuron. In peaches (*Prunus persica* var. *vulgaris*), terbacil is proving useful and may find application in other stone fruits.

Other residual herbicides used to some extent in orchards are dichlobenil and trifluralin, while asulam will probably prove useful for control of docks (*Rumex* spp.).

There is also widespread use of paraquat for rapid knockdown, non-residual weed control in orchards.

PASTURES AND FORESTS

The most significant recent development in weed control in pasture and forest situations has been the development of picloram for control of *Eucalyptus* spp. and some other woody species. Picloram in mixtures with 2,4-D or 2,4,5-T has provided effective and economical control of a wide range of *Eucalyptus* spp. when applied by stem injection techniques.

In Queensland alone in the 1969-70 financial year, it is estimated that $1,300,000 was spent on arboricides and over $1 million of that total comprised picloram which would be sufficient to treat approximately 0.2 million hectares of timber.

Picloram-based herbicides are making a very significant contribution to land development in Australia and offer marked advantages over the techniques previously used. Picloram is also proving useful for selective thinning in eucalypt forests.

A recent development in Western Australia has been the use of a combined herbicide-grazing treatment to control annual pasture weeds. A low rate of 2,4-D (0.7 kg/ha) is applied which is sufficient to produce epinasty of the weeds and an increase in palatability, apparently because of an increase in sugar levels. Weeds which were previously unattractive to sheep are then readily grazed. Because of the low cost of the treatment and the increased growth of pasture caused by removal of competition, the spray-graze system has been widely accepted by Western Australian farmers.

Biological control of several important weeds affecting pastures is being investigated, mainly in Queensland. Weeds for which biological control shows promise include groundsel bush (*Baccharis halimifolia*), lantana (*Lantana camara*), Noogoora burr (*Xanthium pungens*) and crofton weed (*Eupatorium adenophroum*). Prickly pears (*Opuntia* spp.) are still controlled satisfactorily by cactoblastis (*Cactoblastis cactorum*) in Queensland. However, herbicides are used for prickly pear control in New South Wales where climatic conditions are apparently not as favourable for the development of the cactoblastis as in Queensland. The herbicides used for pear control are mixtures of picloram and fenoprop.

CONCLUSION

Methods of weed control have been evolved to handle most of the important weed problems affecting agricultural and pastoral production in Australia. The methods used include herbicides, cultural practices and biological agents. Changes in weed flora will require continuing investigation of weed control techniques.

WEED CONTROL IN WARM-ZONE CROPS IN NEW ZEALAND

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Summary

In general, New Zealand has a temperate insular climate. Cool night temperatures restrict the areas in which warm-zone crops may be grown mainly to coastal regions. Maize and sweet-corn are the main crops grown in these areas. Warm-zone broadleaved weed species have always been troublesome, but more recently, annual grasses have come into prominence, four species of which are now agronomically important. The most effective control is obtained with a combination of broadleaved and grass weed killing herbicides.

INTRODUCTION

The temperate insular climate of New Zealand restricts the areas where warm-zone crops may be grown successfully. Figure 1 delineates the warm-zone areas which are coastal and frost-free, at least for the growing period of the crops.

In the past few years, warm-zone crops have increased in an attempt to diversify the traditional agricultural produce of meat, wool, dairy products and timber. The success or otherwise of such crops depends very largely on successful weed control. Once weed control is assured, agronomic factors may be tested more effectively, such as plant densities, choice of varieties or hybrids, time of sowing, fertilizer application, and insect control.

MAIZE AND SWEETCORN

In the main maize-growing areas, the continued use initially of 2,4-D and subsequently atrazine has resulted in a dominance of grasses, mainly *Echinochloa crus-galli*. In new maize-growing areas normally straight out of pastures, broadleaved weeds may or may not be troublesome in the first year, depending on the age of the pasture. Within three years, annual grasses are dominant, mainly members of the Panicae — *Panicum dichotomiflorum; Digitaria sanguinalis* and *Echinochloa crus-galli. Eleusine indica* may also be present. Generally, broadleaved weeds depress yields more than grasses.

Highest yields (decreasing order of importance for the one variety) have been obtained by:

(1) Selection of suitable hybrids with high yields.

(2) Increasing planting density from the traditional 18 000 plants per acre (row spacing of 75 cm) to 30 000 to 40 000 plants.

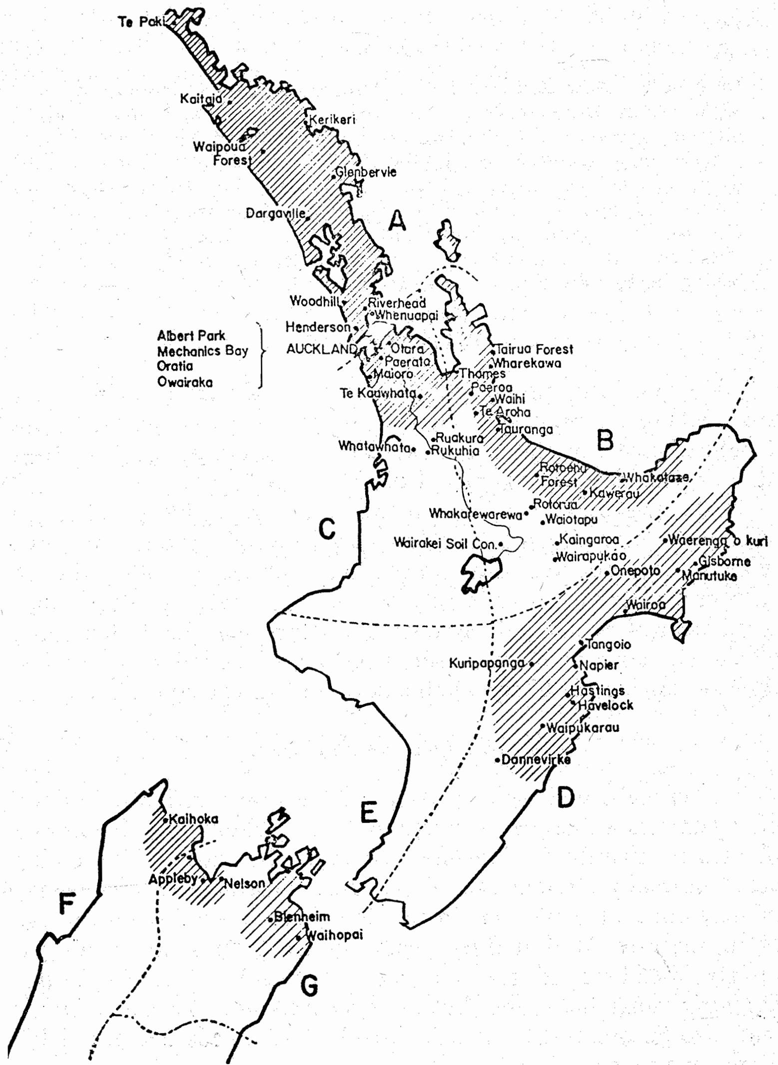

Fig. 1: The warm-zone areas of New Zealand.

(3) Eliminating weeds before or at crop emergence.

(4) Fertilizer application; this is important only after the third or fourth crop out of pasture.

Lepidopterous insects are usually not important if the crop is weed-free. In clean crops, cultivations *per se* may be disadvantageous.

Herbicides

Atrazine (1.12 kg/ha) is still the base herbicide applied at weed emergence. This rate is more than adequate for broadleaved weeds (mainly *Amaranthus* spp., *Polygonum* spp., *Solanum* spp., and to a less extent *Chenopodium* spp.) and there is little advantage in adding surfactants or oil. However, with or without adjuvants, this rate is totally inadequate for annual grass control and even high rates of 4.48 to 6.72 kg/ha with adjuvants will not control the more resistant *Panicum* and *Digitaria* spp. Cyprazine at the same rate produces much the same results as atrazine, and its claim for superior grass control is not substantiated under New Zealand conditions. Cyanazine (at twice the rate of atrazine) has shown slightly superior grass control and possibly broadleaved weed control under drier conditions.

The triazines as a group are not adequate on members of the Panicae and *Eleusine indica*. These species show greater susceptibility if the triazines are soil-incorporated or applied at strict pre-emergence, but the high organic matter levels of most New Zealand soils (the average soil is usually greater than 8%) severely restricts the value of such application.

Grass Herbicides

Alachlor (2.24 kg/ha) and prynachlor (2.24 kg/ha) have proved superior to propachlor (3.36 kg/ha) when applied in conjunction with atrazine (1.12 kg/ha), cyprazine (1·12 kg/ha) or cyanazine (2.24 kg/ha) at seedling emergence. The soil must be moist (preferably near field capacity) and further rain must fall for full efficiency. Under hot, dry conditions results are poor. These mixtures at present are the soundest recommendations for soils over 10% organic matter but are only adequate under favourable conditions.

Butylate (3.36 to 6.72 kg/ha) pre-plant soil-incorporated is the most reliable additive for soils of less than 10% organic matter but this material may fail under continuous wet conditions. It has proved more selective than EPTC.

CULTIVATED SORGHUMS

The tolerance of cultivated sorghums has not been tested widely under New Zealand conditions. There are some data to suggest propazine (2.24 kg/ha) and noruron (2.24 kg/ha) may be considered as the base herbicides with alachlor (2.24 kg/ha) for improved grass control.

SOYA BEANS

As yet, this is not a fully commercial crop in New Zealand. Yields of up to 4000 kg/ha have been obtained in weed control experiments. Soya beans are sown at about the same time as maize, and warm-zone weeds, mainly *Amaranthus* spp., *Solanum* spp., and members of the Panicae, are the most troublesome. As for maize, optimum yields have been obtained by eliminating weeds before crop emergence.

The base herbicides are trifluralin, nitralin and vernolate for soil of less than 10% organic matter. The rates required are dependent on soil organic matter — trifluralin (0.84 kg/ha), nitralin (1.12 kg/ha), vernolate (3.36 kg/ha) being satisfactory for soils up to 5% organic matter content. Rates of trifluralin (1.12 kg/ha), nitralin (1.68 to 2.24 kg/ha) are required for soils up to 10% organic matter. It is doubtful if vernolate rates should be increased beyond 3.36 kg as this material and EPTC have not shown the same degree of selectivity as trifluralin and nitralin. These materials used alone or in mixture with one another—*e.g.*, trifluralin (0.56 kg), vernolate (3.36 kg) have not proved satisfactory against all broadleaved species and show weaknesses under high rainfall and where the organic matter level is greater than about 10%. Broadleaved herbicides such as linuron (1.12 to 2.24 kg), chlorbromuron (1.12 to 2.24 kg) and metobromuron (2.24 to 3.36 kg) show considerable merit as additives for early pre-emergence applications, provided moisture conditions are suitable.

Alachlor (2.24 kg) and to a less extent propachlor (3.36 to 6.72 kg) are adequate alternatives to trifluralin, nitralin and vernolate under moist conditions. In mixtures with methoxy ureas, near-complete weed control is obtained except for *Polygonum* spp. which show resistance to both groups of materials. At present there is no suitable control for weeds in soya beans in soils of high organic matter level (above 10%), as the efficiency of the above materials is drastically reduced. Chloramben (3.36 to 4.48 kg) as a pre-emergence application is less dependent on soil organic matter levels than the above herbicides but has proved reliable only under optimum conditions of moisture. Post-emergence materials have not proved satisfactory. Chloroxuron at rates adequate for weed control is excessively damaging to soya beans.

SUNFLOWERS AND SAFFLOWERS

These crops show similar tolerances — trifluralin and nitralin at the rates employed for soya beans and EPTC (3.36 kg) are the superior materials. When *Solanum* spp. are present, pronamide (1.68 kg) is a suitable additive as a pre-emergence treatment. Low rates of prometryn (1.12 kg) have been used with marginal tolerances. No reliable post-emergence materials are available.

RICE

The small acreage grown is drilled and surface-flooded or sown by aircraft with pre-germinated seed in shallowly flooded fields. Propanil (4.48 to 6.72 kg) possibly has not proved as effective as in tropical areas, where temperatures are warmer, nor is the residual activity of molinate (3.36 kg) adequate for the full control of *Echinochloa crus-galli.* Mecoprop (2.24 kg) is normally required, once the rice is tillered, for broadleaved weed control.

Early post-emergence applications of propanil (4.48 to 6.72 kg) and mecoprop (2.24 kg) have shown high promise in experimental areas of dryland rice.

PEANUTS (GROUNDNUTS)

Peanuts are not a commercial crop in New Zealand. No single herbicide or mixture of herbicides has been adequate owing to the poor competitive effect of the crop. Benfluralin (3.36 kg) or trifluralin (1.12 kg), depending on variety, plus alachlor (2.24 kg), linuron (2.24 kg), metobromuron (2.24 to 3.36 kg), or chlorbromuron (2.24 kg) appear most promising.

STATUS OF WEED CONTROL IN INDIA

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The losses caused by weeds in India are considerable and warrant urgent attention.

Apart from the weeds of arable land, aquatic weeds such as water hyacinth are a serious problem in the north-eastern states. The losses due to this weed in Bengal alone have been estimated as 100 million rupees annually (Rs. 7.50 = $1.00 U.S.). The algal weeds like *Chara* and *Nitella* also cause serious losses in paddy fields in West Bengal. Recently, a species of *Salvinia* has become a problem in Kerala State. There are also angiospermic parasites which inflict serious losses; the damage caused by "broom rape" (*Orobanche* sp.) on tobacco is 5 to 10% in Bengal, 15 to 20% in Maharashtra and Gujarat, and 30 to 35% in Madras State. The losses caused by *Striga* to paddy and Kharif crops, particularly Jowar and Bajra, all over the country, are also considerable.

The losses caused by weeds in India could in some cases be as high as 70 to 80%. Even if the loss is assumed to be 10% (a most conservative estimate) of the total agricultural produce, the amount would come to Rs. 4,200 million for the principal cereals, pulses, oil seeds, cotton, sugarcane and chillies.

Control of weeds by mechanical and cultural means has figured prominently in the agronomic practices adopted by the cultivators. With increased experience and availability of better tools, these techniques continue to be improved and modified. It is even asserted that many age-old practices, such as sowing rate, sequence and interculture, were primarily intended to keep the weed population in check. The techniques generally worked well except in some cases where the cultivator continued to fight a losing battle, such as in the case of kans (*Saccharum spontaneum*), *Lantana* sp., *Carthamus oxyacantha, Pluchea lanceolata, Xanthium strumarium, Cannabis* spp., *Chenopodium* spp., *Asphodelus tenuifolius, Eichhornia crassipes* (water hyacinth), *Oxalis* spp. (in hill areas), *Mimosa pudica, Striga* spp. (parasites of Jowar and Bajra), *Argemone mexicana, Ageratum* spp., and *Chara* spp.

In India, until now little has been achieved in controlling weeds by the use of chemicals, although insecticides, fungicides and rodenticides have been widely adopted by farmers for the control of insect pests, plant diseases and rodents.

It is estimated that weed control measures at present are being adopted annually only over 80,000 to 100,000 ha which is insignificant compared with the total cultivated area.

For various reasons, chemical weed control has not received much attention in India. First, the availability of agricultural labour at a comparatively cheap rate makes the farmer rely on the traditional methods of hand-weeding for controlling weeds. Secondly, the cost of herbicide application is rather high, and the farmer is reluctant to use it extensively. Next, weed control work was, until now, done mainly on government or institutional farms only. The idea and practice were not conveyed to the farmers. More extension work is yet required to make a breakthrough in the use of herbicides. Finally, Indian farmers generally follow mixed cropping and these mixtures mostly consist of dicotyledonous crops with monocotyledons. The use of herbicides in mixed cropping is not advisable.

Despite these difficulties, efforts are being made to test and popularize herbicides, since, with the intensification of cultivation and rising labour costs, chemical control using herbicides will play an increasingly important role in deriving the full benefits from inputs such as fertilizers and water.

The herbicides that are being used or will be used for tackling weeds in India are 2,4-D, MCPA, 2,4,5-T, TCA, dalapon, monuron, diuron, diquat, paraquat, trifluralin, MSMA, DSMA and propanil.

2,4-D and MCPA: Of all the herbicides, these have been used the most. The former is available indigenously in three different formulations (*i.e.*, ester, amine and sodium salt). 2,4-D sodium salt and 2,4-D esters in wheat crops and 2,4-D amine in maize have given excellent results.

Dalapon, TCA and 2,4,5-T: The use of 2,4,5-T is very much restricted, as it is mainly used for killing woody shrubs (*i.e.*, *Lantana* and *Zizyphus*) and is also used for increasing latex in rubber plants. The sodium salt of TCA has been tried against grassy weeds. Dalapon is another promising herbicide for controlling grasses in such crops as legumes and potatoes. The chemical has also proved very effective against kans (*Saccharum spontaneum*), baru (*Sorghum halepense*) and doob (*Cynodon dactylon*).

Simazine and Atrazine: Simazine and atrazine have proved promising in controlling weeds in maize, sugarcane and sorghum. The high cost of these herbicides (*i.e.,* Rs. 125 per hectare), however, seems to be the main limiting factor to their large-scale use.

Propham, Chlorpropham, EPTC and PEBC: These carbamate herbicides have been used in controlling weeds in vegetable crops, but their use is so far confined to research farms only. Their cost is very high.

Monuron, Diuron and Linuron: Monuron is a very strong weedicide and has been used for control of kans (*Saccharum spontaneum*). At lower dosage rates, it has also been used for controlling weeds in sugarcane. No commercial application of these is made on agricultural crops. Nevertheless, they hold great promise for total weed control in many crops.

Propanil: This has been used in India for the last six years for controlling weeds in paddy. However, because of relatively high cost its use is not widespread.

Diquat and Paraquat: These two herbicides have been used in India since 1960 and hold great promise as desiccants and total weedkillers and are suitable either as directed sprays or for pre-emergence application to many crops. Paraquat has been a great help in controlling weeds in tea plantations.

Trifluralin, MSMA and DSMA: These weedicides have controlled weeds in different crops. Trifluralin has proven effective in controlling weeds of cotton. Similarly, the two arsenical herbicides, MSMA and DSMA, also proved effective in the control of the perennial weed *Sorghum halepense*.

Out of such a large range of herbicides tested, only four, namely 2,4-D, 2,4,5-T, pentachlorophenol and ammonium thiocyanate, are produced in India, so far in rather limited quantities because of poor demand. Anticipating a spurt in demand because of the quick spread of various programmes of high-yielding varieties, cash crops and multiple cropping, herbicides belonging to sophisticated groups (propanil, simazine, arsenicals, dalapon) are being licensed.

Since their introduction to India in 1948 the annual consumption figures of these weedicides have shown a slight increase.

The Central Government is also keen to help the herbicide manufacturing industry by following a liberal policy in allocation of foreign exchange. At present, the total capacity licensed for

the production of herbicides in the country is about 2,800 tonnes, of which 1,700 tonnes has already been installed. The current production of herbicides (*i.e.,* 2,4-D, 2,4,5-T, etc.) is at present about 400 tonnes.

Out of the total of 80 million hectares fixed for plant protection measures, the Central Government proposes to cover 2 million hectares in weed control during the end of the Fourth Plan period (1973-4). The Government also proposes to start a pilot project for the demonstration of the use of herbicides in various crops in different locations. In the beginning, the weeds which are widespread and obnoxious will be tackled and would include about 2000 ha of infested land.

SOME MAJOR WEEDS AFFECTING IMPORTANT AGRICULTURAL CROPS IN INDIA

Crop and Weed	Common English Name	Vernacular Name	Manner of Treatment*	State
PADDY				
1. *Chara* spp.	Chara		+	W. Bengal
2. *Eichhornia* spp.	Water hyacinth	Jalkumbhi	+	Madras
3. *Echinochloa crus-galli*	Barnyard grass	Samak	+	Assam
4. *Striga lutea*	Witch weed	Agiya	+	Orissa, U.P.
5. *Ammania baccifera*	Red stem	Kuranda	+	
6. *Cynodon dactylon*	Bermuda grass	Doob	+	
RABI CEREALS (WHEAT) INCLUDING PULSES				
1. *Carthamus oxyacantha*	Wild safflower	Pohli	+	Uttar Pradesh
2. *Asphodelus tenuifolius*	—	Piazil	+	Punjab, Madhya
3. *Chenopodium album*	Lambsquarter	Bathua	+	Pradesh, Bihar Maharashtra
4. *Convolvulus arvensis*	Bindweed	—	+	
5. *Cynodon dactylon*	Bermuda grass	Doob	+	
6. *Heliotropium* spp.	—	Niakatti	+	
JOWAR				
1. *Sorghum halepense*	Johnson grass	Baru	+—	Rajasthan Madhya Pradesh Maharashtra Mysoro and Madras
2. *Cyperus rotundus*	Nutsedge	Motha		
3. *Striga lutes*	Witch weed	Agiya		
4. *Trianthema monogyna*	Carpet weed	Pathar chatta		
5. *Cynodon dactylon*	Bermuda grass	Doob		
SUGARCANE				
1. *Striga* spp.	Witch weed	Agiya	+—	Uttar Pradesh and Bihar
2. *Cyperus rotundus*	Nutsedge	Motha		
3. *Sorghum halepense*	Johnson grass	Baru		
4. *Celosia argentea*	—	Safed murga		
POTATO				
1. *Cynodon dactylon*	Bermuda grass	Doob	—	Himachal, Pradesh, Uttar Pradesh, West Bengal, Bihar and Madras
2. *Chenopodium album*	Lambsquarter	Bathua		
3. *Asphodelus* spp.	—	Piazi		
4. *Carthamus oxyacantha*	Wild safflower	Pohli		
5. *Cyperus rotundus*	Nutsedge	Motha		
COTTON				
1. *Cynodon dactylon*	Bermuda grass	Doob	—	Punjab, Madhya
2. *Cyperus rotundus*	Nutsedge	Motha	M	Pradesh, A.P. Maharashtra
3. *Trianthema monogyna*	Carpetweed	Pathar chatta		
4. *Chrozophera* spp.	—	—		
5. *Aristolochea* spp.	—	Gandan		
RUBBER, TEA, COFFEE, AND OTHER MISCELLANEOUS CROPS				
1. *Eupatorium spp.*	—	—	+	Madras, Kerala, Assam
2. *Imperata cylindrica*	—	—		
3. *Pennisetum polystachyon*	—	—		
AQUATIC WEEDS IN PONDS AND IRRIGATION CHANNELS				
1. *Eichhornia crassipes*	Water hyacinth	Jalkumbhi		W. Bengal, Bihar, Rajasthan, Tripura and Kerala
2. *Typha* spp.	Cat tail	—		
3. *Potamogeton* spp.	Pond weed	—		
4. *Salvinia* spp.	Salvinia	—		
OTHER WEEDS				
1. *Saccharum spontaneum*	—	Kans	+	M.P., U.P., Rajasthan and Bihar
2. *Zizyphus rotundifolia*	—	Jharberi		
3. *Oxalis* spp.	Wood sorrel	Tipatia		
4. *Pluchea lanceolata*	—	Balauri		
5. *Xanthium strumarium*	Cocklebur	Chhota gokhru		

* + = post-emergence. — = pre-emergence. M = mechanical.

WEED PROBLEMS AND WEED RESEARCH IN KENYA

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Climatic conditions in Kenya vary from the hot, humid coastal strip, and the semi-desert of the northern districts, to cool highlands above 3000 m, where crops and weeds are more characteristic of temperate regions than of the tropics. The most sophisticated agriculture and the most advanced methods of weed control are found in the areas of higher altitude and rainfall. Nevertheless, agricultural conditions in Kenya have much in common with those of the Asian-Pacific countries, and it is hoped that a consideration of East African weed problems will be relevant to the conference.

Kenya's tourist industry is enjoying a current boom but, apart from this, there are few natural resources other than agriculture. As in most developing countries, there is a large population of subsistence farmers, a high level of unemployment, and a low level of agricultural wages. There is also a strong contrast between the standards of peasant agriculture and of the larger commercial farms and plantations (including Government-owned farms), which contribute about half of the total agricultural production.

SMALLHOLDER CROPS

Maize is the principal subsistence crop, a total slightly in excess of 1 000 000 ha being grown, 90% by smallholders. Sorghum and millet occupy another 360 000 ha, while various legumes, especially dwarf French beans (*Phaseolus*) and pigeon pea (*Cajanus*), are grown on 600 000 ha, often in mixed cropping systems with maize or sorghum. Annual and perennial weeds present a considerable problem in these crops and the principal control method is hoeing, a heavy hoe being used with a chopping action, which disturbs the soil to about the same extent as the original digging. Hand-weeding of food crops provides employment for a large number of people in areas where no alternative employment exists. Improvements in weed control technique, however, could undoubtedly provide scope for more

profitable use of labour, even if this only consisted of more care being devoted to cash crops, normally attended to only after the food crops have been weeded.

Cotton is one cash crop grown by smallholders for which considerably increased production is planned. The importance of very simple improvements in weed control in this crop has been illustrated by the work of Druijff and Kerkhoven (1970). On an irrigated cotton-grown scheme in eastern Kenya, these workers showed that, by substituting a light, "Dutch" hoe for the traditional "jembe", and commencing weeding operations earlier, the average farm yield of seed cotton was increased from 900 to 2100 kg/ha, while labour requirements dropped from 67 to 25 man-days/ha. Farmers in this area are no less conservative than subsistence farmers elsewhere, yet a period of two years was found to be sufficient for the voluntary adoption of the improved weeding system.

Other crops may offer the possibility of obtaining similar yield increases through simple improvements in weed control, and the prospects would seem particularly good with crops grown on irrigation schemes, where there is often a greater possibility of controlling the efforts of the cultivator than elsewhere. At present, however, little research is being done on weed control in subsistence crops, so that progress is unlikely to be rapid.

In highland areas pyrethrum is a valuable cash crop grown by smallholders on about 3400 ha. Being a rather weakly competitive perennial, weeds are particularly troublesome but, in spite of herbicide trials conducted at the Horticultural Research Station, a safe and effective chemical treatment has yet to be developed.

PLANTATION CROPS

The situation is very different in plantation crops, where managements have been quick to take advantage of any improvements in weed control made possible by research. Much of the weed research that has been done in Kenya has been directed towards these crops.

COFFEE

The arabica coffee crop accounted for 30% of the total value of exports in 1969 and was produced on approximately 85 000 ha, of which plantations made up 38% of the area and 50% of the crop. The Coffee Research Foundation supports a Coffee Research

Station, in whose research weed control has played an important part (Mitchell, 1969). For general weed control, many estates have now adopted a minimum cultivation programme based in the drier areas on 6 to 8 applications during the year of paraquat at a low dose of 0.14 to 0.28 kg/ha (Outram, 1970). Some use of diuron and other residual chemicals is also made, either as separate treatments or, more commonly, in mixture with paraquat. Such control programmes are of particular value in mulched coffee, and work well in the absence of perennial weeds. *Digitaria scalarum* and *Cynodon dactylon,* the most serious perennial grasses, can be successfully eliminated with dalapon, but *Cyperus* spp. remain a difficult problem in certain areas. As yet, smallholders make little use of herbicides but, with the organization of growers into co-operatives, it seems likely that their use will extend, as management standards rise and the advantages of chemical weed control become more apparent.

Tea

This is the second most important export crop and occupies 40 000 ha, 60% of which are in commercial estates. Weed problems are similar in nature to those in coffee, but less serious, and weed studies have been made by the Tea Research Institute. On most estates herbicide treatment is now routine in the first year or two after pruning and low doses of paraquat are applied as spot treatments up to 12 times a year (Outram, 1971).

Sisal

Sisal has been planted on the same scale as coffee, and has a research station of its own, which has given much attention to herbicides. Bromacil has been found very selective in bulbil nurseries (Hopkinson, 1971). In field sisal, *Digitaria scalarum* is a major problem. Detailed studies of TCA and dalapon have been made, but interest in weed control has declined with the general decline of the industry.

Sugar

Most of Kenya's 26 000 ha of sugar is grown on large estates, the largest of which undertake their own research. The weed problems and control measures vary considerably from one area to another. 2,4-D and MCPA are the main stand-by for control of dicotyledonous species and are often used in combination with

TCA or dalapon where perennial grasses are important. *Cyperus* species are generally troublesome and, in western Kenya, the parasitic *Striga hermontheca* is a local problem for which, as yet, there is no satisfactory solution.

Pineapple

A small but flourishing pineapple industry has been started with the support of a major canning concern. The original aim was for the processing factory to be supplied by small-scale growers. It has proved difficult to obtain regular supplies of the required quality fruit from this source, however, and fruit has tended to come increasingly from larger plantations. The cropping system is to a large extent controlled by the canning company, and involves soil-sterilization for nematode control, use of bromacil for weed control, and laying down of black polythene for moisture conservation. The company conducts its own research, but the results of this are not widely publicized.

COMMERCIAL CEREAL GROWING

Wheat succeeds at higher altitudes in Kenya and an area of 165 000 ha is grown, mostly in large-scale farming enterprises. Herbicide treatment is routine, the greater part of the area being sprayed from the air with 2,4-D or MCPA. As in other wheat-growing countries, continued use of these chemicals has led to a build-up of resistant weeds, many introduced from Europe, and some use of mecoprop, dichlorprop, dicamba and 2,3,6-TBA is made to deal with *Polygonum* spp., *Galium spurium, Spergula arvensis, Silene gallica,* etc. Annual grasses such as *Setaria verticillata* are more difficult to control and, although pre-emergence treatment with terbutryn or propachlor have given good control on an experimental scale (Terry, 1971), they have yet to be used widely in practice. No satisfactory control has been found for *Cyperus rotundus* and the other *Cyperus* spp. sometimes troublesome in wheat.

Although primarily grown for subsistence, a proportion of the maize crop is grown commercially and weeded chemically, or mechanically with inter-row cultivators. The principal herbicide used is 2,4-D applied either pre- or post-emergence. A number of triazines and other residual herbicides are available for use in maize, but the returns from this crop are low and only the cheapest forms of weed control are practicable.

BUSH CONTROL IN RANGELAND

The land suitable for crop production in Kenya is limited to about one-fifth of the total area. On the remaining four-fifths, the rainfall is too low or erratic for cropping, but there are large grassland areas suitable for livestock production. Bush limits the grazing capacity on an estimated 10 000 000 ha of this rangeland (Heady, 1960), and a further 14 000 000 ha harbours "tsetse" (*Glossina* spp.), flies carrying a trypanosomal disease fatal to cattle.

Much work on methods of controlling bush has been done in the past by the Tsetse Division of the Ministry of Agriculture and, more recently, by the UNDP/FAO Range Management Project, in which the writer participated (Ivens, 1971a). Some of the smaller types of bush — for example *Aspilia mossambicensis* (a yellow-flowered composite of the same general appearance as *Eupatorium odoratum*) and *Solanum incanum* — can be effectively controlled by 2,4-D, applied at low-volume with a mistblower (Ivens, 1971b), and control appears to be economical, though not as yet widely practised.

On a number of larger shrubs and trees, including various *Acacia* spp., a formulation of picloram + 2,4-D has been more effective than either 2,4-D alone or 2,4,5-T. The mixture is considerably more expensive than 2,4-D, but expenditure on chemical can be reduced to a minimum by applying small volumes of herbicide concentrate, either by injection or to the cut surface of stumps, and such treatment can be economical on rangelands of relatively high potential. In the less productive areas where extensive development of co-operative and group ranching is now taking place, the only form of bush control likely to be economically possible in the immediate future is controlled burning, with or without preliminary slashing.

WEED CONTROL RESEARCH

TROPICAL PESTICIDES RESEARCH INSTITUTE

Research on agricultural problems of common interest to the three East African Community countries, Kenya, Tanzania and Uganda, is the responsibility of the East African Agriculture and Forestry Research Organization, with which is associated the T.P.R.I. at Arusha, Tanzania. This station was set up originally to work on insect (especially tsetse) control, but has now expanded, with support from the British Overseas Development Administration, to cover work on a variety of medical and agricultural pests, including weeds. Weed control research has covered bush control and most of the important East African crops. Particular studies have been made on perennial grass weeds and *Cyperus* spp., and the susceptibility of annual weeds to a wide range of herbicides determined. Screening trials of new compounds on sown crops have been carried out and a considerable amount of information obtained about the persistence of residual chemicals under local conditions. Close contact is maintained with other East African research stations interested in weed control, and advisory publications on weed identification and control produced from time to time (Hocombe and Yates, 1963; Ivens, 1967; Terry, 1969). T.P.R.I. has also been closely concerned with the organizing of weed conferences in East Africa, the fourth of which was held in Arusha in August, 1970.

NATIONAL RESEARCH STATIONS

Reference has already been made to the Coffee and Sisal Research Stations, the Tea Research Institute and the Horticultural Research Station, all of which are crop oriented. The Coffee Research Station is currently the most active in weed work, though this work is only one of several responsibilities of the officer concerned. At various regional agricultural stations, weed investigations have been conducted from time to time, but there is no programme as yet for sustained research. A full-time weed specialist has been included in plans for the development of a new agricultural research centre in the Embu district, however, and if the plans are implemented as anticipated, better coordination of weed control work will be possible.

TECHNICAL ASSISTANCE

The bush control work supported by UNDP in the Kenya Range Management Project has already been mentioned. On the completion of the project, a Government counterpart officer is due to take up work on bush control, and will become the first Kenyan with a full-time post in the field of weed science. Before the initiation of the project, U.S.A.I.D. also provided consultants to advise on problems of bush in rangeland, as well as equipment and chemicals for bush control work.

British budgetary aid for T.P.R.I., mentioned above, has supported a considerable amount of research on weeds. In future, aid from the Overseas Development Administration will be granted for more specific projects, and arrangements are currently being made for a project to continue the weed work at Arusha. Until plans for the new Kenya research station materialize, therefore, T.P.R.I. will remain the only official centre maintaining an interest in weeds beyond the context of a specific crop.

Technical assistance has also been provided by the Netherlands Government in the form of the investigation of cotton weeding techniques conducted by the Dutch firm ILACO (International Land Development Consultants N.V.). Details of this useful piece of organization and methods research were given earlier (Druijff and Kerkhoven, 1970).

Commercial Research and Development

Commercial organizations concerned with the intensive production of crops such as sugarcane and pineapple conduct their own weed control research as previously mentioned. Those concerned with the marketing of agricultural chemicals have been reducing expenditure on research in Kenya in recent years, though in the past some firms have undertaken extensive development work. The probable reason for this trend is that sufficient work has already been done for the successful introduction of such well-established treatments as 2,4-D and MCPA for wheat, paraquat for tea and coffee, etc., and insufficient returns are foreseen from the development of new treatments. Economic factors, however, are constantly changing, and it is quite possible that some such factor as an increase in agricultural wages, a reduction in the cost of chemicals, or increased crop prices could result in greatly increased sales and stimulate fresh commercial interest in development.

CONCLUSIONS

It will be clear from this review of weed control in Kenya that the introduction of herbicides has already had a major impact on the growing of plantation crops. The research, on the basis of which these advances have been made, has been a result of the joint initiative of government and technical assistance workers, backed by the agrochemical industry and the more progressive growers themselves. In Kenya, as in many other developing countries, there is little doubt that improvements in weeding techniques could have an equal or greater impact on the production of food and cash crops by smallholders, even if this only meant the introduction of a better design of hoe.

The initiative for research into ways of advancing the weed control standards of subsistence farmers, however, will have to come mainly from governments, either through requests for weed workers to technical assistance agencies or, preferably, through the provision of their own official weed specialists. In this connection, the progress of the weed control part of the South East Asian BIOTROP Project, and, in particular, the development of training facilities for weed workers, will be followed with great interest by countries in East Africa.

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THE USE OF HERBICIDES IN TEA ESTATES IN NORTH SUMATRA

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INTRODUCTION

Tea estates in North Sumatra are generally in areas where the warm, humid climate and the good loamy, volcanic soil are conducive to rapid and abundant weed growth. Clean-weeding, except for young planted areas, introduces grave danger of erosion, especially on this type of soil. Cover crops are necessary for protection of the soil, and the cheapest method to achieve this condition is to keep soft weed cover which is not competitive with tea plants. However, in practice it is very difficult to have an ideal weed cover as noxious weeds grow as well as the soft, desirable weeds (Schoorel, 1949; Eden, 1965; Rochecouste, 1971).

Hand-weeding is done by hoeing and piling the weeds between the rows of tea plants, usually at monthly intervals. This system has some disadvantages for both the tea plant and estate operations as follows:

(1) High requirements of labour, ±10 to 40 man-days per hectare, depending on the period of time after planting and pruning. The degree of shade determines weed growth to a large extent. Nowadays, shortage of labour has become serious and control of weeds in some fields is delayed to the detriment of the tea.

(2) Hoeing disturbs the soil and the feeder roots, and often the lateral roots, are damaged.

For some years, herbicides have been used in practice for successful control of alang-alang (*Imperata cylindrica*) with alang-alang oil (S.A.O.) at rates of 50 litres in 2500 litres H.S.D. oil per hectare in three applications. Dalapon and paraquat have given satisfactory results in sheet alang-alang (Seth, 1969; Soedarsan, 1969). Other contact or translocated herbicides have been reported to give effective control against broadleaved and grass weeds in rubber and oil palm estates in Malaysia (Eden, 1965; Barnes and Tan, 1969; Brown, 1969; Ramachandran *et al.*, 1969; Pushparajah, 1970; Seth, 1970; Rochecouste, 1971). Most

of the weeds in oil palm and rubber are also found in tea estates in North Sumatra at altitudes from 300 to 1200 m above sea level (Schoorel, 1949). The main weeds of tea in Sumatra are as follows:

Soft Weeds: *Ageratum conyzoides/mexicana, Borreria latifolia/laevis, Erechtites valerianifolia, Oxalis corymbosa/latifolia, Centella asiatica.*

Noxious Weeds: *Imperata cylindrica, Panicum barbatum/pilipes/repens, Paspalum conjugatum, Axonopus compressus, Mikania cordata, Leersia hexandra, Cyperus rotundus.*

It is feasible that some of the same herbicides that successfully control weeds in oil palm and rubber may be used in tea. Simazine, diuron, amitrole and paraquat have been tested for use in tea as an alternative to hoeing (Anon., 1964). The cost of using herbicides for weed control must be competitive with hand-weeding. On the assumption that it will be less expensive, some experiments and practical trials were carried out to obtain data on the possible use of herbicides to supplement or replace hand-weeding. In certain conditions, chemical weeding can replace hand labour where there is a shortage of labour.

EXPERIMENTS

EXPERIMENT 1

Material and Methods

The experiment was carried out on Mardjandi Estate, North Sumatra, in pre-war planted tea fields. Three different periods of time after pruning were used: Just after pruning (100% open sun); at 6 months after pruning (60% shade); at 12 months after pruning (90% shade).

Four treatments were applied to each field:

(1) 5.4 l "Ansar 529 M" (67% MSMA), 1.8 l 2,4-D amine (72% a.e.), 7.5 kg sodium chlorate in 600 l of water per hectare.

(2) 3.6 l "Ansar 529M", 0.9 l 2,4-D amine in 600 l of water per hectare, with 3 applications at intervals of 2 weeks.

(3) 6.0 kg "Sordox" (63% DSMA + diuron*) + 7.5 kg sodium chlorate in 600 l of water per hectare.

(4) 7.5 kg "Sordox" + 0.9 l "Gramoxone" (paraquat 20% a.i.) + 1.8 l 2,4-D amine in 600 l of water per hectare.

*Diuron was at a concentration to give a field rate of 0.5 kg/ha.

The weeds in these fields were *Paspalum conjugatum, Axonopus compressus, Ageratum* sp., *Imperata cylindrica, Panicum barbatum, Mikania scandens, Borreria* sp., and other broadleaf weeds.

RESULTS AND DISCUSSION

Assessments were made by estimating the percentage of the field covered by weeds. Results are shown in Table 1.

TABLE 1: WEED COVER BEFORE AND AFTER SPRAYING IN THREE DIFFERENT FIELDS

Field Conditions and Treatments	*Percentage of Weed Cover* *1 day before*	*2 wk after*	*1 mon. after*	*2 mon. after*	*3 mon. after*
100% open sun:					
MSMA + 2,4-D amine + sodium chlorate	100	18	8	70	100
MSMA + 2,4-D amine	100	80	17	50	100
DSMA + sodium chlorate	100	26	16	70	100
DSMA + paraquat + 2,4-D amine	100	22	10	70	100
60% under shade:					
MSMA + 2,4-D amine + sodium chlorate	100	15	5	8	100
MSMA + 2,4-D amine	100	80	12	35	70
DSMA + sodium chlorate	100	18	8	40	100
DSMA + paraquat + 2,4-D amine	100	20	10	40	100
90% under shade:					
MSMA + 2,4-D amine + sodium chlorate	70	10	0	7	70
MSMA + 2,4-D amine	80	40	5	15	40
DSMA + sodium chlorate	70	35	25	55	70
DSMA + paraquat + 2,4-D amine	70	35	25	50	75

The data presented in Table 1 show that all treatments gave maximum effect one month after application. The effectiveness of the MSMA/2,4-D amine/sodium chlorate mixture on both the 60% and 90% shaded areas is still apparent up to two months. However, in 100% open sun, young soft weeds were rapidly re-established and three months later the condition was back to starting conditions. In this case, the flora of weeds had changed. Soft weeds and alang-alang occurred instead of *Paspalum conjugatum, Panicum* sp. and *Axonopus compressus.* MSMA/2,4-D amine at application of three rounds at two-weeks intervals, gave the same result as MSMA/2,4-D amine/sodium chlorate, except for the fields at 60% and 90% shading, where effectiveness was a little longer (up to 3 months). Both of the mixtures mentioned have similar weed control effect.

"Sordox"/sodium chlorate and "Sordox"/paraquat/2,4-D amine mixtures were effective for only 2 months after application. Without the influence of shading, the control of *Paspalum conjugatum, Panicum* sp. and *Axonopus compressus* was less than with the MSMA mixtures.

Tea plants treated with "Sordox" mixtures showed a yellowish grass leaf colour on new tea leaves. This could be due to diuron.

It appears that sodium chlorate and paraquat used as contact herbicides and 2,4-D amine as translocated herbicides did not give additive effect when mixed with DSMA.

EXPERIMENT 2

Material and Methods

Effectiveness of dalapon for controlling lalang (*Imperata cylindrica*) in sheet lalang areas has been reported by Soedarsan (1969). In tea estates, most of the lalang is found growing sporadically, mixed with other weeds. This experiment was carried out with different mixtures of "Basfapon" (74% a.e. dalapon) + "U 46-D Fluid" (72% 2,4-D a.i.) for controlling the mixed weeds including lalang. Weeds other than lalang were *Paspalum conjugatum, Panicum barbatum* and *Mikania cordata.* Treatment at three different rates of "Basfapon" combined with three different rates of "U 46-D Fluid" was as follows:

1. Basfapon 5 kg + U 46-D Fluid 0.5 l
2. Basfapon 5 kg + U 46-D Fluid 1.0 l
3. Basfapon 5 kg + U 46-D Fluid 1.5 l
4. Basfapon 4 kg + U 46-D Fluid 1.0 l
5. Basfapon 4 kg + U 46-D Fluid 1.5 l
6. Basfapon 4 kg + U 46-D Fluid 2.0 l
7. Basfapon 3 kg + U 46-D Fluid 1.5 l
8. Basfapon 3 kg + U 46-D Fluid 2.0 l
9. Basfapon 3 kg + U 46-D Fluid 2.5 l

"Citowett" (150 ml), a non-ionic wetting agent, was added to each treatment. A spray rate of 600 l of solution per hectare was sprayed three times at monthly intervals.

Results and Discussion

The results are shown in Table 2.

"Basfapon"/2,4-D amine mixtures at several rates had practically no effect against *Paspalum conjugatum* and *Mikania cordata.* Initially both of these weeds had shown toxicity symptoms, but

TABLE 2: WEED COVER BEFORE AND AFTER SPRAYING WITH DIFFERENT DOSAGES OF "BASFAPON" AND 2,4-D AMINE

Weeds and Time of Observation Relative to Spraying	*Percentage of Weed Cover in Treatments* 1	2	3	4	5	6	7	8	9
Paspalum conjugatum									
1 day before	30	35	30	60	40	30	25	30	35
1 mon. after 1st	25	35	25	60	40	30	25	30	35
1½ mon. after 2nd	40	35	35	65	45	35	30	35	35
1½ mon. after 3rd	45	45	45	70	50	40	40	40	35
Panicum barbatum									
1 day before	20	15	10	5	15	10	5	10	10
1 mon. after 1st	15	10	5	*	10	5	5	10	10
1½ mon. after 2nd	15	10	*	*	10	5	5	10	*
1½ mon. after 3rd	5	*	*	*	5	*	5	5	*
Imperata cylindrica									
1 day before	15	20	20	15	10	5	25	10	*
1 mon. after 1st	5	5	5	10	5	*	20	10	*
1½ mon. after 2nd	*	*	5	10	5	*	20	10	*
1½ mon. after 3rd	*	*	*	5	*	*	5	5	*
Mikania cordata									
1 day before	30	30	40	20	35	55	40	45	55
1 mon. after 1st	25	30	30	15	30	55	40	45	55
1½ mon. after 2nd	30	35	35	20	40	55	45	45	60
1½ mon. after 3rd	40	40	40	25	45	60	50	55	60

*Too small to estimate, below 5%.

eventually the young shoots continued healthy growth. Complete control of a pure stand of *Mikania cordata* was obtained by two applications of 1 l/ha of 2,4-D in 225 l solution (Ramachandran *et al.*, 1969). That rate is nearly equivalent to treatment 9 (2.5 l in 600 l solution). Perhaps the ineffectiveness of 2,4-D was due to its being mixed with "Basfapon"; also, the existing *Mikania cordata* was not a pure stand. Mixtures mentioned above provide some effect in suppressing the growth of alang-alang, especially at rates of 5 kg/ha of "Basfapon". Nevertheless, new alang-alang soon emerged, owing to rhizomes that survived. This is probably caused by the fact that "Basfapon"/2,4-D amine mixtures were sprayed on weeds as a whole, and only part was applied to alang-alang itself.

In addition, the effect of 2,4-D amine is not clear. "Basfapon"/2,4-D amine mixture at high rates was effective against *Panicum barbatum*.

PRACTICAL USE

Based on experience gained and compilation of results in herbicide trials reported by other authors, further trials were carried

out on a larger scale varying from 10 to over 100 ha on six estates.

The type and rates of herbicides used and the intervals between application were as follows:

(1) Mixture of 5.4 l "Ansar 529M"/"Asazol", 1.8 l 2,4-D amine and 7.5 kg sodium chlorate with spray intervals of 2 to 3 months.

(2) Mixture of 4.3 l "Ansar 529M", 6 kg sodium chlorate and 2.1 kg "Gramevin" with spray intervals of 1.5 to 2 months.

(3) Mixture of 5 kg "Basfapon", 1 litre "U 46-D" (2,4-D amine) and 150 ml "Citowett" at spray intervals of 1 month.

(4) 1.5 to 2.0 l "Gramoxone" at spray intervals of 1 to 2 months.

(5) 5 kg "Basfapon" sprayed following the MSMA mixture (only in fields with alang-alang).

The volume of spray solution was 600 l/ha. Spraying per treatment was done twice, except for "Basfapon" or its mixtures which were sprayed three times.

EFFECTIVENESS OF HERBICIDES

The herbicides did not show detrimental effects on the tea plants if carefully sprayed. Direct contact of herbicides with tea leaves and young branches caused damage. The leaves and stems showed scorch and became dry. The tips and young shoots finally died.

A mixture of MSMA/2,4-D amine/sodium chlorate controlled *Paspalum conjugatum, Axonopus compressus, Panicum barbatum* and broadleaved weeds effectively, as reported by Barnes and Tan (1969). Two months after the second application, the field was covered with soft weeds such as *Borreria* sp., *Ageratum* sp. and *Erechtites* sp. but only a few grasses survived. It did not kill fern and *Imperata cylindrica,* but only scorched the leaves contacted by the herbicide. In fields where *Imperata cylindrica* grew sporadically, after the second application, it expanded rapidly and only a few soft weeds could be found.

Mixtures of MSMA/sodium chlorate/"Gramevin" gave satisfactory control of soft weeds and grasses, but not of alang-alang. The growth of alang-alang was depressed after the second spraying, but was not totally diminished.

Mixtures of "Basfapon"/2,4-D amine/"Citowett" gave good control of broadleaved weeds (*Panicum* sp. and alang-alang), but one month later the young, fresh alang-alang emerged. *Paspalum* *conjugatum* was not killed, except for the leaves directly hit by spraying. The rest showed a yellowish colour and continued to grow but at a slower rate. Two months after the second application, the field was dominated or became a pure stand of *Paspalum conjugatum,* depending on the percentage of cover at the start.

Paraquat appears to be an effective herbicide for controlling weeds at rates of 1.5 l/ha. After one week all the weeds were desiccated if sprayed evenly. However, it did not kill the stolons and rhizomes of different kinds of grasses and alang-alang. Two months after the second spraying, the grasses grew vigorously and sometimes totally covered the soil. Young leaves of alang-alang grew normally because paraquat is not translocated and thus does not affect the rhizomes.

"Basfapon" sprayed two weeks after the MSMA mixtures gave effective control against alang-alang. Usually there is no succession of alang-alang after this application.

Mikania cordata could not be controlled by any herbicide. Most herbicides gave only sub-lethal effect. This was not due to the control ability of the chemical, but to the difficulty in spraying techniques and the ability of *Mikania cordata* to propagate rapidly even from one small part of its stem. For *Mikania cordata,* 2,4-D amine alone is reported to be effective (Ramachandran *et al.,* 1969; D. van Staalduino, pers. comm.).

Succession of Weeds

With hand-weeding, the vegetative and generative parts of weeds remain in the field piled in the rows between the tea bushes as sources of regrowth and, more or less, survive throughout the years. Dominance of certain weed species is determined by the intensity of shade, altitude, humidity and fertility of soil. Sometimes cattle grazing helps *Axonopus compressus* and *Paspalum conjugatum* to become dominant.

Experience with chemical weeding has shown that weed succession is determined by resistance of weeds toward a particular herbicide. For example, soft weeds will be dominant after the use of:

(1) MSMA/2,4-D amine/sodium chlorate where alang-alang was absent before spraying.

(2) Paraquat in the field which was not infested by *Paspalum conjugatum, Panicum barbatum, Axonopus compressus* and alang-alang before spraying.

(3) Dalapon for killing alang-alang after use of MSMA mixture.

Observation after two or more applications of a herbicide mixture in different fields, showed that domination of noxious weeds became a problem after:

(1) *Imperata cylindrica* domination, where this weed was found sporadically before spraying with MSMA mixtures.

(2) *Mikania cordata* domination, where *Mikania cordata* was found to compose over 40% of the weeds in the field and was sprayed with the herbicides mentioned above.

(3) *Panicum* sp. and *Paspalum conjugatum* domination, in fields that were sprayed with paraquat and dalapon.

From these results the use of certain herbicides as repeated applications is not recommended. Spraying programmes must be studied, based on observation of the type of weeds in the field, if the soft weed growth described by Shepherd *et al.* (1970) is to be obtained and maintained.

Failures of Herbicides Used

Successful control was not obtained in all fields, owing to the specific and peculiar conditions of the fields.

Length of Time after Pruning

When the tea was pruned, the fields became open to the sun and the weeds grew rapidly, vigorously and massively. In this period, the amount of herbicide used is higher than in the other fields one year after pruning. The effectiveness of herbicides was excellent in fields one year or more after pruning. The most difficult period is up to 6 months after pruning. This problem could be solved by spraying the field before pruning with a mixture of contact and soil-acting herbicide to keep the area free from weeds after pruning (D. van Staalduino, pers. comm.). The pruning debris will prevent soil erosion during the first months.

Pruning Debris

In pruning, branches and leaves are piled in the rows between the tea plants to cover the weeds. The debris persists in the field for three to four months and then decays. During this period, spraying work is difficult and less effective. Special care is needed to prevent drift of contact herbicide from damaging the growing points or the young shoots.

Piles of Weed Debris

The initial use of herbicides to replace hand-weeding did not give satisfactory results owing to obstruction by the piles of weed debris between the rows of tea plants. The stoloniferous weeds like *Paspalum conjugatum* and *Panicum* sp. were not well controlled. In fields where these piles were not apparent, weeds were more easily controlled. It is recommended that, before the initiation of chemical weeding, the soil should be levelled and the piles of weed dispersed.

Rain

Some herbicides need a few hours to translocate into the weeds to control them successfully. In general, translocated herbicides require several hours of sunny weather.

In North Sumatra in the mountainous tea regions where tea is cultivated, there is no distinct dry season. The precipitation is 2500 to 4000 mm per year. Rain sometimes delays herbicide programmes and it makes labour management difficult. It is advisable to manage the spraying work in such a way that, on suspected rain days, spraying can be shifted to the fields ready for contact herbicides (paraquat) not influenced strongly by rain.

CONCLUSION

Weed control in tea estates using MSMA, sodium chlorate, 2,4-D amine, paraquat and dalapon herbicides did not damage tea plants, but gave effective control of weeds. DSMA caused a yellowish colour on the tea leaves (probably due to diuron). Use of proper herbicides must be justified each time, depending on the situation and condition of weeds in the field.

Paraquat and MSMA mixtures are very effective on broadleaved weeds. MSMA mixtures control *Paspalum conjugatum, Panicum* sp. and *Axonopus compressus.*

Dalapon can be recommended for control of alang-alang only. Nevertheless, there are still some handicaps in the field that make the application of herbicides less effective than they might be. Further research is required to test other mixtures of herbicides in an effort to improve the effectiveness of weed control in tea.

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WEED CONTROL IN PLANTATION CROPS

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Summary

In attempting to replace sodium arsenite, a number of herbicides have been identified with useful activity against important plantation crop weeds. None of these used alone provides long-lasting control, particularly of perennial grasses in open or light shade conditions. Sequential applications of a translocated herbicide (*e.g.*, dalapon or amitrole), followed by a contact herbicide (*e.g.*, paraquat), give extended control but their use requires close supervision and has other disadvantages. Recently single application treatments using mixtures of herbicides with complementary activity have been increasingly tried. The trials described have shown that mixture of 0.28 kg/ha paraquat/0.28 kg/ha diuron/1.68 kg/ha MSMA or 0.84 kg/ha paraquat/0.84 kg/ha diuron will give equal or better control than an amitrole/paraquat sequential treatment.

The war against weeds is a continuing battle and only a resourceful armoury equipped with a range of herbicides and well thought out methods of application can ensure success. Constant use of a single herbicide would eventually result in a build-up of resistant weeds. The most effective approach to weed control in plantation crops, on both a cost and an efficiency basis, is to adopt programmes of spraying with the herbicides or mixtures of herbicides and application techniques best suited to any given situation.

INTRODUCTION

In plantation crops in Malaysia, grasses are usually the dominant weeds. Among these, *Paspalum conjugatum, Axonopus compressus, Ottochloa nodosa* and *Panicum* spp. tend to be dominant, with *Eleusine indica, Digitaria* sp. and *Ischaemum muticum* also present commonly but in relatively small amounts. *Imperata cylindrica* is usually the most important species in smallholdings. Amongst dicotyledonous weed species, *Mikania cordata* is considered to be the most important weed.

Traditionally, sodium arsenite has been used for weed control but it presents serious toxicological hazards both to the user and also to young crop plants. In an attempt to arrive at safe and effective alternatives to sodium arsenite, Riepma (1962a, b, 1963, 1965) evaluated a number of compounds — *e.g.*, dalapon, amitrole, disodium methylarsonate and paraquat — and concluded

that paraquat is the most effective treatment for use against *A. compressus;* in the short term it was also the most effective treatment against *P. conjugatum* and *O. nodosa*. For prolonged control of *P. conjugatum,* amitrole and DSMA were found to be more effective. More recently MSMA has been evaluated but again found to be most effective against *P. conjugatum* only.

From these experiments and from preliminary trials carried out by the author (s), it appears that none of these chemicals used alone gives lasting control of all weeds, particularly under the fully open conditions commonly encountered in plantations. Consequently, novel techniques, using one or more of these herbicides, have been developed in order to obtain long-term control of either specific or mixed weed stands. As paraquat had already been shown by Riepma (1962a) to be the most effective chemical for short-term weed control, in most of the work reviewed here, it was utilized either on its own or in combination with other chemicals in an attempt to provide prolonged, broad-spectrum control of the dominant plantation crop weeds.

EXPERIMENTAL

SEQUENTIAL APPLICATIONS OF SINGLE HERBICIDES

Paraquat is a contact herbicide with rapid desiccant action and quick inactivation on contact with soil. In the case of perennial weed species, many of which have underground storage organs, a single application of paraquat rapidly desiccates the foliage and this is followed by rapid regeneration from the underground rhizomes (*e.g., Imperata cylindrica*) or from protected axillary buds (*e.g., Mikania cordata*). In such situations, repeated applications aimed at exhausting the carbohydrate reserves have been shown to provide good control of these difficult weeds but the timing of the repeat applications is critical in that the regenerating foliage must be destroyed before it starts contributing to the plant reserves (Seth, 1970a, b, 1971).

The trials with *I. cylindrica* were laid out on a 162 ha site where this species formed a continuous mature stand. One application of paraquat at 0.56 kg/ha was compared with the same dose followed by two repeat applications at 0.28 kg/ha, applied when regeneration had reached 25%, 50% or 75%. A single application of dalapon at 16.80 kg/ha and an application of 16.80 kg/ha followed by a further 11.20 kg/ha applied at 50% regeneration were used as standard. Paraquat was applied using a volume rate of 450 l/ha whereas dalapon was applied in 900 l/ha. Results obtained are presented in Fig. 1. Maximum dura-

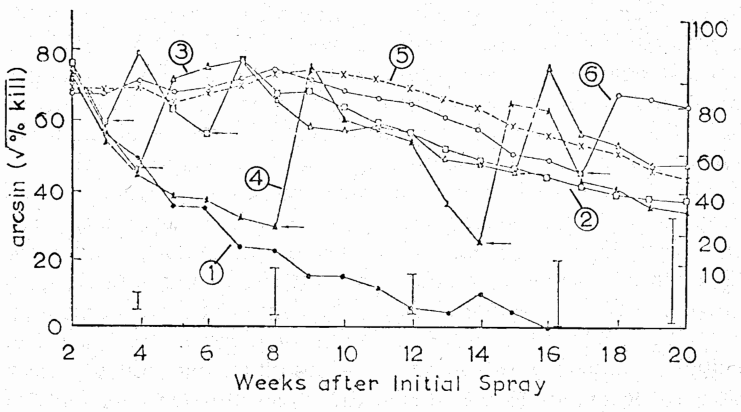

Fig. 1: Control of Imperata cylindrica *using paraquat or dalapon. Vertical bars are LSDs (P = 0.05) for the arcsin-transformed data. (1) 0.56 kg/ha paraquat; (2) 0.56 kg/ha paraquat followed by two resprays (←) of 0.28 kg/ha paraquat at 25%; (3) at 50%; or (4) at 75% regeneration; (5) 16.80 kg/ha dalapon; and (6) 16.80 kg/ha dalapon followed by 11.20 kg/ha at 50% regeneration.*

tion of control was given by the application of 16.80 kg/ha dalapon followed by a further 11.20 kg/ha. A single application of paraquat provided control only for a very limited period. The optimum time for repeating the application of paraquat as shown by the overall duration of control was when regeneration had reached 50%. The 75% regeneration stage appeared to be too late for an effective repeat application of paraquat. An initial application of paraquat at 0.56 kg/ha followed by two repeat sprays at 50% regeneration gave a duration of control comparable to that of a single application of dalapon 16.80 kg/ha. Timely repeated applications of paraquat have not only been found cheaper than high rates of dalapon but also much more acceptable under many cropping situations — *e.g.*, young tea, rubber and oil palm.

Trials with *Mikania cordata* produced very similar results. This species, helped by its ability to form adventitious roots at each node or branch in contact with soil, quickly establishes itself on open patches and amongst cover crops. Under fully open conditions, if allowed to grow unchecked, it rapidly covers the ground, swamping all other growth. A very effective treatment for the control of this species has been found to be the application of 0.28 kg/ha paraquat applied at volume rate of only

112.5 l/ha followed at about 50% regeneration (2 to 3 weeks) by a second application at the same rate and volume. Results are presented in Fig. 2. In the absence of any storage organs, the carbohydrate reserves in *Mikania* are unlikely to be very high. The use of a single spray of paraquat does not provide lasting control, but is likely to create conditions of carbohydrate starvation through rapid destruction of the foliage and the regrowth under these conditions, although quick, is usually impoverished. A timely second spray of paraquat consequently provides complete and lasting control. This treatment against *M. cordata* has found wide acceptance in crops which are susceptible to translocated herbicides (*e.g.*, 2,4-D), for example, young oil palm and tea.

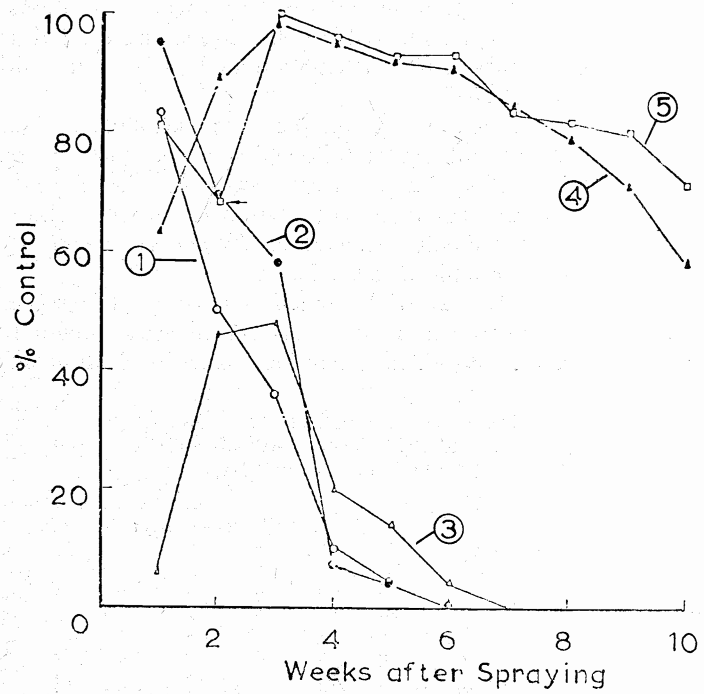

Fig. 2: Control of Mikania cordata *using paraquat or 2,4-D. (1) Paraquat 0.28 kg/ha; (2) paraquat 0.56 kg/ha; (3) 2,4-D 0.56 kg/ha; (4) 2,4-D, 2.24 kg/ha; (5) paraquat 0.28 kg/ha followed by paraquat 0.28 kg/ha applied 2 weeks later.*

SEQUENTIAL APPLICATION OF TWO HERBICIDES

Headford (1966), while studying measures for the control of *P. conjugatum,* recommended the application of 0.28 to 0.56 kg/ha paraquat 3 weeks after an initial application of a sub-lethal dose of amitrole at 0.42 kg/ha rate. This treatment gave much better results than can be expected from two herbicides applied individually. Since the pre-treatment with amitrole in Headford's experiments did not reduce the speed of desiccation by paraquat and showed no obvious stimulation of new shoot growth, it is unlikely that the synergistic effect is derived from enhanced uptake or movement of paraquat. Amitrole is a slow-acting but freely translocated herbicide and moves rapidly in the phloem to regions of meristematic activity. In contrast, paraquat is a highly efficient desiccant with relatively limited mobility. Thus he argued that the rapid destruction of foliage may create conditions of carbohydrate starvation under which new shoots are limited sufficiently to enable amitrole already accumulated in the shoot initials to exert a toxic action.

A similar approach using another translocated herbicide, dalapon, at 2.24 to 4.48 kg/ha followed 3 weeks later by paraquat at 0.28 to 0.56 kg/ha has very successfully been used for the control of a very common weed *Ottochloa nodosa* and also less common but difficult weeds like *Paspalum commersonii, Ischaemum muticum* and *Eleusine indica.*

Results from a typical trial carried out on a pure stand of *O. nodosa* are presented in Table 1. As can be seen, single applications of paraquat provided quick but short-lived desiccation.

TABLE 1: COMPARISON OF PARAQUAT AND DALAPON ALONE, IN MIXTURE, AND AS SEQUENTIAL APPLICATIONS FOR THE CONTROL OF *O. NODOSA*

Treatment (kg/ha)	% Kill weeks after Spraying 2	4	6	8	10	12	14
paraquat 0.28	73	48	18	8	<5	<5	<5
paraquat 0.56	80	61	24	9	5	<5	<5
dalapon 2.24	<5	<5	<5	<5	<5	<5	<5
dalapon 4.48	5	<5	<5	<5	<5	<5	<5
paraquat 0.28/dalapon 2.24	68	58	39	18	8	<5	<5
paraquat 0.56/dalapon 2.24	70	58	41	19	10	<5	<5
paraquat 0.28 → dalapon 2.24	71	62	36	17	8	<5	<5
paraquat 0.56 → dalapon 2.24	79	72	50	23	12	5	<5
dalapon 2.24 → paraquat 0.28	10	97	91	80	63	48	35
dalapon 2.24 → paraquat 0.56	10	97	92	81	63	50	35

Dalapon alone at 4.48 kg/ha provided hardly any control and attempts to obtain both rapid and lasting control with a mixture of dalapon and paraquat failed. Since dalapon is a foliar-absorbed herbicide, it is likely that the poor control obtained from an initial application of paraquat followed 3 weeks later by dalapon resulted from inhibition of entry and movement of dalapon following rapid desiccation by paraquat. However, when dalapon was applied 3 weeks before paraquat, long-lasting control was obtained.

SINGLE-APPLICATION TREATMENTS USING MIXTURES OF HERBICIDES

To avoid the need for the two spray rounds and the weed recognition required with sequential treatments, the use of single-

TABLE 2: COMPARISON OF DIURON, ATRAZINE AND BROMACIL ALONE AND IN COMBINATION WITH PARAQUAT FOR THE CONTROL OF *P. CONJUGATUM*

Treatment (kg/ha)	% Kill weeks after Spraying 2	4	6	8	10	12
diuron 0.28	—	—	—	—	—	—
diuron 0.56	1	—	—	—	—	—
bromacil 0.28	—	—	—	—	—	—
bromacil 0.56	—	—	—	—	—	—
atrazine 0.28	—	—	—	—	—	—
atrazine 0.56	—	—	—	—	—	—
paraquat 0.56	60	38	21	8	—	—
paraquat 0.56/diuron 0.28	72	65	54	41	23	10
paraquat 0.56/diuron 0.56	73	72	46	37	25	<5
paraquat 0.56/bromacil 0.28	79	74	47	28	19	5
paraquat 0.56/bromacil 0.56	83	66	64	30	18	5
paraquat 0.56/atrazine 0.28	79	64	44	28	14	<5
paraquat 0.56/atrazine 0.56	76	72	55	41	16	<5
diuron 1.12	40	15	3	2	—	—
diuron 2.24	68	42	29	9	—	—
bromacil 1.12	—	—	—	—	—	—
bromacil 2.24	—	—	—	—	—	—
atrazine 1.12	—	—	—	—	—	—
atrazine 2.24	—	—	—	—	—	—
paraquat 0.56	60	38	16	6	—	—
paraquat 0.56/diuron 1.12	90	83	71	61	37	18
paraquat 0.56/diuron 2.24	85	78	61	47	31	12
paraquat 0.56/bromacil 1.12	88	82	68	46	24	14
paraquat 0.56/bromacil 2.24	80	76	54	40	12	9
paraquat 0.56/atrazine 1.12	73	56	34	8	2	—
paraquat 0.56/atrazine 2.24	64	54	30	13	7	2

TABLE 3: EFFECT OF PARAQUAT/DIURON MIXTURES ON *P. CONJUGATUM* DOMINATED SWARD UNDER FULLY OPEN CONDITIONS

paraquat (kg ion/ha)	% Kill weeks after Spraying Diuron (kg/ha) 1st wk 0.28	0.56	1.12	2.24	3rd wk 0.28	0.56	1.12	2.24	5th wk 0.28	0.56	1.12	2.24	7th wk 0.28	0.56	1.12	2.24
0.28	57	60	84	—	57	60	88	—	47	36	80	—	32	33	73	—
0.56	66	74	77	80	50	80	88	95	38	62	60	82	22	45	45	65
0.84	76	80	71	77	76	78	82	91	65	65	70	73	59	60	60	65
1.12	—	82	81	72	—	83	90	91	—	67	77	82	—	49	53	78

TABLE 4: EFFECT OF PARAQUAT/DIURON MIXTURES ON *P. CONJUGATUM* DOMINATED SWARD UNDER FULLY OPEN CONDITIONS

Paraquat (kg ion/ha)	% Kill weeks after Spraying Diuron (kg/ha) 1st wk 0.56	0.84	1.12	2nd wk 0.56	0.84	1.12	3rd wk 0.56	0.84	1.12	4th wk 0.56	0.84	1.12	5th wk 0.56	0.84	1.12	6th wk 0.56	0.84	1.12	7th wk 0.56	0.84	1.12
0.56	75	72	77	80	85	90	75	80	88	70	75	77	62	71	60	56	62	66	45	56	42
0.84	90	90	85	78	93	90	75	90	90	73	89	85	70	87	80	65	80	78	60	75	70

application treatments or mixtures of herbicides with complementary activity is becoming increasingly popular.

Seth (1970a) presented results from trials evaluating mixtures of paraquat and photosynthesis inhibitors. All the trials were carried out in *P. conjugatum* dominant swards growing vigorously when sprayed. Initial trials compared representatives from the substituted urea (diuron), uracil (bromacil) and triazine (atrazine) groups, either alone or in mixture with paraquat 0.56 kg/ha. The rates of photosynthesis inhibitors used in the first trial were 0.28 and 0·56 kg/ha, whereas in the second trial higher rates, 1.12 and 2.24 kg/ha were used. When the inhibitors were sprayed alone on standing vegetation, only diuron had any activity and only at the highest rates used (Table 2). In mixture with paraquat, diuron and bromacil at 0.28 and 0.56 kg/ha had very similar effect, but at 1.12 and 2.24 kg/ha, diuron appeared to be a slightly better additive. Atrazine, particularly at higher rates, was considerably less effective than either diuron or bromacil.

Trials comparing the activity of mixtures of paraquat and diuron at various rates showed that, despite certain anomalies, there was a tendency for activity to increase as rates of paraquat increased from 0.28 to 0.56 to 0.84 to 1.12 kg/ha (Table 3). With diuron, activity tended to increase with each increase in rate from 0.28 to 0.56 to 1.12 to 2.24 kg/ha.

In a further trial (Table 4) paraquat 0.56 and 0.84 kg/ha were evaluated in mixtures with 0.56, 0.84 and 1.12 kg/ha diuron. Again, increasing the paraquat rate from 0.56 to 0·84 kg/ha improved activity. Similarly, the 0.84 kg/ha rate for diuron was better than 0.56 kg/ha but the activity with the 1.12 kg/ha rate was similar to that obtained with 0.84 kg/ha. Thus, under fully open conditions, the best combination appeared to be a mixture of 0.84 kg/ha paraquat + 0.84 kg/ha diuron. The degree of improvement that can be obtained with these compounds was well illustrated in one trial where 0.84 kg/ha paraquat ion alone gave 4 weeks' control (60% kill taken as adequate control), whereas 0.84 kg/ha paraquat + 0.84 kg/ha diuron gave control for well over 8 weeks (Fig. 3).

Trials comparing paraquat, diuron and MSMA alone on two separate areas dominated by *P. conjugatum* and *O. nodosa*, respectively, show that MSMA at rates of 2.69 kg/ha and above is the most effective chemical against the former, followed by paraquat which in turn is better than diuron (Table 5). However, against *O. nodosa*, paraquat was the most effective chemical,

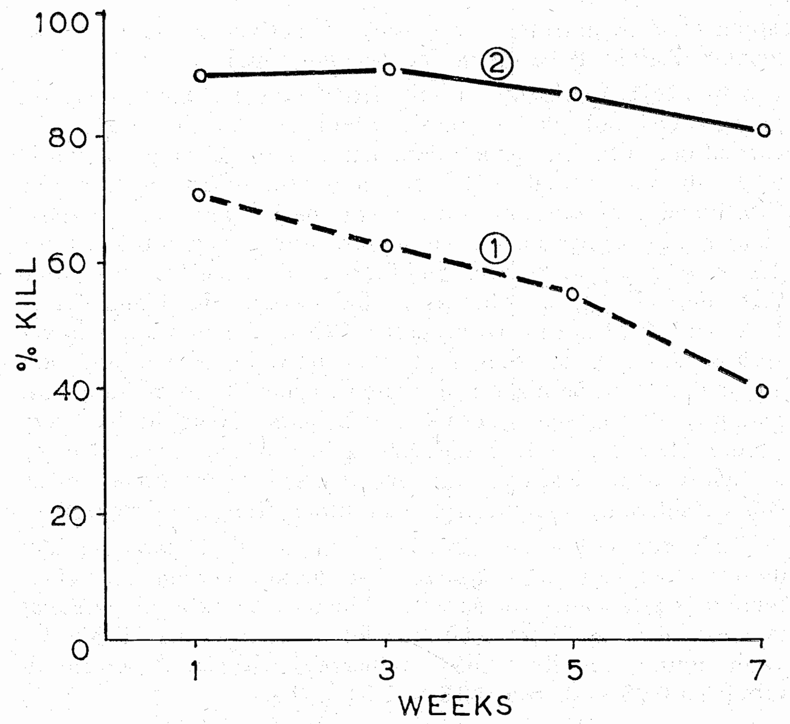

Fig. 3: Control of Paspalum conjugatum *using (1) paraquat 0.84 kg/ha and (2) paraquat 0.84 kg/ha/diuron 0.84 kg/ha.*

TABLE 5: CONTROL OF PURE STANDS OF *PASPALUM CONJUGATUM* AND *PANICUM NODOSUM* WITH MSMA, PARAQUAT AND DIURON

Treatment (kg/ha)	*% Control — weeks after Sprayings* *P. conjugatum* *1st*	*3rd*	*5th*	*7th*	*P. nodosum* *2nd*	*3rd*	*4th*	*5th*
*MSMA 0.90	65	38	5	—	—	—	—	—
MSMA 1.80	83	59	12	—	64	27	10	5
*MSMA 2.70	86	90	65	40	—	—	—	—
MSMA 3.60	97	92	70	63	73	30	16	10
paraquat 0.28	55	23	8	5	70	67	55	35
paraquat 0.56	60	38	22	7	76	73	65	45
paraquat 0.84	70	63	55	40	88	88	80	60
paraquat 1.12	79	67	59	30	95	95	88	66
diuron 0.28	15	5	—	—	—	—	—	—
diuron 0.56	20	10	—	—	5	—	—	—
diuron 1.12	40	25	5	—	5	—	—	—
diuron 2.24	68	70	55	30	5	—	—	—

*MSMA at 0.90 and 2.70 kg/ha was not evaluated against *Panicum nodosum.*

with MSMA providing very limited control. Diuron as a post-emergent spray had practically no effect.

In an attempt to obtain a treatment effective against a wide range of species, but at lower rates of herbicidal application than the chemicals applied alone or in the two component mixtures described above, combinations of paraquat, diuron and MSMA were tried. Because of its effectiveness against *P. conjugatum,* MSMA was chosen as the third component. In a larger series of trials, a range of MSMA rates from 1.12 to 3.36 kg/ha were tried in combination with 0.28 kg/ha paraquat + 0.28 kg/ha diuron. The results obtained (Table 6) show that rates of MSMA higher than 1.68 kg/ha produced little or no increase in activity; thus an optimum combination appeared to be a mixture containing 0.28 kg/ha paraquat + 0.28 kg/ha diuron + 1.68 kg/ha MSMA.

This triple component mixture was then compared on a *P. conjugatum* dominant sward with 3.58 kg/ha MSMA, 0.84 kg/ha paraquat + 0.84 kg/ha diuron and a sequential application of 0·42 kg/ha amitrole followed two weeks later by 0.56 kg/ha paraquat. The results presented in Table 7 show that the paraquat/diuron and the triple component mixture were the best treatments; further experience in the field has shown these treatments to be of particular value for the control of mixed grasses.

TABLE 6: EVALUATION OF VARIOUS RATES OF MSMA IN COMBINATION WITH PARAQUAT FOR THE CONTROL OF *PASPALUM CONJUGATUM*

Treatment (kg/ha) *Paraquat*	*+ Diuron*	*+ MSMA*	*% Control — weeks after Spraying* *1*	*2*	*3*	*4*	*5*	*6*
0.28	0.28	1.12	83	70	59	57	46	40
0.28	0.28	1.68	87	83	76	75	72	68
0.28	0.28	2.24	88	84	79	75	73	71
0.28	0.28	2.80	89	87	84	80	75	73

TABLE 7: COMPARISON OF PARAQUAT/DIURON AND PARAQUAT/DIURON/MSMA MIXTURES WITH MSMA ALONE AND A SEQUENTIAL APPLICATION OF AMITROLE AND PARAQUAT ON A *PASPALUM CONJUGATUM* DOMINANT SWARD

Treatment (kg/ha) *Paraquat*	*+ Diuron*	*+ MSMA*	*% Control — weeks after Spraying* *1*	*3*	*5*	*7*	*9*
0.28	0.28	1.68	90	90	87	86	75
0.84	0.84	—	90	90	87	80	—
—	—	3.60	97	92	70	60	50
amitrole 0.42 → paraquat 0.56			—	75	56	45	42

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THE PLACE OF DINOSEB IN ESTATE WEED CONTROL

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Summary

Dinoseb does not give sufficient control over a long period when used alone, although it can readily eradicate *Mikania* at rates of less than 2.80 kg/ha. In a mixture, dinoseb improves the performance of other herbicides, and a mixture of 4.20 kg dinoseb/0.028 kg picloram/2.80 kg dalapon per sprayed hectare is in the same price range as other recommended mixtures, although giving longer control with repeat applications.

Dinoseb has been commercially available for 25 years, and is in general use in Europe and the United States of America in a wide variety of applications, ranging from pre- and post-emergent weed control to crop desiccation prior to harvest. However, its possibilities as a general contact herbicide in the rubber and oil palm plantations of South-east Asia has never been exploited.

Dinoseb is listed as one of the most toxic of the herbicides in general use, yet it is also one of the safest to use. In 25 years, only one person's death has been attributed to dinoseb, a record which no other contact herbicide can even remotely approach. It has a LD_{50} of 35 to 50 mg/kg body-weight which puts it on a par with sodium arsenite, but the reasons for its safe usage are:

(1) There is no accumulation of the chemical or its residues in the body.

(2) Dermal contact is obvious and immediately noticeable because it stains the skin bright yellow.

(3) Vapour inhalation contact is immediately known by a disagreeable nasal and throat irritation that precludes receiving a lethal dose. It can, therefore, be said that dinoseb has its own built-in safety factors.

(4) Dinoseb is a metabolic stimulant and kills by over-exciting the metabolism of both plants and animals, thus exhausting their immediate food reserves. The effect of oral contamination can, therefore, be remedied by keeping the patient very cool and supplying cold drinks of glucose water. The fact that the effects of this herbicide can be remedied makes it unique among the contact herbicides.

In late 1969, Dow Chemical International Inc. decided to investigate the potential of dinoseb (Dow General Weedkiller) in the plantation industry in comparison with the contact herbicides already in use, paraquat, MSMA, and sodium chlorate.

METHOD

The areas selected for trials were in both shaded rubber and open young oil palm areas where the vegetation was particularly abundant, and had no history of herbicide treatment during the previous six months. Most of them had received no treatment whatsoever.

The "Dow General Weedkiller" mixture, consisting of 50% dinoseb, 35% diseline and 15% "Emgard" by volume, was prepared in bulk and used at rates of 12.5, 18.75 and 25.0 ml per litre of water diluent; "Gramoxone" (20% paraquat) was used at 12.5 ml/l water and "Ansar 529M" (56% MSMA) at 12.5 ml/l water.

The spraying was carried out between the hours of 9.00 a.m. and 12.00 noon, using a Serval pump, and a double-head jet which gave a coverage of roughly 225 l per sprayed hectare.

As will be seen from Table 1, the results obtained when using dinoseb on its own, although impressive for the first two weeks after spraying, did not compare with either paraquat or MSMA at one month. The kill of dicotyledonous weeds such as *Borreria, Ageratum, Embelia, Stachytorpheta* and *Sida* was better than either paraquat or MSMA, but the grasses, particularly *Paspalum conjugatum* and *P. commersoni* seemed to come back quickly. Although some of the contact herbicides gave more than 50% control of these *Paspalum* species, it was noticeable that the areas treated with dinoseb quickly developed numerous new leaflets as if dinoseb had stimulated growth in the unkilled grasses.

However, the effect of dinoseb at the lowest concentration of 12.5 ml/l water diluent on *Mikania cordata* was most impressive, and indicated that, as the recovery of cover from such a low concentration of dinoseb was very rapid, the use of this herbicide to eradicate *Mikania* in a mixed cover was eminently feasible.

Follow-up experiments have indicated that with 9.75 and 12.5 ml/l water diluent dinoseb will kill all *Mikania* in a mixed cover and affect only the youngest leaves of *Centrosema* and *Pueraria*. It will also kill *Borreria* at this same concentration, but leaves the bulk of the cover unaffected.

TABLE 1: WEED CONTROL WITH DINOSEB IN SHADED AND OPEN PLANTATIONS

(0 = no control. 10 = complete control)

Estate	Treatment (per ha)	Shade/Open	Control at 1 wk	2 wk	3 wk	4 wk	5 wk
A	dinoseb 8.4 l	Open	9	3	1	0	0
B	dinoseb 8.4 l	Shade	9	8	7	5	2
	dinoseb 7.0 l	Shade	8	6	4	1	—
	dinoseb 5.6 l	Shade	5	2	0	0	0
	dinoseb 4.2 l	Shade	4	1	0	0	0
	"Gramoxone" 2.8 l	Shade	10	10	8	6	4
C	dinoseb 5.6 l	Open	6	4	0	0	0
	dinoseb 7.0 l	Open	8	5	1	0	0
	dinoseb 8.4 l	Open	9	6	2	0	0
	"Gramoxone" 2.8 l	Open	9	8	7	6	4
	MSMA 2.8 l	Open	8	7	6	4	2
D	dinoseb 8.4 l	Shade	9	—	—	3	0
	dinoseb 5.6 l	Shade	8	—	—	0	0
	"Gramoxone" 2.8 l/ 2,4-D amine 1.4 l	Shade	10	—	—	6	2
	sodium arsenite 7.84 kg	Shade	9	—	—	6	3

MIXTURES

Contact herbicides have a place in various mixtures, and dinoseb because of its metabolic stimulatory action offers scope to improve the performance of other components in the mixture. Using as a comparison, the mixtures MSMA 2.8 l, 2,4-D/amine 1.4 l or "Tordon 101" 0.7 l and sodium chlorate 5.6 kg, and "Gramoxone" 2.8 l plus 2,4-D amine 1.4 l, or "Tordon 101" 0.7 l, a dinoseb mixture was made with dinoseb 4.2 l mixed with "Tordon 101" 0.7 l and dalapon 2.8 l (see Table 2).

The MSMA was "Ansar 529M" containing 560 ml a.i. per litre.

TABLE 2: PERCENTAGE WEED CONTROL WITH DINOSEB MIXTURES

Treatment (per ha)	% Control at 1 month	2 months
dinoseb 4.2 l/"Dalapon M" 2.80 kg/"Tordon 101" 0.7 l	75	25
dinoseb 4.2 l/"Dalapon M" 2.80 kg/"DMA-6" 1.4 l	70	15
dinoseb 4.2 l/"Kenapon" 5.6 l	60	0
dinoseb 4.2 l/"Kenapon" 4.2 l/"DMA-6" 1.4 l	70	15
"Gramoxone" 2.8 l	70	15
MSMA 2.8 l/"DMA-6" 1.4 l/sodium chlorate 5.60 kg	75	30

The degree of control of the vegetation two months after spraying was only fair with all of the mixtures, principally because the trial areas had very luxuriant cover. Therefore, a third set of trials was carried out with the object of improving the degree of control. Table 3 gives the summarized results of these trials.

TABLE 3: PERCENTAGE WEED CONTROL WITH DINOSEB MIXTURES

Treatment (per ha)	% Control at 1 month	2 months
dinoseb 4.2 l/dalapon 2.80 kg/"Tordon 101" 0.71	75	25
MSMA 2.8 l/dalapon 2.80 kg/"Tordon 101" 0.7 l	90	50
dinoseb 5.6 l/dalapon 2.80 kg/"Tordon 101" 0.7 l	90	60
dinoseb 5.6 l/sodium chlorate 5.60 kg/"Tordon 22K" 0.35 l	100	75
"Gramoxone" 2.8 l/"Kenapon" 5.6 l	100	70
"Gramoxone" 2.8 l/dalapon 2.80 kg/"Tordon 22 K" 0.35 l	100	80

The mixtures can be improved by substituting "Tordon 101" for 2,4-D amine, and markedly improved if "Tordon 22K", the potassium salt of picolinic acid, is used instead. Clearly 4.2 l/ha dinoseb in the mixture was not optimum, and the performance of the mixture containing 5.6 l/ha dinoseb proved much better.

The decision on whether or not to use a mixture depends to a large extent on cost. Table 4 gives the cost of various mixtures. The MSMA formulation has changed and instead of "Ansar 529M" at 2.8 l/ha, one now needs 4.7 l/ha of the new "Ansar 529" to achieve the same quantity of active ingredient. In practice, Ansul now recommends 5.6 l/ha as the basis for their mixtures.

The costs are based on the retail prices of "Ansar 529" being $13.25/gal ($2.95/l), "DMA-6" at $14.00/gal ($3.11/l), sodium chlorate at 40 c/lb (88c/kg), dalapon $1.80/lb ($3.97/kg); "Tordon 22K" $136/gal ($30.22/l); "Gramoxone" $42/gal ($9.33/l); and "Dow General" (dinoseb) at $16/gal ($3.51/l).

TABLE 4: COSTS OF DINOSEB MIXTURES

Treatment (per ha)	Cost/ha
"Ansar 529" 5.6 l/2,4-D amine 1.4 l/sodium chlorate 5.60 kg	$25.64
"Ansar 529" 5.6 l/"Tordon 22K" 0.28 l/dalapon 2.80 kg	$31.69
"Gramoxone" 2.8 l/"Tordon 22K" 0.28 l	$30.13
dinoseb 4.2 l/"Tordon 22K" 0.28 l/dalapon 2.80 kg	$30.13
dinoseb 5.6 l/"Tordon 22K" 0.28 l/sodium chlorate 5.60 kg	$30.13

The cost difference between any of these mixtures is not large, but it is now noticeable from repeat applications that killing the cover systematically using herbicides such as "Tordon 22K" and dalapon, in addition to a contact herbicide, does give longer control, and, therefore, any extra expense incurred by using these herbicides will be recouped over a period of time.

DISCUSSION

Dinoseb kills only the part of the plant that it touches; there is no translocation whatsoever. It kills because at low concentrations it excessively stimulates respiration, and, at high concentrations, it inhibits the coupling during phosphorylation and oxidation of pyruvate. It can also act as a protein coagulant, thereby disrupting enzymic reactions.

At first sight the rapid yellow staining of skin and clothing during the use of dinoseb as a herbicide would seem to be a distinct disadvantage. But in point of fact, it indicates how much dermal contact with herbicides occurs during normal spraying which goes unnoticed. The ubiquitous yellow stain has the advantage of making the operators much more careful with their solutions and since it can be washed off, but only after a thorough scrubbing, it enforces a hygiene which might otherwise be overlooked.

Briefly, dinoseb by screaming to all that it is poisonous makes itself safe to use, and the result of this self-advertisement is to be seen from its record over 25 years.

THE CONTROL OF BAMBOO

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Bamboos are a familiar form of vegetation throughout South-east Asia; their occurrence is only sporadic in West Malaysia, but they become much more abundant in the monsoon forests of Burma, Thailand and Laos. Some bamboos are deliberately planted near villages for their usefulness, while some are native, frequenting particular habitats like riverbanks, and edges of forest. Bamboos frequently colonize road margins and clearings, and in the hill forests any form of shifting cultivation as practised by Orang Asli or Meo tribes usually gives rise to a climax bamboo-Shima type vegetation.

Once present, bamboo becomes a serious problem, for its rapid growth retards or entirely prevents regeneration of desirable tree species and vigorously competes with any other plants for nutrients and soil moisture. Therefore, in spite of their multitude of uses, bamboos can be a pest in plantations, right-of-way maintenance (power-lines, road-sides, and railway embankments) and in the successful regeneration of both Dipterocarp and teak forests. Specific examples of bamboo as a weed are as follows: On the main range of West Malaysia, *Dendrocalamus pendulus* colonizes clearings in the hill-forest, its weak culms up to 18 m in length making use of the surrounding vegetation for support; once these culms have gregariously flowered they die, and in falling may damage regenerating tree seedlings and saplings, as well as form an almost impenetrable barrier. In Northern Thailand's Lampang Province, where teak is an important product, bamboos often form virtually the sole middle and ground layers of vegetation of the teak forests, greatly reducing the chances of natural regeneration of the teak, while the cutting of the useful bamboo, Pai Bong (*B. tulda*), in these areas often acts as a screen for illegal teak extraction, thus aggravating the regeneration problem.

Again, the Mekong River electricity projects have necessitated thousands of miles of overhead power-lines supported by pylons, and in Thailand, in the clearings necessary for these cables, *Bambusa tulda, B. burmanica* and *Gigantochloa scortechinii,* all of whose culms grow rigidly erect up to 18 m, can touch the cables in the centre of the pylon span and so cause a costly short-circuit if left to grow.

In areas of the Malay-Thai peninsular north of Kedah, where the climate becomes pronouncedly monsoonal, bamboos are much more extensive because they are one of the few species to survive the forest leaf fires that tend to occur towards the end of the dry season. The survival is due to the bamboo's very tough underground rhizome system carrying numerous viable buds which readily give rise to new culms.

The vigour of the rhizome system is the main cause of the difficulty in controlling the growth of bamboos. Slashing or ground fire merely activates the buds on the rhizome so that there is regeneration of several smaller culms instead. Only repeated slashing can reduce the vigour of the underground stems. Lacerating the rootstock mechanically has some effect on pachymorph rhizome species, but it is a very laborious and costly means of control.

Watson and Wyatt Smith (1961) showed that with *Gigantochloa levis* slashing three times in fourteen weeks gave only slightly less vigorous regeneration than a single slashing, and that within six months the culms were again 3 to 5 m high. 2,4,5-T, as the butyl ester, had no effect unless the culms were cut and even then the effect was small; even 7½% sodium arsenite gave only 50% defoliation and did not affect regeneration. Only 20% sodium chlorate, 10% TCA (sodium salt), 5% amitrole and 7½% dalapon gave adequate control when the culms were left uncut.

Cruzado *et al.* (1961) showed that in Puerto Rico, TCA, amitrole and dalapon controlled 12 species of bamboo: *Bambusa* (5 species), *Dendrocalamus* (3 species), *Gigantochloa* (1 species), and *Sinocalamous* (*Dendrocalamus* ?) (1 species).

With other monocotyledonous plants, such as grasses, sodium arsenite is considered to be a more effective contact herbicide than sodium chlorate, and as both kill the above-ground tissues, the underground rhizomes are relatively unaffected by both chemicals.

If it is accepted that sodium chlorate's effect was perhaps fortuitous in the work of Watson and Wyatt-Smith, then the next most cost-efficient treatment was 7½% dalapon, as shown by the following costs for 10 gal (45.4 l) of solution:

20% sodium chlorate	—	M$12.00
7½% dalapon (74% a.e.)	—	M$18.00
5% amitrole (50% w.p.)	—	M$26.00
10% TCA (95% a.e.)	—	M$20.00

Dalapon is absorbed as an undissociated molecule by the plant; it is translocated with the food material, and is not metabolized to any appreciable extent. It accumulates at the sites of metabolic activity such as meristems (buds), and, because it is translocated throughout the plant, affects the underground meristems. Dalapon is, however, rapidly broken down by micro-organisms in the soil, and hydrolyses (in aqueous solution) at the rate of 1% per hour at South-east Asia ambient temperatures.

While a foliar spray on bushy bamboo is practicable and Watson and Wyatt-Smith (1961) sprayed 7½% dalapon solution on the bottom 1 m of the culms with success, the control of bamboos in hill forest and power-line rentises, where water is not readily available, requires a more concentrated application technique.

METHOD

Near the foot of Genting Simpah, Selangor, where *Dendrocalamus pendulus* was vigorously invading an abandoned lines-site, the area was divided into a series of plots, each plot containing two or more clumps averaging at least twenty culms per plot. The treatments were:

(1) 20 g of dalapon/"Lissapol", a paste containing 12 g of active ingredient smeared on to two nodes (each 15 cm long) of each culm.

(2) 30 g of dalapon/"Lissapol" paste containing 18 g a.i. smeared on to three nodes (each 15 cm long) of each culm.

(3) 20 g of "Kenapon"/dalapon paste containing 18 g a.i. smeared on to three nodes of each culm.

(4) 45 g of "Kenapon"/dalapon paste placed on the exposed rootstock after scraping away leaf mould and earth.

(5) 45 g of "Dowpon S" (dalapon plus "Dalawet") on exposed rootstock.

(6) 15 ml of "Kenapon" (9 g a.i.) injected into one node of each culm after making a short cut with a paranga.

The treatments were examined at intervals with a final observation six months after treatment. The first observation at two weeks showed only yellowing of leaves in some cases and death of some of the young culms (rebong), not present in all clumps. Table 1 gives a summary of the treatment records at a later date.

The three successful treatments (2), (3) and (6) were repeated on three separate clumps of *Gigantochloa scortechinii* in

TABLE 1: TREATMENT OF *DENDROCALAMUS PENDULUS* WITH DALAPON

Treatment per Plant	*1 month*	*2 months*	*6 months*
(1) 12 g a.i. on 2 nodes	30% defln.	30% defln. 10% culms dead	25% culms dead otherwise regeneration
(2) 18 g a.i. on 3 nodes	60% defln.	100% defln. 60% culms dead	Dead
(3) 20 g "Kenapon" on 3 nodes	75% defln.	100% defln. 80% culms dead	Dead
(4) 45 g "Kenapon" on rootstock	10% defln.	10% culms affected	Regeneration
(5) 45 g "Dowpon S" on rootstock	No effect	No effect	No effect
(6) 15 ml "Kenapon" injection	60% defln.	100% defln.	Dead

the same area. Observations were made after two months and six months, with almost exactly similar results. *Gigantochloa scortechinii* is very much easier to inject than *Dendrocalamus pendulus,* since the culms were relatively thin-walled.

It was interesting to note that 9 g active ingredient in the form of "Kenapon", the glycol ester of dalapon, when inserted into the hollow nodes killed just as efficiently as 18 g of the same chemical smeared on the outer waxy culm surface, while although 18 g a.i. of dalapon in a paste with non-ionic wetting was just as effective as "Kenapon", 12 g a.i. of the paste was inadequate for total kill. As expected, the solid "Dowpon S" on the exposed rootstock was completely inactivated by bacteria before sufficient quantities could be absorbed.

In the trial recorded in Table 1, the costs would appear to be:

Chemicals	*Labour*	*Total*
"Kenapon" 15 ml at $6.60/l = 10.0c	Cutting and injection of 18 culms in 20 min = 2.4c/culm	12.4c/culm
Dalapon paste 30 g at $4.4/kg = 13.2c	Wiping 60 culms in 20 min = 0.5c/culm	13.7c/culm
Dalapon spray 2.25 l 7½% soln. for 17 culms = 6.0c	30 culms in 20 min = 1.0c/culm	7.0c/culm

The aqueous spray technique used by Watson and Wyatt-Smith (1961) required only 10 g a.i. per culm in spite of possible splash-back, whereas in this trial 12 g a.i. was found to be inadequate.

An explanation of this discrepancy may be sought in not only the size of the culms, but also the species. *Gigantochloa levis* is an edible bamboo and, therefore, less lignified in the young state; the stated culm diameters were 5 to 6 cm, whereas mature culms would be up to 10 cm in diameter. The *Dendrocalamus pendulus* in the trial had culm diameters of nearly 9 cm, while *Gigantochloa scortechinii* with culms up to 18 m tall had culm diameters of 11 to 12 cm. It is, therefore, suggested that the rates and cost of the dalapon paste and the dalapon spray would be equatable on similar sized bamboos.

In clumps of both of the species used in the trials there were several young, newly emergent culms (rebong) of 0.6 to 1.2 m in height. These invariably died within 2 weeks of treatment indicating that, with rapidly growing tissues or sites of high metabolic activity, the chemical was rapidly absorbed and effective.

It was also noted that the culms receiving the paste on the lowest internodes died more quickly than where the three treated internodes were at head height (1.7 m). A possible explanation of this is that the culm grows in height by extension of the lower nodes first, and therefore this site of metabolic activity close to the rhizome buds receives the chemical first, and translocates it to the underground stems. Alternatively, the lower nodes tend to be less waxy so that degree of penetration of chemical could be a factor.

The importance of the wax layer on the culms of bamboo was demonstrated by using "Dowpon S" mixed into a paste with a wax solvent. Five hundred grams of "Dowpon S" was made into a smooth paste with 675 g of "E 3390", an Esso solvent similar to kerosene, of low flash point and low cost. The paste was used on 45 culms of *Shizostachyum zollingeri;* three internodes, each 25 cm long and 6 cm in diameter, of each culm were wiped with the paste, and 320 g of "Dowpon S" in the paste was used, thus averaging 7 g per culm.

There was a rapid absorption of the solvent, leaving a bloom of "Dowpon" on the surface. A brown streaking of the large, 30 cm long and 4 cm wide, leaf blades was evident 10 days later. Thereafter, the browning progressed steadily — the loss of green colour from the culm and the beginning of leaf fall one month after treatment were the symptoms heralding the death of the culm.

Translocation of the herbicide from mature to immature culms was demonstrated on two clumps of *Shizostachyum zollingeri,* each of which had at least 24 culms over 2.4 m in height. A solvent "Dowpon S" paste was smeared on three internodes of 12 mature culms in each clump, the paste containing just under 200 g of the herbicide — *i.e.,* 10 g per culm. The treated culms were considered dead two months later, and chlorosis of leaves on other culms was evident at that time. Four months after treatment, 16 of the untreated culms had defoliated and the internodes turned a yellowy brown, while the remaining 8 culms showed leaf chlorosis, but had not died. In view of the small amount of active ingredient involved, translocation to and death of an additional 16 culms were considered a promising result, and showed that the underground rhizome system had been affected.

"Tordon 101" (a mixture of picloram and 2,4-D as amines) sprayed as an aqueous solution, and "Tordon 10K" pellets failed to affect those species of bamboo on which it was tested. In no case were the culms cut, nor were the culm sheaths removed as this stops growth. One trial using 5% 2,4,5-T butyl ester behaved in much the same way as "Tordon", and it is thought that what slight effect was produced was as much a result of the action of diesoline as of the herbicide.

DISCUSSION

The importance of using a concentrated herbicide technique can be assessed in the silviculture of hill-forest, where chemicals and equipment need to be man-handled to a large extent.

A man doing five hours of herbicide work and three hours of travel a day would need to carry 60 kg of water plus dalapon, plus spray equipment to kill 450 culms using the spray technique, but only 14 kg of dalapon paste to kill the same number of culms, or carry 28 kg to do 900 culms — a full five hours' work. Therefore, there is no doubt which technique is preferable.

Although the "Kenapon" injection technique is cheaper than dalapon paste, it is more time-consuming. Five hours' work by one man involving slashing and injection would be unlikely to maintain a rate of 18 culms in 20 min, and even at this rate he could do only 270 culms using 7 kg of chemical. Therefore, in hill-forest silviculture where foresters must be supplied with food, and given camping allowances, a laborious technique proves to be much more expensive than appears in lowland areas of easy access. Also, the injection technique is not practicable with thick-walled bamboo species, such as *Dendrocalamus strictus,* or

Gigantochloa ligulata, or the thin rotan type species such as *Dinochloa scandens,* or *Schizostachyum aciculare.*

For clearing of power-line rentises and roadsides, a concentrated spray technique is preferable because of the ease of application. At Nam Ngum, Laos, where species of *Gigantochloa* and *Dendrocalamus* are in great abundance, control of bamboo was effected using an aerial spray of "Kenapon" in undiluted form at 22.4 kg a.i./ha; *Gigantochloa scortechinii, G. levis, Schizostachyum zollingeri,* and *S. grande* with their large leaves are particularly suited to such a method of control.

Near Tak and Pak Chong, Thailand, an aqueous preparation of both dalapon at 16.8 kg/337.5 l water per hectare and "Kenapon" at 33.75 l/225 l water per hectare have been used to control bamboos of *Thyrostachya oliveri* (Pai Rauk) and *B. blumeana* (Pai Sisook) which had regenerated into a bush clump after slashing. Power spray equipment was found to be particularly effective with species that grow up to only 9 m in height.

One could not recommend a wiping with paste technique on culms of *Bambusa blumeana* or *B. arundinacea* because of the thorns on the numerous lower branches, but for *B. vulgaris* where the culms are spaced 7 to 10 cm apart, and the three species which are a pest in Malayan forest silviculture, *Gigantochloa scortechinii, Dendrocalamus pendulus* and *Schizostachyum grande,* a wiping technique offers the most practicable method of control of the sporadic patches of these bamboos.

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WEED CONTROL IN RUBBER PLANTATIONS

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INTRODUCTION

Rubber (*Hevea brasiliensis*) is the main plantation crop in West Malaysia, covering an area of 1.6 million hectares. The economic life span of the trees, including the period of immaturity, is about 30 years. During the period of immaturity, which is about 6 years, weed control constitutes a major proportion of maintenance requiring between 59 and 65% of the total cost of upkeep which includes manuring and disease control (Ng Choong Sooi, 1967).

COVER MANAGEMENT

In the early years of rubber cultivation, clean weeding was practised as this gave an initial advantage in rubber growth when compared with weeding along the rubber rows. Considerable erosion of the resulting bare soil was, however, observed (Haines, 1932). Besides, there was considerable loss of organic carbon and great nutrient leaching losses (Watson *et al.,* 1964), and recent work has indicated a reduction in stability of soil structure resulting in compaction (N. K. Soong, pers. comm.). Even though the rubber plantation is considered akin to forestry, experiments have shown that at some 5 to 6 years after closing of canopy the plots kept bare since clearing from jungle have lower organic matter than those areas with some cover initially (Pushparajah and Chellapah, 1969). Over the past few decades, maintenance of covers in the inter-row areas has become an established practice. Three groups of cover are recognized:

(1) Leguminous covers — often creeping legumes like *Pueraria phaseoloides, Calopogonium mucunoides, Centrosema pubescens* — generally established and maintained.

(2) Light grasses and some woody shrubs — mainly *Paspalum conjugatum, Axonopus compressus* and *Ottochloa nodosa* — self-grown but encouraged.

(3) Undesirable weeds — this category includes *Mikania cordata, Melastoma malabathricum, Eupatorium odoratum,*

Ficus spp., *Imperata cylindrica* and *Gelichenia linearis.* In fact, the latter two species have been shown to suppress growth of *Hevea* so severely that death of the plants may occur (Anon., 1938). Growth of immature rubber is also depressed by *Mikania cordata* (Wong Phui Weng, 1964), and by the other species listed but to a lesser extent (Wycherley and Chandapillai, 1969).

In fact, during the early stages of its growth, even the covers in the first and second group are likely to compete with the rubber and keeping the planting strips clear of all weeds is shown to be desirable (Rubber Res. Inst., 1940). The current policy is to establish legume covers where possible and where terrain conditions will not permit establishment of covers to maintain a cover of light grasses with extra nitrogen manuring to offset the competition from them. Weed control in rubber would be particularly demanding during the first 4 to 5 years after establishment of rubber, owing to the vigour of the vegetation, but, as the trees mature, the crowns meet and the reduced light intensity reaching the ground results in a sparse ground vegetation.

CHEMICAL COVER OF WEEDS

Use of chemicals in weed control dates to pre-war years, but intensified research on herbicides in rubber set in only in the late 1950s and early 1960s. Until this time, alkaline solutions of sodium arsenite together with sodium chlorate were the main chemicals used in controlling weeds. Then dalapon was found useful for controlling a rank weed, *I. cylindrica,* but sodium arsenite continued to maintain prominence because of its low cost. However, legislation to limit the use of sodium arsenite because of its toxicity hazards and its ineffectiveness against some weeds like *Tetracera scandens* (Riepma, 1964) generated a larger programme of herbicidal research.

WEED CONTROL IN LEGUME COVERS

Weeding in legume cover areas is generally carried out by hand and costs of such hand-weeding rounds could be considerable. A large number of herbicides were tested for control of weeds in legumes (Riepma, 1962c, 1965c, 1965d). None of the herbicides tested gave a complete selectivity together with long persistence. The most suitable herbicide was found to be neburon applied at the rate of 2.5 kg/ha. But even this showed some sensitivity to *P. phaseoloides* and precautions in such areas were

necessary; hence the use of neburon has not become an established practice. Recent work with alachlor indicated the possibility of this chemical being suitable for weed control in legume cover areas (Wong Phui Weng, 1969).

SOIL-ACTING HERBICIDES

In testing soil-acting herbicides for use in rubber cultivation (Riepma, 1962a, 1962c, 1965a) emphasis was on selectivity to avoid damage to the legume cover. The chemicals tested included simazine, atrazine, atraton, prometryn, diuron, monuron and neburon. These gave effective weed control for about 13 to 16 weeks. The effect of these and some others tested subsequently in controlling five common weeds is summarized in Table 1. The variability of the effectiveness and persistence of these chemicals, according to soil conditions in Malaya, cannot be overemphasized. Simazine on a sandy loam soil extended the period of weed control by six weeks over that in a coastal clay soil. Use of soil-acting herbicides should, however, be made with caution for, though there were no adverse effects on *Hevea* seedlings prior to budding, there were some indications that some of the chemicals affected the percentage of budding successes (Riepma, 1968).

TABLE 1: EFFECT OF SOME PRE-EMERGENT HERBICIDES ON COMMON WEEDS

Treatment (kg/ha)		Axonopus compressus	Paspalum conjugatum	Eleusine indica	Cyperus *sp.*	Borreria latifolia
bromacil	2-4	++	±	++	++	++
diuron	2.4-4.8	++	++	±	NT	NT
linuron	2.5-5.0	++	++	±	++	NT
neburon	2.5-5.0	+	++	—	++	—
atraton	2.5-5.0	++	+	++	+	++
simazine	2.5-5.0	++	++	++	+	++
dicamba	2.4-4.8	+	++	NT	—	+
alachlor	0.9-1.5	++	++	++	++	—
atrazine	1.0-2.0	++	++	++	++	++

Note: ++ = effective
+ = effective only at higher rates used
± = very variable in effect
— = no effect
NT = not tested

TABLE 2: REACTION OF WEEDS TO HERBICIDE MIXTURES

Weeds	Mixtures* A	B	C	D	E
Grasses:					
Axonopus compressus	±	+	++	++	+
Centotheca lappacea	+	±	+	+	+
Digitaria adscendens	±	NT	+	+	+
D. fuscescents	—	—	±	+	+
Eleusine indica	±	—	±	+	+
Eragrostis spp.	±	—	±	+	+
Ischaemum aristatum	—	NT	+	+	+
I. muticum	+	+	++	+	+
I. timorense	+	+	++	+	+
Ottochloa nodosa	+	+	+	++	+
Panicum pilipes	+	±	+	+	+
P. samentosum	+	—	+	+	+
P. trigonum	++	+	++	+	++
Paspalum conjugatum	+	++	++	++	++
P. commersonii	±	—	±	+	±
Sporobolus indicus	—	—	—	+	+
Tricholaena rosea	+	±	+	+	+
Sedges:					
Cyperus rotundus	±	±	±	±	±
Fimbristylis spp.	±	±	+	+	+
Seleria spp.	±	±	+	+	+
Dicotyledons:					
Ageratum conyzoides	++	+	++	+	+
Borreria latifolia	±	±	+	±	±
Eupatorium odoratum	++	+	+	±	+
Melastoma malabathricum	++	±	±	±	±
Mikania cordata	++	+	+	±	+
Scorpia dulcis	±	±	+	±	+
Ferns:					
Cyclosorus spp.	+	±	+	+	+
Gleichenia linearis	+	—	+	+	+
Lygodium spp.	+	±	+	+	+
Nephrolepis bisserata	+	±	++	++	+
Pityrogramma calomelanos ..	+	+	++	+	++
Stenochlaena palustris	±	+	+	+	+

Note: NT = not tested
± = somewhat resistant
++ = very susceptible
— = resistant
+ = susceptible

*A = 2,4-D 1 kg/ha/sodium chlorate 20-35 kg/ha
B = MSMA 1.6 kg/ha/2,4-D 1 kg/ha
C = MSMA 1.6 kg/ha/2,4-D 1 kg/ha/sodium chlorate 10 kg/ha
D = MSMA 1.6 kg/ha/2,4-D 1 kg/ha/dalapon 1.6-3.2 kg/ha
E = MSMA 1.6 kg/ha/paraquat 0.5 kg/ha/diuron 0.25 kg/ha

CONTACT AND TRANSLOCATED HERBICIDES

The results of the earlier trials on these individual herbicides have been reviewed by Riepma (1968). From these chemicals, a number of mixtures, consisting generally of systemic and contact herbicides, were then tested for the effectiveness on the various weeds (Anon., 1967, 1968). The susceptibility of major weeds to these various combinations are given in Table 2.

LIGHT INTENSITY ON SUSCEPTIBILITY

Variability in weed control is often experienced in the field. One of the important factors that influences this is the effect of light on the behaviour of different weed species and also on the different herbicides themselves. For instance, *A. compressus* grows better in slightly reduced light intensities (Riepma, 1965b). Thus a higher dose of herbicides would be required to control this grass at 70 to 80% daylight than at either 100% or 40% daylight. Though *P. conjugatum* is initially more susceptible to amitrole under full light, the effect is more persistent under reduced light.

VOLUME OF APPLICATION

The volume of application influences the cost of spraying considerably. In spraying trials with translocated herbicides, the difference in volume of application in the range of 280 to 1120 l/ha had little effect on the herbicidal efficiency (Riepma, 1962b, 1963b). The volume to be chosen for use must, therefore, enable adequate wetting of the foliage and at the same time there should be little excess solution flowing into the soil (especially important when the herbicides have no soil-acting properties).

EFFECT OF CHEMICALS ON PLANT SUCCESSION

With continued use of a fixed regime of chemicals, certain resistant species tend to become dominant. When a short-lived effect was obtained by using paraquat against a dominant stand of *P. conjugatum* and *M. malabathricum,* these weeds soon recolonized the area, but when paraquat was used on *O. nodosa,* marked development of other species occurred — *e.g.,* by germination of seed of *Borreria latifolia* and *Cleome ciliata.* When amitrole was used against an almost pure stand of *M. malabathricum,* the sprayed area was invaded from outside by *M. cordata* and *I. cylindrica,* but where the *Melastoma* was in a mixed population, the regenerating weeds were *Seleria* spp. and

T. scandens (Riepma, 1963a). More recently, in immature rubber, the use of mixtures of contact and translocated herbicides has also resulted in the development of resistant species. After three rounds of an MSMA/2,4-D/sodium chlorate mixture on a strip infested predominantly with *P. conjugatum, Sporobolus indicus* established as the main weed, while in the same area, use of "Weedazol"/paraquat resulted in the predominance of *Paspalum commersonii.* When sodium chlorate/2,4-D mixtures had been used for some time, *P. conjugatum* became the dominant species and weeds like *Brachiaria mutica, Cynodon dactylon, Eragrostis* spp., and *Panicum repens* were found to be resistant. It is likely that these latter weeds could, if they are present, become dominant species with time. In a third case where inter-cropping was carried out, *Eleusine indica* established itself as a predominant weed in the inter-row and eventually invaded the tree-row area, although the latter had, over a period of a year, been treated with three rounds of MSMA/2,4-D/sodium chlorate mixture — the encroachment mainly being from the germinating seeds. Similar effects on changes in plant population are apparent when pre-emergence herbicides are used.

Besides the above factors influencing weed regeneration, the other factor to be considered is that of soil type — *e.g.,* Selangor series, one of the more fertile rubber soils, has a higher nitrogen status and water-table than the inland soils, and hence is likely not only to stimulate weed regeneration (Riepma, 1962a), but also to affect predominant weed species. The change in canopy conditions resulting from growth of rubber would alter the light intensity and thereby change the composition of weeds.

FUTURE DEVELOPMENT AND OUTLOOK

It appears that, with a tendency to use a fixed regime of herbicide mixtures in many areas, the eradication of the susceptible species could lead to resistant species becoming dominant.

As mentioned earlier, re-establishment of weeds in planting strips can be due as much to encroachment from inter-row areas as by germination of seeds in the soil. While the encroachment weeds can be killed with post-emergence herbicides, those from seeds could possibly best be prevented by use of pre-emergence herbicides. A combination of sequential spray of post- and a soil-acting (pre-emergence) herbicide may prove more useful on profusely seeding species like *E. indica, P. conjugatum, A. compressus, B. latifolia,* and *C. ciliata.* Selection of such combinations

can be initially made from Tables 1 and 2. That such combinations would give longer periods of control has been shown by Riepma (1962a, 1962c) who reported that a combination of amitrole and simazine extended the period of weed control by more than six weeks over that obtained by amitrole alone. Similarly, a combination of diuron (a pre-emergence herbicide) with a post-emergence herbicide (*e.g.,* paraquat or MSMA) gave a better control of weeds than a combination of the latter or on their own. It is believed in this instance that the low levels of diuron used had acted more on the existing vegetation (Seth, 1970).

Changes in weed population occur in the field because of chemicals applied as well as the shading effect of the rubber trees. Thus, the need for constantly studying the weed population in order to select an effective regime of herbicides cannot be over-emphasized.

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CIRCLE WEEDING TECHNIQUES IN IMMATURE OIL PALM

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Summary

Pre-emergent application of diuron at 2.24 to 3.36 kg/ha on to the clean-weeded palm circles effected efficient weed control. Use of contact herbicide mixtures often caused damage to lower palm fronds; however, experimental evidence indicated that neither herbicide injury nor deliberate removal of at least 10 lower fronds adversely affected the subsequent growth of the palms. It is suggested that the use of diuron, followed up with cheap contact herbicide containing diuron to control the peripheral encroachment of weeds into and regeneration within the palm circles, offers the most efficient weed control techniques in oil palm areas.

INTRODUCTION

One of the important considerations in the management of young oil palm replants is to keep the palm circles free from weeds. Shortage of manual labour in Malaysia, as a whole, has become an acute problem, so much so that in certain parts of the country satisfactory maintenance of the replants remains difficult. Herbicide usage is the only solution to these problems associated with weed control and upkeep. Although there is a wide range of herbicides available in this country, there is nevertheless a growing need to search for the most effective and economical herbicide that would achieve effective and prolonged control of weeds with no resultant damage to the main crop. With this objective in mind, Chemara Research Station has undertaken a series of trials in young oil palm replants to study the efficacy of a wide range of herbicides on the degree and duration of weed control. The paper presented here reports preliminary results of Chemara herbicide trials, some completed and others still in progress. The results, although by no means conclusive enough to provide precise recommendations on the choice and methods of weed control to be adopted in the future, nevertheless enable tentative conclusions to be drawn which could be of practical value and provide guidance for further research in the field.

MATERIALS AND METHODS

Three investigations were conducted on two adjoining estates in Negri Sembilan on Rengam series soil. These experiments were designed to study techniques of weed control in young oil palms. Reference is also made to spraying established herbicide demonstration areas in co-operation with Ansul (M) Sdn. Bhd., Dupont and ICI (M) Sdn. Bhd. on three Guthrie estates.

EXPERIMENT HB4

This was an observational trial mainly to study the reaction in the growth of newly planted young oil palms to pre-emergence herbicides applied to the weeded circle. The experimental area was recently planted with oil palm to tidy up the office premises. The trial comprised five pre-emergent herbicides applied at two rates which were compared with an untreated control as follows:

Formulations	Active Ingredients	*Rate/ha Actual product* *L1*	*L2*
1. "Karmex" WP	80% diuron	3.36 kg	6.72 kg
2. "Planavin" WP	75% nitralin	3.36 kg	6.72 kg
3. "Amiben" EC	24% chloramben	4.2 l	8.4 l
4. "Lasso" EC	48% alachlor	4.2 l	8.4 l
5. "Hyvar X" WP	80% bromacil	3.36 kg	6.72 kg

A simple randomized block of 12 palms (each treatment allotted to 1 palm only) was laid in 4 replications. The total number of palms in the trial was intentionally limited to 48 palms in order to minimize the risk of otherwise having to lose a greater number of palms owing to possible herbicidal injury. The herbicides were applied at the rate of 675 l of water per hectare, sprayed on the clean weeded palm circles of 1 m radius. The trial was established in November 1968 and the relevant observations were completed by March 1969.

RESULTS AND OBSERVATIONS

The regenerated weeds consisted of *Imperata cylindrica, Cyperus rotundus, C. zollingeri, Axonopus compressus, Paspalum conjugatum. Ottochloa nodosa, Phyllanthus niruri,* and a few ephemerals. The mean percentage cover in the palm circle, the dry weight of regenerated weeds, the length of the first fully opened frond and the number of newly formed fronds under the various treatments are shown in Table 1.

The data, though not statistically analysed, reveal obvious differences among treatments in respect of their relative efficacy in controlling weed regeneration as shown, especially by bromacil, diuron and alachlor. The growth of the palms was not affected by diuron and no toxicity symptoms were observed on the palms.

EXPERIMENT HB5

This experiment was conducted in a 1969 new clearing sustaining a Rengam series soil planted with young oil palms. The object was to study in detail the effect of various rates of diuron on the control of weed regeneration in the circles and the growth of the palms. Diuron was used at rates of 1.34, 2.78, 5.56, and 11.12 kg a.i./ha.

These were applied in water at the rate of 675 l per sprayed hectare into the clean-weeded palm circles of 2 m radius. The experiment was laid out following a single palm-plot design in which the 5 herbicide treatments were laid on groups of 5 palms, replicated 25 times. The maintenance of the palms followed routine estate practice. The vegetation comprised sown leguminous creepers with a mixture of grasses, mainly *Ottochloa nodosa* and *Axonopus, Paspalum conjugatum* and *Digitaria* spp. and a few ephemeral herbs. The trial was established in June 1969 and observed for a period of 9 months. The following observations were made:

(1) Pre-treatment recordings on the number of fronds and the length of first fully opened frond.

(2) Post-treatment recordings on the number of newly produced fronds and the length of the first fully opened frond at 3-month intervals.

(3) Visual assessment on the percentage weed regeneration in the palm circles.

RESULTS AND OBSERVATIONS

The mean percentage cover assessed at 3 months after spraying under the various treatments is given in Table 2.

Analysis of variance of data showed highly significant differences due to treatments, and suggested that diuron applied at 3.36 kg/ha gave the most efficient weed control. It was observed that weed control in the circles was maintained for a period of 3 to 4 months, but weeds and creepers encroaching from the periphery of the circles soon covered the circles and, in some

TABLE 1: % COVER AND DRY WEIGHT OF REGENERATED WEEDS, LENGTH (cm) OF THE FIRST FULLY OPENED FRONDS AND NUMBER OF NEWLY EMERGED FRONDS AFTER HERBICIDE APPLICATION

(Weeds sampled 12/2/69; length and number of fronds recorded 6/3/69, three months after treatment)

Treatments	Weeds: % Cover L1*	L2*	Mean†	Dry Wt. (g) L1	L2	Mean	Length of First Fully Opened Frond (cm) L1	L2	Mean	No. of Newly Formed Fronds L1	L2	Mean
1. "Karmex"	31.3	32.5	31.90	233	263	248	96.5	110.0	103.25	2	3	3
2. "Planavin"	66.3	56.3	61.30	488	364	426	108.7	109.2	108.95	2	3	3
3. "Amiben"	58.0	55.0	56.50	794	468	631	107.4	96.5	101.95	3	2	3
4. "Lasso"	31.5	37.0	34.25	299	255	277	99.1	101.6	100.35	2	3	3
5. "Hyvar X"	15.8	13.8	14.80	255	148	202	103.6	111.8	107.70	2	3	3
6. Control			60			888			97.16			2

*L1, herbicide at 3.36 kg/ha, L2, herbicide at 6.12 kg/ha actual product.
†Mean of 8 palms.

TABLE 2: MEAN PERCENTAGE COVER OF REGENERATED WEEDS IN THE PALM CIRCLES

Treatment (kg/ha)	% Cover
diuron 1.34	38.2
diuron 2.78	20.8
diuron 5.56	21.0
diuron 11.12	17.0
Control	57.8
Mean	31.0
SE	±4.79
Min. 5% significance level	13.4

instances, climbed over the fronds. The number of fronds produced and the length of the first fully opened frond measured at intervals of 3 months are given in Table 3.

TABLE 3: MEAN LENGTH (cm) OF THE FIRST FULLY OPENED FROND AND THE NUMBER OF NEWLY PRODUCED FRONDS

Diuron Treatment (kg/ha)	Mean Length of 1st Fully Opened Frond (cm): Pre-treatment 18/6	Post-treatment 16/9	Post-treatment 31/12	No. of Fronds: Pre-treatment 18/6	Newly produced 18/6-16/9	Newly produced 16/9-31/12
1.34	75.2	115.3	167.9	14.6	7.2	8.8
2.78	74.4	112.5	165.2	14.1	7.2	8.8
5.56	76.2	115.6	166.4	14.4	7.0	8.6
11.12	74.2	114.8	168.7	14.0	7.2	8.9
Control	74.2	110.2	164.6	14.0	7.0	8.8

No differences were observed either in the mean length of the first fully opened frond or the number of newly formed fronds under the various diuron treatments and at the different dates when the measurements were taken.

At the end of 9 months, the palm circles were fully covered with leguminous creepers, *Paspalum conjugatum*, *Ottochloa nodosa* and *Digitaria* and other ephemeral herbs. The experimental area was later subjected to a spraying trial in co-operation with ICI (M) at the beginning of March 1970. The area was divided into two blocks, A and B. Block A was sprayed in March 1970 with a mixture of paraquat 0.28 kg/diuron 0.28 kg/MSMA 1.79 kg/ha. Block B was sprayed with a mixture of paraquat 0.56 kg/diuron 0.56 kg/ha. The quantity of water used was at the rate of 450 l/ha.

Assessment of the weed control of both regenerated and encroached weeds made by ICI on 30/3/70 showed 65 to 70% kill. Block A, in general, showed a better kill compared with Block B. It was also observed that an average of 10 live lower fronds per palm were killed owing to application of the above treatments. The premature killing of these live fronds caused some concern among the management. The trial was, therefore, terminated on the decision that the possible effect of herbicidal injury to the lower fronds on the subsequent performance of the palms will first be studied in a separate trial.

EXPERIMENT HB6

In order to study more precisely the effect of herbicidal injury to live lower fronds on the subsequent growth of the young palms and also to test the efficacy of selected herbicides (singly or in mixtures) on the circle weed control, a statistically designed trial was laid in mid-June 1970 on an estate in Negri Sembilan in a field with a Rengam series soil. The palms were planted in March 1969. The trial compared the following treatments.

Herbicidal Treatments (per ha)	*Applied when Palm Circles were:*	*Palm Fronds*
1. I.C.I. Tank Mix: "Gramoxone" 1.4 l/MSMA 4.2 l/ diuron 0.35 kg	Not weeded	Not removed
2. "Karmex" 2.24 kg/MSMA 4.2 l	Not weeded	Not removed
3. "Karmex" 2.24 kg/MSMA 4.2 l	Not weeded	Removed
4. "Karmex" 2.24 kg	Weeded	Not removed
5. "Karmex" 2.24 kg	Weeded	Removed
6. Hand-weeded control	Weeded	Not removed
7. Hand-weeded control	Weeded	Removed

The treatments were laid out in randomized blocks and replicated 25 times. Treatment (1) — ICI Tank Mix — was replicated twice in each block. The herbicides were sprayed in June 1970 with water at the rate of 450 l/ha.

During the first six months, the control plots were hand-weeded at monthly intervals. The number of fronds removed under treatments (3), (5) and (7) was based on the mean number of fronds per palm found killed under treatment (1). The herbicide treatments were first applied in June and a second application in September 1970.

RESULTS AND OBSERVATIONS

Results and observations for the period June - October 1970 only are reported; measurements were made on the percentage of weeds regenerated in circles, the number of fronds produced per palm and the length of the first fully opened frond, both prior to and after applying the herbicides. The percentages of weeds in the palm circles are given in Table 4.

TABLE 4: AVERAGE PERCENTAGE WEED GROWTH IN PALM CIRCLES

Treatment	*Before Spraying 26/5/70*	*After Spraying on 10/6/70* 10/7/70	*After Spraying on 10/6/70* 14/8/70
1. ICI Tank Mix	83.9	8.0	25.0
2. "Karmex"/MSMA	83.4	11.0	12.3
3. "Karmex"/MSMA (frond removed)	85.8	9.6	17.1
4. "Karmex" (pre-weeded)	80.5	0	6.7
5. "Karmex" (pre-weeded/frond removed)	82.2	0	3.2
6. Hand-weeding	85.4	2.2	19.2
7. Hand-weeding (frond removed)	82.7	1.8	18.1

The palm circles treated with diuron either singly or in combination with MSMA showed better weed control.

The number of fronds produced and the length of the first fully opened frond of palms under the various treatments until September 1970 are given in Table 5.

TABLE 5: MEAN NUMBER OF FRONDS AND MEAN LENGTH OF FIRST FULLY OPENED FROND

Treatment	*No. of Fronds Produced* — *Before Spraying* *Total up to* 25/5/70	*No. of Fronds Produced* — *After Spraying Newly Produced* 2/10/70	*Length of 1st Fully Opened Frond (cm)* — *Before Spraying* 26/5/70	*Length of 1st Fully Opened Frond (cm)* — *After Spraying* 2/10/70
1. ICI Tank Mix	25.2	11.6	451.1	536.9
2. "Karmex"/MSMA	25.0	11.4	483.4	547.4
3. "Karmex"/MSMA	25.0	11.7	471.9	543.1
4. "Karmex" (pre-weeded)	26.4	11.3	471.9	538.5
5. "Karmex" (pre-weeded/frond removed)	25.9	11.3	468.6	540.8
6. Hand-weeding	26.0	11.4	471.4	545.1
7. Hand-weeding (frond removed)	25.0	11.5	384.6	556.3

The data in Table 5 showed no significant differential effects owing to treatments, either in the number of fronds produced or the length of the first fully opened frond.

DISCUSSION

The most salient observation from the above trials has been the efficacy of diuron at the rate of 2.24 to 3.36 kg/ha sprayed on to the clean-weeded circles, which gave better control of weed regeneration for a period not less than 3 months. Sheldrick (1969) reported that substituted urea herbicides such as diuron and monuron, in the first year of applying, provided exceptional weed control for nine months. Chandapillai (1970) showed that diuron sprayed on to newly prepared oil palm nursery prior to emplacing the polybag palms, achieved most efficient and economic control of weed regeneration in the nursery for a period of 4 to 6 months, with no adverse effect on the subsequent growth of young palms, either in the nursery or after they were planted out in the field. Although palm circles treated with diuron remained weed-free, invasion of the circles by weeds from the periphery posed problems of upkeep. It is suggested that this problem could be solved by the following procedure:

(1) When applying diuron on to the clean-weeded circles, the radius of the initial circle be at least 0.3 m beyond the drip-line of the fronds, and

(2) The peripheral encroachment, together with the odd regenerated weeds within the circle, be sprayed with an economic contact herbicide containing diuron which would perform the dual role of killing the sward and, at the same time, preventing dormant weed seeds from growing. Sheldrick (1969) reported adequate weed control achieved by twice-yearly spraying of diuron combined with a contact herbicide.

Chemara Research Station organized a commercial herbicide spraying trial in June 1970 in co-operation with the leading local herbicide promoters Ansul (M), Dupont and ICI (Agriculture), to assess the techniques and relative efficacy of the recommended herbicides. The trials were conducted on three Guthrie estates under different conditions of soil and ground cover. Comparisons were made on the efficacy of ICI Tank Mix (*i.e.,* a mixture of 1.4 l "Gramoxone", 2.8 l MSMA and 0.35 kg diuron per hectare), Ansul Tank Mix (*i.e.* a mixture of 5.6 l "Sordox L33"*, 5.60 kg sodium chlorate and 1.4 l of non-ionic surfactant such as "Lissapol"), diuron at 2.24 kg/ha, and manual weed control. (A full treatise of this observational trial is beyond the scope of this paper and will be reported elsewhere.) The most significant observation from the above trials were that, while the two types of mixture produced variable effects on both the degree and duration of weed control and damage to lower palm fronds, diuron effected more satisfactory control of weed regeneration within the circles with no injury to the lower fronds. However, it was relieving to note from the results of Experiment HB6 that damage to lower palm fronds, caused by herbicide spraying or the deliberate removal of at least 10 lower fronds, did not adversely influence the subsequent growth of the palms.

*"Sordox L33" contains 40% a.i. MSMA plus 10% diuron in a special formulation.

Barnes and Tan (1969), from their numerous field trials using MSMA in oil palms, observed no systemic damage to the palms. Seth (1970) produced data to confirm that the growth of palms weeded chemically by a mixture of paraquat/MSMA/diuron was as good as or even better than that of hand-weeded regimes, despite the observed herbicidal damage to lower fronds. It is the opinion of the writer that use of diuron, a residual herbicide, on a clean-weeded palm circle has much to recommend it since it keeps the circles clean for a substantial period, avoids herbicidal injury to growing points, and renders collection of loose fruits easy, rather than encouraging weeds to grow first and later trying to control them by contact herbicides with possible disadvantages.

Regular weeding, Sheldrick (1969) observed, with substituted ureas such as diuron, did not affect the vegetative growth of the palms, nor did it upset their early flowering and yield of fruit bunches.

In conclusion, the results of trials reported here and those of parallel studies elsewhere suggest that application of a pre-emergent herbicide such as diuron on to the clean-weeded palm circles, followed up with application(s) of an efficient and economic contact herbicide containing diuron to control regeneration with and peripheral encroachment into the palm circles, offers the most efficient weed control techniques in young oil palm replants.

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WEED CONTROL IN TEA IN INDIA

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Summary

A large number of field trials were conducted in tea gardens in north-east and southern Indian tea estates to evaluate the efficacy of Dow General Weed Killer (containing 5.5 lb dinoseb/U.S. gal) and a General Weed Killer (GW) (containing 2.5 lb dinoseb/U.S. gal) comparatively against the common practice in each garden which involves applying 1.24 l/ha paraquat 20% EC. As one should expect, the dosage depended upon the climatic zone as affecting weed vigour, age and extent of coverage by weeds, and the specific composition of weed population at each location. Generally speaking, 2.47 to 4.94 l/ha of GW was adequate for obtaining up to 13 weeks' control of monocotyledonous weeds, including some which are not easily affected by paraquat. In southern Indian conditions, the minimum required dosage of GW was 4.94 l/ha. At this dosage, up to 50% weed control was maintained for about 5 to 6 weeks. At higher dosages (7.41 or 9.88 l/ha) GW maintained good weed control for up to 9 weeks. Dinoseb at all effective dosages in addition produced effective control over some weeds not generally susceptible to paraquat. Some weeds, like thatch grass, *Cynodon* spp., *Panicum* spp., are not controlled by either dinoseb or paraquat and it is suggested that dalapon be used as a sequential treatment.

INTRODUCTION

Tea is a crop of great importance to India and Ceylon. The plant is a native of Assam and was growing there, unknown to the Government, even before Chinese tea was introduced in 1834 in southern India. As an export commodity, Indian tea was able to compete successfully as early as 1852. The development of the tea industry in India, particularly in the north-east region, was very fast thereafter. It is estimated that there are about 347,000 ha producing about 380 million kg of finished tea. Of this, southern India has about 75,000 ha and produces approximately 97 million kg of tea. Tea is one of the largest earners of foreign exchange. In 1968-9 about 201 million kg of tea was exported and earned 1,565 million rupees, or about 14% of the total foreign exchange earning. India thus produces 43% of the world tea and has 38% of the world export market.

Tea growing is almost exclusively confined to the hill slopes and is highly labour intensive. Tea labour has always been the highest paid and best looked after. Yet, in the recent past, labour unions have made it very difficult for the tea estate managements to use labour peacefully and to best advantage. Excessive competition in export markets imposes the urgent need to reduce the cost of production. Because labour cannot be retrenched easily, the least that planters have to do is to contain their number and cost, and to introduce means of increasing their productivity. A successful plan of chemical weed control in tea has to fit into this situation.

THE WEED PROBLEM

Tea culture is akin to silviculture inasmuch as tea and shade trees once planted remain there easily for 60 to 70 years, or sometimes even 100 years. The soil is manured, but cannot be disturbed because this would damage the feeder roots and reduce the yield of tea and, in extreme cases, lead to soil erosion. Most of the tea areas in India have a warm and humid climate. All these factors are conducive to the growth of weeds.

Weeds assume greater importance in old plantings where bushes are spaced apart for easy movement of pickers, and are less important in the new system of close, hedge-type planting. Furthermore, the problem is greater during the first 3 to 5 years of new plantings and after heavy pruning every 3 to 5 years, when there is inadequate shading of the weeds by the bushes.

Weed growth in tea gardens is perpetuated and spread by seeds being blown in or creepers invading it from adjoining uncultivated areas, embankments or thatch grass plantations meant to be used for roofing labour quarters. The following are the more commonly occurring weeds in tea gardens:

Monocotyledons	Dicotyledons
Axonopus spp.	*Ageratum* spp.
Cyanotis spp.	*Bidens* spp.
Cyntococcum spp.	*Borreria hispida* (Bagrakote)
Digitaria spp.	*Erichthytis* spp.
Eleusine indica	*Galinsoga* spp.
Eragrostis spp.	*Oxalis* spp.
Paspalum spp.	*Polygonum alata*
Panicum repens	*Polygonum* spp.
Pennisetum clandestinum	*Ipomoea* spp.
Thatch grass	*Eupatorium glandulosum*

The conventional method of manual weed control locally known as "cheeling" involves lightly scraping the soil surface with a steel blade fixed to a long handle. A certain amount of damage to feeder roots did happen and the garden was never really clean enough unless an expensive labour force was constantly on the job. More recently, chemical weedkillers which became commercially available and were found useful by tea research stations were recommended for use. Thus, sodium salt of 2,4-D (1 kg in 400 l of water) has been used in tea for controlling morning glory and other broadleaf weeds, but in the hands of labourers this could be a hazard to the tea bushes also. Others which find use in tea gardens are 1 kg in 100 l of water applied at the rate of 450 to 560 l/ha during September-November and followed by a repeat application at the rate of 225 to 340 l/ha in the April to June period. It is estimated that about 75,000 tonnes is currently consumed annually.

SIMAZINE

One kilogram in 200 litres water during wet weather is sometimes used, preceded by clean-weeding, manually or with paraquat. This is not much used.

PARAQUAT

This is the most popular treatment today. The recommended dosage is 310 ml of 20% paraquat EC in 100 l of water. The rate of spray is about 450 l/ha. Quite often even half the above dosage is applied if the weeds are young or sparse. The current annual consumption is estimated to be about 200,000 to 300,000 l of 20% paraquat.

Simultaneously, wherever new planting is undertaken, spacing between the tea bushes is reduced to achieve complete shading of the ground when they are full grown. This has been done with particular success in Ceylon. In such areas, use of chemical weedicides are limited to early life of transplants and post heavy pruning periods.

DOW GENERAL

In 1969 and 1970, a number of experiments were conducted in Indian tea gardens to evaluate the comparative performance of dinoseb formulations Dow General (5.5 lb dinoseb per U.S. gallon) or General Weed Killer (containing half the active ingredients) against paraquat.

The first year was devoted to feeler trials with Dow General. These trials were conducted in several north India tea plantations, namely, Nudwa, Lepetkata, Singlijan, Hatimara, Ledo, Ophulia, etc. Dow General Weed Killer (DG) sprayed at the rate of 2.47 l in 400 to 750 l/ha water gave satisfactory control of all broadleaf weeds including mature Bagrakote and *Ageratum*, for about a month. However, grasses like *Cynodon* and *Paspalum* were only superficially scorched and revived after one month. A dosage of 4.94 l DG/ha was required to get 6 to 8 weeks' control of grasses.

In 1970, a General Weed Killer (GW), formulated indigenously by Tata Fison Industries, our collaborators, was used. The change from Dow General to General Weed Killer was made to conform with general practice elsewhere, and also because Dow General Weed Killer does not require agitation during spraying. This was formulated according to our formula, except that mineral oil was replaced by xylene. These probes conducted at Nudwa and Lepetkata tea estates indicated that, wherever broad-leaved weeds predominated, even 2.47 l/ha of Dow General, with about 750 l water, gave commercially acceptable control for a period of about 6 weeks in rainy weather and 8 weeks in normal weather. All stages of *Borreria*, *Ageratum* and *Paspalum* were killed by the fourth day after treatment. Grasses like *Paspalum* began to revive after one month.

In predominantly grassy weed areas, as in Singlijan and Hatimara estates, 4.94 l/ha or more was required to obtain highly satisfactory control, whereas 2.47 to 3.81 l/ha merely scorched the grasses which revived completely by one month so as to look like untreated plots.

Similarly, satisfactory reports were obtained from independent trials done by a few tea planters (Itakhooli, Ledo and Ophulia tea estates), and the Indian Tea Association Experiment Station, Tocklai. Itakhooli TE and Tocklai used 25 l diesel oil and 375 l water per hectare to dilute Dow General (DG) and found that 3 l DG/ha gave satisfactory control of all weeds for at least 20 days.

Initial probes with General Weed Killer in 1970 indicated that application at the rate of 1.24 l/ha did not control more than 50% of the weeds, resulting in repeat carpet spraying the entire area. In places where 2.47, 4.94 or 7.41 l/ha were applied, all dicotyledonous weeds, including those not effectively controlled by paraquat, and most of the monocotyledons, except a few grasses, were controlled. In such cases, only spot application was

needed to maintain control, reducing the need of spray per chemical to half or one third of the initial dosage.

In further trials, the results were visually evaluated on 0 to 5 gradings (0 = no control, 5 = complete control). Each trial had 4 dosages (2.47, 4.94, 7.41 and 9.88 l/ha) of General Weed Killer and one dosage (1.24 l/ha) of paraquat 20% EC for comparison, and was run throughout the season to determine the need for repeat spraying to keep the weeds under control. Private trials in the Northern Indian tea gardens (Singhijan, Lepetkata, Margherita, Raidang, Beesakopee, Chubva, and Sycotta) as well as those conduced by ITA experiment station, Tocklai, showed that under conditions prevailing in north-eastern India tea gardens (Table 1) the treatment differences were significant and the differences in effectiveness at various periods after a spraying were highly significant. General Weed Killer performed much better in comparison with paraquat than in southern Indian estates. The weed control success by the two lower dosages (2.47 and 4.94 l GW/ha) was statistically similar to that by 1.24 l paraquat whereas the two higher dosages (7.41 and 9.88 l GW/ha) were significantly superior to the rest. At 4.94 l/ha or more, GW had the added advantage that it controlled even Bagrakote and *Ageratum* at all stages of growth. For effective suppression of perennial and mature grasses, 7.41 to 9.88 l GW were needed and the overall effect at these dosages was far superior to that of paraquat.

Repeat application during this period (12 May to 31 August, 1970) maintained a relatively high standard of weed control

TABLE 1: PERCENTAGE EFFECTIVENESS OF GENERAL WEED CONTROL IN NORTH INDIAN TEA ESTATES, 1970

Treatment (l/ha)	*Weeks after Treatment* 1 wk	2 wk	3 wk	4 wk	5 wk	10 wk	13 wk	*Av. Effectiveness*
paraquat 20% 2	63.44	58.05	53.73	45.00	47.29	53.15	63.44	54.8
GW 2.47	90.00	55.55	39.23	63.44	50.77	66.42	63.44	61.2
GW 4.94	50.77	53.13	55.55	39.23	56.79	66.42	63.44	55.0
GW 7.41	90.00	67.21	47.29	63.44	63.44	63.44	63.44	66.4
GW 9.88	90.00	63.44	63.44	63.44	63.44	63.44	63.44	67.2
Average angular form	76.84	59.48	51.85	54.91	56.36	62.57	63.44	
Standard error (treatments)	....	....	....	....	....	....		± 3.29
Critical difference at 5%	....	....	....	....	....	....		9.60
Standard error (dates)	....	....	....	....	....	....	....	± 3.89
Critical difference at 5%	....	....	....	....	....	....		11.36

right up to the end of the trial period. The effect up to the 1st week was spectacular. Treatment differences disappeared after 6 weeks — the longer period of control was achieved where tea bushes covered the ground more effectively. However, neither paraquat at normal dosages nor GW produced real and lasting control of monocotyledons, particularly of tough ones like *Cynodon* and thatch grass. In such cases, dalapon should be used as a supplementary treatment. Nevertheless, the scorched look imparted by paraquat spraying was more impressive to planters than that achieved with 4.94 to 7.41 litres GW. At 9.88 l/ha GW gave much better overall weed control than 1.24 l paraquat 20% and was comparable to 2.47 l paraquat 20%.

In south Indian tests conducted at Karamalai, Highforest, Pallivasal HR, Paralai, Craigmore, Chamraj and Mayfield tea estates, the findings were in general similar to experience in the north-eastern region, but as the climate is generally warmer and more humid, even during winter months, weed growth was generally more vigorous with grasses forming a larger percentage.

TABLE 2: PERCENTAGE EFFECTIVENESS OF GENERAL WEED KILLER IN SOUTH INDIAN TEA ESTATES, 1970

Treatment (l/ha)	*Centres/Replication* I *Karamalai*	II *H. Forest*	III *Pullevasal*	IV *Paralai*	*Av. Effectiveness (Angular Values)*
paraquat 20% 2	47.87	68.61	52.24	48.62	54.33
GW 2.47	26.56	35.24	20.70	37.76	30.00
GW 4.94	39.23	54.76	37.76	45.00	44.19
GW 7.41	47.87	54.76	37.76	48.62	47.25
GW 9.88	50.77	63.44	45.00	48.62	51.96
Standard error					± 4.0584
Critical difference at 1%					16.9116

The data in Table 2 indicate that there were statistically highly significant differences between the treatments. The average performance of paraquat 20% at 2 l/ha was not significantly different from the performance of 4.94, 7.41 or 9.88 l/ha of General Weed Killer; 4.94 l GW/ha was, however, slightly inferior and may be regarded as a marginal dose.

At 4.94 l/ha GW controlled some weeds (*Calsularia* and *Polyonum*) and at higher dosages grasses, *Cyanotis, Cyntococcum,* and *Eragrostis* as well. These are not properly controlled by paraquat.

TABLE 3: PERCENTAGE EFFECTIVENESS AT VARIOUS INTERVALS AFTER TREATMENT, 1970

Treatment (l/ha)	*Days after Treatment* 8	16	26	38	51	66	97	*Av. Effectiveness (Angular Values)*
paraquat 20% 2	69.30	55.98	37.76	60.00	41.38	41.38	37.76	49.08
GW 2.47	45.00	30.00	30.00	41.38	20.70	25.62	20.70	30.48
GW 4.94	52.24	41.38	47.85	55.98	37.76	37.76	30.00	43.28
GW 7.41	60.00	48.56	52.24	55.98	45.00	48.56	30.00	48.62
GW 9.88	69.30	54.76	60.00	60.00	45.00	52.24	37.76	54.16
Average angular form	59.17	46.14	45.57	54.67	37.97	41.11	31.24	
Standard error (dates)								± 1.8317
Critical difference at 1%								7.2442
Standard error (treatments)								± 1.66
Critical difference at 1%								6.56

In experiments where multiple treatments were given (Table 2) treatment differences as well as periodic variances were found to be highly significant statistically. 4.94, 7.41 and 9.88 l/ha GW gave results statistically similar to that of 1.24 l paraquat 20% EC and were significantly better than 2.47 l/ha GW.

The effectiveness of treatments decreased significantly as time passed (except observations recorded around 38 days after treatment which have not been explained) (Table 3). Generally speaking, over 50% weed control level was maintained for 4 to 5 weeks. Beyond this period and up to 9 weeks, the two higher rates of GW gave somewhat better results than by paraquat. These observations were recorded between 18 May and 19 October 1970.

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These trials were conducted by our collaborators, Tata Fison Industries Limited, to whom we owe our thanks. The weedicides were provided by our company.

WEED CONTROL IN ARABICA COFFEE IN THE CENTRAL HIGHLANDS OF NEW GUINEA

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INTRODUCTION

Arabica coffee production in New Guinea is concentrated in the highand areas between Kainantu in the east and Mount Hagen in the west, with a smaller centre in the Wau Valley south-west of Lae. It is grown in upland valleys at altitudes mostly around 1,524 m above sea level, although the range is from about 915 m to 1,980 m. Mean annual rainfall in these valleys varies from about 165 mm in parts of the eastern section to 305 mm at the western end. Rain falls in all months of the year, but is highest between December and April with mean monthly recordings of 200 to 330 mm. In the drier season, monthly falls vary from 50 to 150 mm in the east and from 100 to 230 mm in the west.

Coffee is produced both by indigenous growers, mostly in small village plantings, and by expatriates on plantations. About 67% of total production comes from indigenous growers. Indigenous coffee is grown under shade provided by *Casuarina* sp. while expatriate plantations until recently have used *Albizia stipulata* and to a lesser extent *Casuarina* sp. and *Leucaena leucocephala*. Now many plantations are removing shade trees and obtaining higher yields, while maintaining tree health and vigour by using higher levels of fertilizer.

WEED CONTROL

Prior to 1967, weed control was carried out almost entirely with hand labour using spades or hoes. In some instances, plantations had tried herbicides such as dalapon and 2,4-D, and, although they offered control of some problem weeds, they did not appear to be an economic alternative to hand-weeding. Similarly, the few trials that had been performed with soil-acting herbicides indicated that on a cost basis they were an even less likely alternative to hand-weeding. With the introduction of paraquat, an economical substitute for hand-weeding seemed a possibility, particularly as it became apparent that labour costs were likely to increase as economic development of the Territory continued.

Paraquat is the most widely used herbicide on plantations and it is also used to a limited extent by more advanced indigenous growers. More recently diuron has gained some acceptance on plantations. Herbicides, which are applied with knapsacks, have now almost entirely replaced manual weed control in plantation coffee.

There are at present two main methods of weed control being used, one based on paraquat and the other on diuron:

(1) In the paraquat-based programme, paraquat is applied to weeds 15 to 25 cm high before they set seed. This requires spraying at intervals of approximately six weeks. By preventing further seed production, the viable weed seed population in the upper soil is gradually reduced, and control costs decrease with time. Applications are made initially at rates of 0.28 to 0.42 kg in 505 l per hectare as overall sprays. Subsequently after about three applications, new weed growth becomes patchy and spot-spraying becomes possible. At the same time, the spray concentration can be reduced to about 0.14 kg per 505 l, and this amount of spray is sufficient to treat about 2½ times the area originally covered. In the ideal situation, this results in very low weed control costs. However, in most cases there will be some weed species not controlled by paraquat which require additional treatment. Herbicides applied in spot-sprayings for these weeds include dalapon, amitrole, 2,4-D and MCPA.

(2) In the diuron-based programme, either overall (blanket) applications of diuron are made to weed-free ground at intervals of three to six months, or diuron is applied as required to standing weeds. In the latter case, either a suitable surfactant or a foliar-acting herbicide such as paraquat or amitrole is included in the spray mix to effect a kill of the existing weeds. When overall sprayings of diuron to clean ground are used, the initial application is at 3.6 kg/ha of diuron and subsequent applications are at 1.8 kg/ha. Usually a total of 7.2 kg/ha of diuron is required in the first year, after which two applications per year, each at 1.8 kg/ha, are required. Between these diuron applications, spot-treatment of resistant species with other herbicides is usually necessary.

Mulching in conjunction with herbicides is not used to any extent, mainly because of a lack of suitable material and the high cost of the operation. To date, maintaining weed-free ground with herbicides does not seem to have produced soil erosion problems.

WEED SPECIES

Appendix 1 lists most of the weed species present in highland coffee. The weeds which are most troublesome are the perennial species, *Paspalum conjugatum, Cynodon dactylon* and *Commelina diffusa,* and to a lesser extent a number of annual weeds which are resistant to one or both of the main herbicides. Eradication of the perennial weeds by hand-weeding was not economically possible except for small infestations. Without a prolonged dry season, the topsoil is likely to remain moist throughout the year, and hand-weeding provides only a temporary check on the growth of perennial weeds. All the perennial species can be eradicated or controlled with herbicides.

Paspalum conjugatum may be eradicated by a number of treatments — amitrole, amitrole-paraquat sequential sprays, MSMA, diuron, and spray mixtures of diuron plus paraquat or amitrole. The cheapest treatment is two applications of an amitrole spray containing 0.28 to 0.57 kg per 205 l, but the treatment chosen is often influenced by the other weeds present.

Cynodon dactylon can be controlled with dalapon, but, at the rates used in coffee, complete eradication is a lengthy process. For spot-spraying, concentrations of 1.9 to 3.8 kg per 205 l with a repeat application about four weeks later are recommended.

Commelina diffusa can be eradicated with repeated treatments of 2,4-D or MCPA. The latter, at 0.57 to 1.13 kg per 205 l has given better results than the same concentrations of 2,4-D. Ioxynil plus MCPA has given excellent results, but is a more expensive treatment.

Ipomoea batatas. Regrowth of sweet potato is often troublesome because it is resistant to paraquat and diuron. However, it is readily eradicated with 2,4-D or MCPA at concentrations of 0.28 to 0.57 kg per 205 l.

Crassocephalum crepidioides is not controlled by pre-emergence applications of diuron and it usually becomes prominent on diuron-treated areas. 2,4-D does not give satisfactory control of larger plants but paraquat is effective.

Several other broadleaf species of fairly minor importance, such as *Lindernia crustacea, L. anagallis* and *Polygonum dichotomum* are resistant to paraquat, but can be controlled with 2,4-D.

EXPERIMENTAL WORK

There have been three main aspects of the weed control work in coffee at the Highlands Agricultural Experiment Station, Aiyura. These are investigating control measures for particular weed species, evaluating newer herbicides, particularly pre-emergents, and, thirdly, examining over an extended period the costs and effectiveness of various weed control programmes.

Trials have been carried out on *Paspalum conjugatum, Cynodon dactylon, Commelina diffusa,* and *Ipomoea batatas.* Control recommendations for these weeds, based on trials and subsequent field experience, have been given briefly above.

The only pre-emergent herbicide being used commercially in coffee in New Guinea is diuron. When it has been compared with other pre-emergents in trials it has been superior on a cost-performance basis to the other herbicides. However, evaluation of other pre-emergents, both alone and in mixtures is continuing.

The third aspect, cost evaluation of different weed control programmes, is being covered by a number of larger-scale trials. Extrapolation of results, particularly of costs, from small-plot trials of relatively short duration to the plantation situation is difficult for a number of reasons. These include:

(1) The large variation in costs which different weed populations can induce.

(2) The appearance of resistant species after a treatment has been continued for some time.

(3) The decrease in costs with time if the weed species present are controlled and re-seeding is prevented.

Consequently, to examine the performance and cost of a herbicide treatment, both in comparison with other herbicide treatments and with hand-weeding, larger-scale trials which continue for several years are necessary. In these trials, the herbicides used in a given treatment and the application rates have to be fairly flexible. This is because it is not possible to control all the weeds present with one herbicide and because the composition of the weed flora will change with time.

EVALUATION OF FOUR WEED CONTROL PROGRAMMES

The first of the longer-term trials commenced at Aiyura in March 1968. Laid down in mature coffee, it compares four weed control treatments under three shade situations on two sites. One site is on the lower slopes of grassland hills, and the other on flat bottom land that prior to draining and clearing had been swamp on which the dominant species were *Saccharum* spp. Although the hillside soils are lighter in texture than those on the lower site, the soil types on both sites are typically clays with over 10% organic matter.

Each shade plot covers 0.25 ha and within this area the coffee is being grown at three spacings — 2.13, 2.44 and 2.74 m on the triangle — and with two pruning systems (single and multiple stem). Weed control costs under each shade are thus an average of costs under these six growing situations. The shade plots are: (1) Fairly dense *Casuarina* sp., (2) less dense *Albizia stipulata*, and (3) unshaded. The weed growth in each shade plot at the beginning of the trial is given in Table 1.

TABLE 1: WEED WEIGHT (kg dry matter/ha) AND PERCENTAGE GROUND COVERED BY WEEDS PRIOR TO COMMENCEMENT OF TRIAL

(Figures averaged over the two sites)

Shade	*Weed Control Plot* *Paraquat*	*Diuron*	*Hand-weeded*	*Hand-weeded + Diuron*	*Mean*
Casuarina:					
Weed weight	 124	116	263	147	162
% Cover	 8	10	12	11	10
Albizia:					
Weed weight	 1287	794	976	635	923
% Cover	 51	46	40	42	45
Unshaded:					
Weed weight	 2178	2356	4426*	2397	2613
% Cover	 84	76	89*	82	82

*Obtained from one site only.

The weed problem in the trial areas was severe on the unshaded and *Albizia stipulata* plots, with perennial grasses forming a high proportion of the weed population.

The four treatments are:

(1) *Based on paraquat*, with no soil-acting residual herbicides. Applications are made as required. Spraying with other herbicides for specific weeds not controlled by paraquat is done as necessary, although for the first 30 weeks only paraquat was used. The other herbicides used were amitrole (for *Paspalum conjugatum, Cyperus brevifolius,* and *C. kyllingia*), dalapon (for *Cynodon dactylon, Paspalum orbiculare,* and *P. paniculatum*), 2,4-D (for *Ipomoea batatas, Rumex crispus, Polygonum* spp., and *Lindernia* spp.) and MSMA (for *C. brevifolius* and *C. kyllingia*).

(2) *Based on diuron.* Overall applications of diuron are supplemented by spot-spraying with other herbicides on specific weeds as necessary. In the first year, three applications of diuron were made at 4.5, 2.2 and 2.2 kg/ha on the unshaded plots and at 3.6, 1.8 and 1.8 kg/ha on the *Albizia stipulata* plots. The *Casuarina* sp. plots received an initial application of 3.6 kg/ha after which only spot treatments were used. In each of the following two years, unshaded and *Albizia stipulata* plots received two applications at 1.8 kg/ha. Other herbicides used were dalapon (for *Cynodon dactylon* and *Paspalum orbiculare*), 2,4-D and MCPA (for *Commelina diffusa, Crassocephalum crepidioides, Ipomoea batatas, Rumex crispus,* and *Dichrocephala bicolor*), paraquat (for *Crassocephalum crepidioides* and various annual grasses and broadleafs) and amitrole and MSMA (for *Cyperus brevifolius* and *C. kyllingia*).

(3) *Hand-weeded.* Weeding is done as necessary, except that during wet weather it is postponed because in such conditions the weeding of perennial grasses is ineffectual. Hoes were used for most of the first two years, but thereafter were replaced by spades, which allowed the work to be done more efficiently.

(4) *Hand-weeded, with an application of diuron during the peak harvest period.* Coffee is picked throughout the year in most areas, although there is a very definite flush period which lasts for two or three months. At this time, labour for weeding is scarce and a herbicide application may be of practical value.

The diuron application was made to recently weeded ground except on one occasion, when standing weeds were sprayed with a spray mix of diuron and amitrole. On the unshaded plots, diuron was applied at 3.6 kg/ha in each year. *Albizia stipulata* plots received 3.6 kg/ha in the first year, and 2.7 kg/ha in each of the second and third years. *Casuarina* sp. plots received only spot-sprayings because weed growth did not justify overall applications.

As in treatment (3), hand-weeding was done with hoes initially, and then replaced by spades.

RESULTS

(1) *Based on paraquat.* Weed growth was slight under the dense *Casuarina* sp. shade and good control was maintained throughout. In the other shade plots, paraquat on its own was not able to eradicate the heavy growth of *Paspalum conjugatum,* although some reduction was achieved, particularly in the *Albizia stipulata* plots. The continuing presence of this weed made frequent sprayings necessary. Amitrole was then applied four weeks prior to paraquat applications, and, after two such sequential sprayings, almost complete eradication was achieved. On the lower site during the second year, *Cyperus brevifolius, C. kyllingia,* and *Cynodon dactylon* invaded the predominantly bare ground and became serious weeds. The grass was controlled with dalapon and control of the sedges was achieved with amitrole and MSMA, although it took some time and was relatively expensive. Weed control on the better drained hillside site was both better and less expensive.

(2) *Based on diuron.* Weed growth under *Casuarina* sp. shade was slight, and after the initial overall application diuron was applied as spot-sprays because weed growth did not justify overall applications. In the other shade plots the first two applications of diuron were applied to growing weeds so a surfactant was included in the spray. After this, applications were to predominantly bare ground, so no surfactant was used. The diuron applications in the first year eradicated *Paspalum conjugatum.* The two sedges, *C. brevifolius* and *C. kyllingia,* appeared, but the partial control exhibited by diuron plus spot-spraying with amitrole and MSMA has prevented them from becoming a problem.

(3) *Hand-weeded.* There was no reduction in the weed density or in the composition of the flora over the three-year period.

(4) *Hand-weeded plus diuron.* There was a decrease in the weed cover and a change in the proportion of the species present. *Paspalum conjugatum* decreased while *Commelina diffusa, Paspalum orbiculare* and *Cynodon dactylon* increased.

The costs, averaged over the two sites, are given in Table 2. Application costs are included in the cost of the herbicide treatments.

In the hand-weeded treatment, the cost figures given for the first year have been reduced from the costs actually obtained to the same costs as those prevailing in the second year. This is because the first-year costs were considered to be unrealistically

TABLE 2: COST OF TREATMENTS ($U.S./ha)
(Costs converted on the basis of A$1.00 = US$1.12)

Treatment and Shade	*Cost $US* Yr 1	Yr 2	Yr 3	*Total*
Basically paraquat:				
Casuarina	30.91	13.17	18.85	62.93
Albizia	84.19	45.29	52.76	182.24
Unshaded	106.23	72.28	90.17	268.68
Basically diuron:				
Casuarina	43.19	25.97	24.49	93.65
Albizia	136.72	54.19	58.14	249.05
Unshaded	175.27	69.21	73.24	317.72
Hand-weeded:				
Casuarina	31.73*	31.73	28.39	91.85
Albizia	89.15*	89.15	78.40	256.70
Unshaded	136.40*	136.40	105.12	377.92
Hand-weeded plus diuron:				
Casuarina	28.27*	35.56	30.07	93.90
Albizia	81.62*	63.55	47.64	192.81
Unshaded	128.94*	101.16	79.29	309.39

*Adjusted figures — see text.

high. The weeding in the first year had produced no decrease in the weed population (and none would be expected because this treatment was a continuation of what had been practised on the area for the preceding 12 years), and yet the hand-weeding costs for the second year on the various plots were between 38 and 48% lower. This decrease in cost was attributed mainly to closer supervision of labour in the second year, although a change-over from hoes to spades for the last two weedings in the second year is also considered to have contributed to the decrease. Weeding can be more rapidly carried out with spades, and their use throughout the third year is considered to be the reason for the decrease in costs from the second to the third year.

Similarly, the hand-weeding costs in the "hand-weeded plus diuron" treatment also decreased considerably in the second year. However, this was partly due to a decrease in the weed population brought about by the diuron treatments and not just to an increase in labour efficiency. The costs given for the first year of this treatment in Table 2 have been adjusted by making the same percentage reduction in hand-weeding costs (not total costs) as occurred in the "hand-weeded only" treatment.

Even with these adjustments, the hand-weeded treatment has been the most costly, but after adjustment the hand-weeded plus diuron treatment compares favourably with the diuron-based treatment.

Over the three-year period, the cheapest treatment in all shade situations has been that based on paraquat, although, in the second and third years, the cost of the diuron-based treatment in unshaded coffee was less than that of the paraquat-based treatment. This was mainly due to the high cost of controlling the sedges, *C. brevifolius* and *C. kyllingia,* on the lower site of the paraquat-based treatment.

Table 1 shows the influence of the three shade conditions on weed growth, and the considerable effect of shade on weed control costs can be seen from Table 2. Although weeding costs are higher in unshaded conditions, trial results at Aiyura have shown that considerably higher yields can be obtained from unshaded coffee, which more than cover the extra weeding costs.

A feature of the continuous timely use of herbicides is the decrease in costs from the initial relatively high levels as the viable weed seed population in the surface soil is gradually depleted. In the paraquat-based treatment, this decrease has been checked by the appearance of species which are relatively costly to control. Now that these weeds have been reduced to low levels, further reductions in the cost of this treatment should be possible. A marked drop in costs in the second year of the diuron-based treatment was not continued in the third year. In future years, some cost reductions may be possible by decreasing further the rates of diuron used. However, any marked improvement in costs will depend upon the elimination of the few species which are resistant to diuron and which are contributing significantly to control costs.

This trial has not, so far, demonstrated any yield increases from using herbicides. However, it has shown that herbicides are an economical alternative to hand-weeding at present wage rates. In the future, the advantage is likely to be even more on the side of herbicides.

APPENDIX 1

Weed Species Found in Coffee in the New Guinea Highlands

Monocotyledons	Dicotyledons
Commelina diffusa	*Ageratum conyzoides*
Cynodon dactylon	*Ageratum houstonianum*
Cyperus brevifolius	*Alternanthera sessilis*
Cyperus distans	*Amaranthus lividus*
Cyperus kyllingia	*Bidens pilosa*
Digitaria pruriens	*Crassocephalum crepidioides*
Eleusine indica	*Dichrocephala bicolor*
Eragrostis tenuifolia	*Drymaria cordata*
Imperata cylindrica	*Erigeron sumatrensis*
Isache myosotis	*Ipomoea batatas*
Leersia hexandra	*Galinsoga parviflora*
Paspalum conjugatum	*Lindernia crustacea*
Paspalum orbiculare	*Lindernia anagallis*
Paspalum paniculatum	*Polygonum dichotomum*
Pennisetum clandestinum	*Polygonum minus*
	Polygonum nepalense
	Portulaca oleracea
	Stellaria media
	Viola betonicifolia
	Youngia japonica

WEED CONTROL IN TEA FIELDS

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Weeds, in general, suppress the tea crop (Eden, 1939, 1960; Glover, 1952; Visser, 1961); grass weeds markedly retard the growth of young tea plants in clearings (Venkataramani, 1962). Weeds also influence the micro-climate and pest and disease incidence, as in the case of the tea mosquito bug and the blister blight disease of tea, apart from being a nuisance to workers. It is little wonder, therefore, that weeds have been ruthlessly condemned and weed control has become a routine practice in tea culture.

The usual method of weed control in tea fields involves the employment of manual labour for pulling out the weed and the use of cutting, digging and scraping implements, and also thatching and mulching whenever and wherever possible.

Digging and scraping lead to much soil disturbance and possibly also erosion and root injury, the effect of which may even be worse than the presence of weeds. It is also now recognized that vigorous cultivation of the soil as such is an unnecessary practice in tea culture.

The traditional method of weed control is an ever-recurring drudgery. Apart from expense, the availability of labour at the appropriate time also poses a real problem. This naturally raises the question whether there is any method of approach to the problem of weed control other than manual weeding.

Far-reaching achievements have been obtained in chemical weed control in crop plants. Fifteen years ago, chemical weed control was relatively undeveloped in the plantation industry, but for the last ten years now such a control measure has become a regular feature in the culture of some perennial plantation crops in the tropics.

For over twenty years, the UPASI has been testing the available weedkillers with the aim of finding out whether, in these days of rising labour costs, the safe use of chemicals could be recommended for routine weed control in tea fields. The observations and results of investigations have been published already in annual reports and bulletins (Venkataramani, 1970). This paper summarizes these results.

CONTROL OF GRASS WEEDS

Grass weeds suppress growth of tea plants, and their effect is markedly noticed in clearings even within a short time. The growth of young tea plants is retarded in the presence of grasses (Table 1).

TABLE 1: EFFECT OF GRASS ON GROWTH OF YOUNG TEA PLANTS, 1961

	Dry Weight of Plants (mg)		
Components	*Control Series*	*Grass Series*	*Sig. Diff. P = 0.05*
Internodal stem of mother leaf	362	289	65.5
New leaf and stem	2107	817	481.3
Total aerial portion	2469	1106	544.1
Roots	845	338	265.1

Of the few weedkillers tried, formulations based on dalapon have given promising results in the control of grasses in tea fields. Two or three applications of dalapon (80% sodium salt) at the rate of 5.6 kg/ha are superior to one application of 17 kg/ha. No visible phytotoxic symptoms developed in tea and no crop depressing effect has been observed provided the dosage of dalapon did not exceed 5.6 kg/ha at any one application.

In warm and moist soils, the breakdown of this chemical, as a result of microbial activity, is rapid. This significant feature, together with its ready absorption and translocation through living grass foliage, makes it a comparatively safe weedkiller formulation for use. If the applications are timed properly and if excessive drenching of the soil is prevented, dalapon may not prove a hazard to the tea crop. Trials have shown that two applications of dalapon, each at 5.6 kg/ha, or better still three applications, the first at the rate of 5.6 kg/ha and the next two at 3.36 kg/ha in a convenient volume of water would give a reasonable control of grass weeds.

The grass weed problem is greatest in the clearings and in mature tea during the first two years of the pruning cycle. If grasses are kept under check during this period with a total of three or four applications of dalapon, properly timed and applied, that should normally be sufficient. With the development of a good cover of tea in subsequent years, weed growth will naturally be suppressed and no further chemical application may be required, but proper timing and follow up of applications are necessary. It is emphasized that the grass must be at the active growing stage and that pretreatment, such as cheeling, may be necessary before dalapon is applied where grass is over-grown and a matted surface has formed.

Soon after the grass is killed, there is an invasion of broadleaf weed flora. In the experiments conducted, two weed species, *Borreria ocymoides* and *Centella asiatica,* were dominant. These two weed species grew so quickly and profusely that no grass species had a chance to establish itself in the treated area. This would show that, if the aim is to eradicate grass, its control must be followed by the sowing of a smother crop, for example a cover crop (*Mimosa invisa*) wherever possible, or encouraging the development of some harmless dicotyledonous weed which could be readily kept under check; this is essential in exposed situations.

Dalapon may kill young dadaps (*Erythrina lithosperma*), wattles (*Acacia* spp.) and silver oak (*Grevillea robusta*) used as shade trees in tea fields, if they are inadvertently sprayed. If the spray application is immediately followed by a heavy rain, leaching the chemical into the soil, some defoliation of older dadaps may take place, but the trees will soon refoliate and recover. The importance of the timing of the weedkiller application might once again be emphasized.

The results of the UPASI experiments are presented in Tables 2 to 4 and it can be seen that, in almost all cases, weedkiller treatments have resulted in increased yields.

TABLE 2: CONTROL OF GRASS WEED WITH DALAPON, 1960-1961

Treatments (kg/ha)	*Green Leaf from 800 Bushes in 11 months (kg)*	*% Increase*
Slash-weeded	1430.3	—
dalapon 5.6, 2 applications	1570.6	9
dalapon 5.6 + 3.36	1475.0	3

TABLE 3: CONTROL OF GRASS WEEDS WITH DALAPON, 1960-1961

Treatments (kg/ha)	*Green Leaf from 250 Bushes in 11 months (kg)*	*% Increase*
Slash-weeded	366	—
Hand-weeded	375	2.4
dalapon 5.6, 2 applications	387	5.8
dalapon 5.6 + 3.36	389	6.0

TABLE 4: CONTROL OF GRASS IN TEA FIELDS, 1962-1963

Treatments (kg/ha)	*Green Leaf from 150 Bushes in 13 months (kg)*	*% Increase or Decrease*
Estate practice (slashing)	155	—
Untreated	137	— 11.6
Digging	159	+ 2.6
dalapon 4.48 + 2.24	166	+ 7.1
paraquat 0.56, 4 applications	163	+ 5.2

If grass weeds are allowed to grow unchecked, tea yield is suppressed and digging and removal of grass is only very slightly better than slash weeding (Tables 2 and 4). In all experiments where grasses were controlled with dalapon, perceptible yield increases were obtained.

CONTROL OF BROADLEAF WEEDS

Species of broadleaf weeds (dicotyledons) commonly found in tea fields are too numerous to mention here. Most of these weeds could be kept under control and they should not be regarded as harmful. But the creepers like climbing hempweed (*Mikania scandens*) and morning glory (*Ipomoea* spp.) form a class by themselves, and should on no account be encouraged in tea fields. Their control will not be discussed in this paper, but formulations based on 2,4-D have been found to give the best control.

The chemical weedkillers currently available are all useful in controlling the common broadleaf weeds. Field trials carried out during the period 1961 to 1963 with several formulations have shown the possibility of using some of them safely in tea fields. The results obtained with three formulations are summarized in Tables 5 and 6.

Very good control of weeds was obtained with 2,4-D, paraquat and simazine as can be readily gauged from the weed density data presented in Table 5.

TABLE 5: CONTROL OF BROADLEAF WEEDS, 1961-3 — WEED DENSITY IN EXPERIMENTAL PLOTS

Treatment	*Fresh Weight of Weeds ($kg/3\ m^2$)*	*Av. Score*
Slash-weeding	4.384	100
2,4-D	0.088	15
paraquat	0.848	25
simazine	1.488	30

TABLE 6: CONTROL OF WOODLEAF WEEDS, 1961-3

Treatments	Green Leaf from 300 Bushes Feb. 62-Mar. 63 (kg)	(+%*)	Apr.-Oct. 63 (kg)	(+%*)
Estate practice (slashing)	439	—	243	—
2,4-D	457	4.1	273	12.3
paraquat	457	4.1	271	11.5
simazine	466	6.1	267	9.9

*Over estate practice of slash weeding.

Yield increases in the range of 10 to 12% were obtained by keeping the weeds under good control for two consecutive years.

Simazine applied at the rate of 2.23 to 3.36 kg/ha at each application in about 560 l/ha of water gave adequate control of most weeds, except perennial grasses, for a period ranging from 3 to 4 months. As this chemical acts through the soil as a pre-emergence weedkiller, it is obligatory that it be applied to a clean-weeded field. Ordinarily the chemical remains in the top 2.5 to 5 cm of soil and acts in this region. Timing of application is, therefore, important. The best time is when at least 50 to 75 mm of rain is expected to follow the application. From theoretical considerations, the two possible times of application in most of the tea areas are: (1) The end of the dry period — *i.e.*, the period just prior to the onset of the S.W. monsoon rains — and (2) the break in the rains, especially the period between the SW and NE monsoon rains — in other words April/May and September/October. Later experiments have shown that the dosage could be reduced to 1 to 1.5 kg/ha per application, but three applications, properly timed, were required to achieve adequate control of weeds.

2,4-D formulations, particularly the sodium salt and amine salt, were found quite useful in controlling broadleaf weeds. When applied at the rate of 1.12 kg of active ingredient per hectare in 100 to 125 l, a very good control of most dicotyledonous weeds was obtained. Repeat applications, were, however, necessary and three sprays were sufficient to keep the fields reasonably clean of weeds. Three years' continuous use of 2,4-D formulations in tea fields did not have any adverse effect on tea bushes.

Paraquat was another formulation which gave excellent control of broadleaf weeds in the experiments. Everyone is now familiar with this weedkiller and it would suffice to add that considerable economy in its use could be effected if the weedkiller application is properly organized. In the first application, a dosage of 0.7 l in about 340 l of water per hectare is all that may be required and it could be readily reduced to half this volume if careful follow-up sprayings are done. With the use of a proper sprayer (low-pressure knapsack) fitted with the right kind of nozzle (04 or 024 flood-jets) and a properly trained spray gang who can go round at frequent intervals and spot-spray young succulent weeds, it is today the cheapest weedkiller available for safe use in tea fields.

Another weedkiller of promise is diuron and preliminary experiments have shown that dosage rates of 0.5 to 0.75 kg/ha will be required to obtain good control of most weeds in the fields. Two applications may have to be made. In recent pilot trials, a formulation based on MSMA has shown some promise in the control of weeds in tea fields.

CONCLUSION

Why have weeds become troublesome in a tea field? What are the factors which influence their uncontrolled growth in a perennial crop like tea? Are not the traditional methods sufficient to keep weeds under control? Should resort be made to chemical treatment, or should a balance between both be aimed at? These questions at once come to mind and can be examined briefly.

Weeds pose a real problem only in clearings and in mature fields during the first year of the pruning cycle — and perhaps in some cases in the second year also where a good cover has not been established. In open situations, with poor or no shade, grass weeds become prominent. With the advent of the blister blight disease and with the unfortunate removal or drastic reduction of shade to combat the disease, opportunities for increased weed growth have arisen. Hard pruning and bad plucking, and adverse effects of pests and disease, reduce the size of the bush and thereby permit more exposed soil to be available for the invasion of weeds. With lighter pruning and improved spread of bushes, and with close planting and quick cover of the field. the problem of weeds will be reduced considerably. Thatching and mulching in the clearings play an important part in weed control in young tea until the tea plants themselves are well developed and cover the ground. Mere disturbance of the soil only encourages dormant seeds to sprout, and in the case of grasses it is not uncommon to find that, the more one digs, the more the grass grows. It has been estimated that the non-removal of only 1% of the existing roots of perennial grasses such as *Digitaria* sp., *Paspalum* sp. and Kikuyu grass (*Pennisetum clandestinum*), in the course of eight weeks, leads to no less than 30% reinfestation of the weeded area, and, where follow-up operations are delayed, the field gets as grassy as before. These factors indicate that good husbandry in itself is partly an answer to the problem of weed control.

With rising labour costs, there is no doubt that a cheap and effective substitute or alternative to manual labour for weed control should be found, and this no doubt lies in the intelligent use of appropriate chemicals. Experiments have shown that most of the weeds commonly occurring in tea fields at all elevations could be tackled with three or four readily available weedkillers. Emphasis is on judicious use of these chemicals, either singly or in combination as the situation warrants.

No one weedkiller formulation can control all weeds occurring in crop lands. Weeds resistant or tolerant to one weedkiller may develop after continual use of a particular formulation. This, indeed, has occurred and every tea planter who has used paraquat extensively knows that such weeds species as *Borreria, Exallage, Polygonum, Calceolaria* and *Centella* have become the dominant members of the weed flora of fields treated with that weedkiller. Such situations, however, are not insuperable and combined sprays of paraquat and 2,4-D or paraquat and diuron or an organo-arsenical formulation, dalapon, diuron and 2,4-D are useful in overcoming such difficulties.

Intelligent and judicious use of chemical weedkillers has been referred to earlier. Here it might be emphasized that successful use of a potent weedkiller presupposes on the part of the user knowledge of the action of the chemical in use and a capacity to judge correct timing of application. As several scientists have already pointed out (Harper, 1957; Woodford, 1962), chemical weedkillers should be regarded as tools of a good husbandman to be integrated into the crop production programme from the very start.

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CHEMICAL WEED CONTROL IN RICE CULTURE IN KOREA

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Summary

Herbicide screening experiments were conducted from 1968 to 1970 in transplanted and direct-sown rice and in rice nurseries in Korea. Two formulations of propanil appeared to be promising herbicides when applied 14 days after sowing in flooded nurseries. In upland nurseries, butachlor and paraquat gave the best weed control when applied at pre-emergence, 3 days after sowing.

For transplanted rice, butachlor applied at a rate of 2 to 3 kg/ha gave good results not only in weeding but in grain yield (an increase of 5% over hand-weeding). A series of experiments in different locations in the southern part of Korea indicated the net return was increased by 15,023 to 45,278 won ($48 to $141) per hectare as a result of increased grain yield and improved weed control by butachlor.

For direct-sown rice, no herbicide was effective for more than 60 days after sowing. Butachlor (3 kg/ha) had the longest soil residual effect of the herbicides tested, and the grain yield per unit area was nearly the same as that from hand-weeded plots.

The application of butachlor in transplanted rice reduced the weeding cost and time by 7,880 won ($24) and 360 hours per hectare, respectively in comparison with conventional weeding practices.

INTRODUCTION

Weed control in rice should be systematic and co-ordinated with other cultural practices to attain the maximum effort from herbicides and hence lower production costs and reduce effort in weed control. It is necessary to be familiar with both crop cultural system and the species and extent of weeds to select the most appropriate chemicals.

The use of herbicides is recognized as one of the best methods of weed control in the savings of labour and cost it makes possible. In Korea, as in many developed countries such as America and Europe, the general trend is towards a predominance of chemical methods of weed control.

The effect of weed control with herbicides in nurseries was studied after the development of the selective material, propanil, in 1956-7. In the tropics the application of herbicides in nurseries

is not necessary because the seedbed is used for only about 20 days. However, in Korea plants are not transplanted from the nursery for 45 to 60 days after sowing and an effective method of weed control is necessary.

In transplanted rice, 2,4-D and other hormone-type herbicides were formerly mainly used for controlling broadleaved annual weeds, usually at the maximum tillering stage of rice. More recent research work has investigated treatment at an early stage rather than a late stage of rice growth to obtain higher efficiency with a smaller rate of herbicide and the use of granular formulations to minimize labour cost and injury to the rice plant. In direct sowing under upland conditions the herbicide should control weeds for 7 to 8 weeks after sowing.

The average area of cultivated land per farm in Korea is about 0.9 hectare so that the benefit from using herbicide over hand-weeding is relatively lower than in other developed countries; this was proved by economic analysis using partial budgeting methods. However the use of herbicides will increase with the development of modern industry. This report presents some results of experiments conducted to select the best, cheapest herbicides for use in rice under nursery, transplanting and direct-sowing conditions in Korea, and to find the optimum rates and times of application.

MATERIALS AND METHODS

The herbicides tested were contributed by Korea Agricultural Chemicals Co., Kyungpuk Agricultural Chemical Co., Monsanto, and Rohm & Haas. The rice variety used was "Palkweng".

To compare the herbicides in nursery practice, the seed was sown on 10 May, the rate of fertilizers applied being 80 kg/ha of N and 50 kg/ha of P_2O_5 and K_2O, respectively. Granular formulations of insecticides and fungicides were applied 5 days after herbicide treatment under flooded conditions.

Herbicides tested for flooded nursery conditions were propanil, nitrofen, MCPA, butachlor and chlorthal. For upland nurseries, butachlor, propanil, paraquat, swep, and alachlor were used.

For the screening test in transplanted rice, 45-day-old seedlings were transplanted on 20 June with planting distance of 30 × 15 cm and 5 seedlings per hill. Herbicides tested were butachlor, nitrofen, prometryn, molinate, BO-301, and EPTC/MCPA.

In direct-sown rice, the seedling rate was 120 l/ha, and fertilizers applied were 120 kg/ha of N, and 80 kg/ha of P_2O_5 and

K_2O, respectively. Herbicides tested were butachlor, alachlor, propanil, and nitrofen.

In addition to these experiments, the effect of herbicides on the cost of weed control was studied in different locations in southern Korea, the results being analysed by partial budgeting methods.

A study was made of means to improve farming management by the use of herbicides and mechanization. The conventional cultural practice, which requires a great deal of labour, was compared with an improved scheme which incorporates herbicide application and mechanization. The differences in production costs and yield between the two farming methods were investigated.

RESULTS AND DISCUSSION

1. *Screening test of herbicides in rice seedbeds under flooded and upland conditions*

Propanil applied at a rate of 3.5 kg/ha about 2 weeks after sowing at the two-leaf stage of the rice gave the best weed control compared with other treatments. Slight damage of the leaves was observed but this was temporary. Propanil effectively controlled not only barnyard grass but also broadleaved weeds and *Cyperus* species. Rice seedlings appeared healthier than those in the hand-weeded plot. A second formulation of propanil applied 8 days after sowing also gave excellent results under flooded conditions. Under upland conditions butachlor (3 kg/ha), paraquat (1 kg/ha), swep (1 kg/ha) and alachlor (2 kg/ha) gave good results when applied at pre-emergence.

2. *Screening test of herbicides for transplanted and direct-sown rice*

Seventeen different herbicides were tested in transplanted rice. In terms of grain yield of rice and dry weight of weeds per m^2, butachlor, nitrofen, prometryn and molinate gave good results as compared with hand-weeding. In particular, butachlor gave excellent weed control, with a longer residual effect, less damage to rice plants and a wider range of time of application; moreover the rice yield tended to be increased by 3 to 7% as compared with hand-weeding.

In direct-sown rice under upland conditions, a greater number of weed species were growing vigorously than under flooded conditions. In these circumstances it may be more difficult to control weeds by a single application of a particular herbicide than by hand-weeding. Most of the herbicides tested gave lower rice yields owing to the remaining weeds than did hand-weeding. Butachlor (3 kg/ha) and propanil (3.5 kg/ha) gave the best results, grain yields in these treatments being nearly the same as from hand-weeding when they were applied 4 days after sowing.

3. *Screening test of herbicides for rice cultivation in different locations and partial budgeting of costs for weed control*

Rice yield and costs of weed control may be greatly influenced by soil structure, depth of water, and climate. Yield tends to increase after application of herbicides on clay soils but not on sandy soils. Butachlor showed the best results on both soil types, rice yield being increased by 2 to 10% over hand-weeding. Applying partial budgeting of costs for butachlor, the cost of weed control could be reduced by 9,150 to 16,040 won ($29 to $36) per hectare and the net income increased by 15,203 to 45,278 won ($48 to $141).

Herbicides significantly reduced the costs of weed control in areas where the labour cost was high. Butachlor and nitrofen were the most satisfactory of the chemicals tested.

4. *Increase in net income by labour-saving cultural practices*

To find a reasonable way of reducing labour and production costs, five different treatments, including conventional cultural practices, were made with "Milsung japonica" rice variety. As compared with the conventional cultural method (ploughing and puddling by a cow, mechanical and double hand-weeding, spraying chemicals by knapsack sprayer, and threshing by foot press thresher), the treatment which included ploughing and puddling by motorized tiller, weeding with butachlor, spraying chemicals by motorized sprayer, and threshing by motorized thresher, gave the best results. This method reduced both cost and time of weed control by 7,880 won ($24.60) and 360 hours per hectare, respectively, and net income was increased by 21,890 won ($68.40) per hectare.

DOWCO 221 IN JAPANESE PADDY FIELDS

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INTRODUCTION

Since 1968, field evaluation tests of Dowco 221 as a paddy rice herbicide have been carried out extensively in the USA (Geronimo and Hunter, 1969), and in several Asian-Pacific countries (de Datta *et al.*, 1969; Anon., 1970b) where Indica rice prevails. Based on the very promising results of those trials, it is being used commercially in some countries such as the Philippines and Malaysia.

The compound has also been evaluated in Japanese paddy fields where virtually all of the rice is of Japonica strains with a comparatively shorter growing period. This report presents the results of the greenhouse and field evaluations conducted at several experiment stations since 1968.

GREENHOUSE TESTS

RICE VS. GRASS

This experiment, conducted at the Experimental Farm of the Japan Association for the Advancement of Phyto-regulators (JAPR) in 1968, was designed to determine the presence and degree of selectivity of Dowco 221 between Japonica rice and barnyard grass, the most prevalent noxious grass in Japanese paddy fields.

The surface of the clay loam soil contained in a 16 cm diameter pot was divided into two parts. Then 25 pre-soaked rice seeds (*Oryza sativa* var. 'Nihonbare') per pot and 30 pre-soaked barnyard grass seeds (*Echinochloa crus-galli*) per pot were sown into each part of the soil surface on 15, 18, 22 and 26 July, respectively. This was done to evaluate effects on different growth stages of test plants. The herbicide was applied on 26 July by dripping diluted Dowco 221 emulsion into the standing water at the rate of 2 ml/pot. The depth of the water at the time of application was 1 cm for the pots sown on 26 July and 3 cm for the other pots, and it was maintained at 4 cm from the next day until the end of the experiment.

TABLE 1: GROWTH STAGES AT TIME OF HERBICIDE TREATMENT AND DRY MATTER WEIGHT OF RICE AND BARNYARD GRASS TREATED WITH DOWCO 221

Date of Sowing	Growth Stage at Time of Treatment*		Rate of Dowco 221 (kg/ha)	Dry Matter Wt % of Control	
	Rice	Barnyard Grass		Rice	Barnyard Grass
26 Jul.	emerging	emerging	0.5	71	10
			1.0	21	2
			2.0	7	0
22 Jul.	1.0 leaf (1.0 cm)	1.0 leaf (4.0 cm)	0.5	68	14
			1.0	47	8
			2.0	30	3
18 Jul.	2.4 leaves (8.6 cm)	2.6 leaves (11.6 cm)	0.5	80	20
			1.0	75	12
			2.0	41	9
15 Jul.	3.1 leaves (15.0 cm)	3.1 leaves (14.8 cm)	0.5	86	33
			1.0	80	23
			2.0	77	23

Height in parentheses.

On 21 August all plants were pulled from the pots for measurement. Table 1 shows the growth stages of both plants at the time of application, the dosage rates of Dowco 221, and the dry matter weight of test plants.

The results of this experiment showed distinct selectivity of Dowco 221 between rice and barnyard grass at the dosage range of 0.5 to 2.0 kg/ha. It was also shown that the tolerance of both plants to the herbicide increased as their growth stages advanced. Therefore, it was considered that Dowco 221 should be applied in actual field conditions from the time rice plants take root to the time when barnyard grass reaches the 2-leaf stage (usually 5 to 12 days after transplant).

Very little effect on the emergence and growth of broadleaved weeds, included unintentionally in the pots, was observed. This suggested the need for some countermeasures against those weeds.

JAPONICA VS. INDICA

A pot test was designed by Nissan Chemicals in 1968 to clarify the difference in tolerance to Dowco 221 of Japonica and Indica strains. The varieties tested were 'Nihonbare' (obtained in Japan), 'Te-Tep' (from U.S.A.) and 'IR-8' (from the Philippines). Sixteen-day-old seedlings of these varieties were transplanted into pots having 3 cm of standing water, and a diluted emulsion of Dowco 221 dripped into the water. The treated rice seedlings were cut at ground level 20 days after herbicide treatment for measurement of height and fresh weight of the aerial parts.

'IR-8' appeared to be the most susceptible variety as far as height was concerned. On the other hand, 'Te-Tep' showed greater tolerance than the other two varieties when the dosage vs. weight curves were compared.

Generally speaking, the three varieties used in this experiment have varied characteristics in their growing habits. Also, tolerance of rice plants to herbicides often differs to some extent, even among varieties belonging to the same strain. It was, therefore, concluded that Dowco 221 should be evaluated against rice plants in general with no noticeable difference between the strains or varieties.

FIELD EVALUATION

PRELIMINARY FIELD TEST (SAGA UNIVERSITY, 1968)

The materials used in this experiment were granular formulations containing 1.67, 3.33 and 6.67% Dowco 221. The field was transplanted with 35-day-old rice seedlings of var. "Kokumasari" on 28 June at a density of 18 hills/m^2. The herbicides were applied 5 days before and 4 and 8 days after transplanting at the rate of 30 kg/ha.

Herbicidal efficacy was assessed 42 days after transplant. As indicated in Table 2, barnyard grass was completely controlled in all treatments except for the lowest dosage level of the 5-day pre-transplant treatment. On the other hand, efficacy against broadleaf weeds was very poor, especially in the 5-day pre-transplant plots, where the rice stand was markedly reduced and *Rotala indica* grew much more vigorously than in untreated control plots.

The influence of the materials on the growth of rice was assessed by several different criteria such as measurement of height, count of the number of tillers and observation of visual abnormalities throughout the growing period. Of them, the number of dead hills per square metre was used as an indicator of the influence during the initial stage of growth and the number of heads per square metre as an indicator of the yield. The results are given in Table 2. Grain yield was not measured. The initial growth of the treated rice was markedly suppressed by the treat-

TABLE 2: RESULTS OF THE PRELIMINARY FIELD TEST ON DOWCO 221

Days from Transplant	Formulation (% a.i.)	kg/ha	Fresh Wt (g/m^2) 42 days post transp. BG*	BL*	Influence on Rice: No. of Dead Hills/m^2	No. of Heads/m^2
5 pre-	1.67	0.5	20	1412	0.2	301
	3.33	1.0	0	1440	0.6	292
	6.67	2.0	0	1540	3.1	255
4 post-	1.67	0.5	0	680	0	286
	3.33	1.0	0	1168	0	279
	6.67	2.0	0	688	0.2	288
8 post-	1.67	0.5	0	408	0	298
	3.33	1.0	0	480	0	318
	6.67	2.0	0	244	0	304
Untreated control		—	168	920	0	284

*BG = barnyard grass, BL = broadleaf weeds, mainly *Rotala indica.*

ment of Dowco 221 before transplanting and as many as 17% of the hills were withered. Four days post-transplant coincided with the time when rice took root and became turgid, and treatment of Dowco 221 at this time affected rice growth more severely than that at 8 days post-transplant, but no dead hills were found in 0.5 and 1.0 kg/ha plots. Slight suppression of growth was observed even in later post-transplant treatments, but all the treated rice recovered fairly quickly and no difference in rice stand was seen by the time of heading in any treatment, with the exception of the highest dosage at the 5-day pre-plant treatment.

Judging from these results, it was considered that the optimum rate for field application would be 0.5 to 1.0 kg/ha, and the optimum time of application would be from the time when rice plants had taken root and become turgid.

FIELD EVALUATION OF GRANULAR MIXTURE (JAPR EXPERIMENTAL FARM, 1969)

Thus far, it had been demonstrated that Dowco 221 had potential utility in Japanese paddy fields as a grasskiller. However, it was also believed that for large practical use in Japan a broad spectrum product controlling both grasses and broadleaved weeds would be essential. In Japan, phenoxy herbicides such as 2,4-D and MCPA are very commonly used for broadleaf weed control, either with foliage application at the middle stage of rice growth or as a supplementary companion ingredient of soil treatment-type grasskillers.

In this experiment, several granular formulations containing Dowco 221 and either isopropyl ester of 2,4-D (2,4-D IPE) or ethyl ester of MCPA (MCPA-ethyl) were compared. The results of this experiment are shown in Table 3.

The experimental field was transplanted with rice seedlings of var. 'Nihonbare' at the 6.9-leaf stage on 10 June. The herbicides were broadcast at 5 and 10 days after transplant into the standing water of 3 to 4 cm in depth at the rate of 30 kg/ha

TABLE 3: RESULTS OF FIELD EVALUATION OF DOWCO 221 — PHENOXY MIXTURES

Formulation (a.i. %)	*Rate (kg/ha)*	*Days after Transplant*	*Dry Matter Wt (g/m²)* BG*	*BL*	*Sedges*	*Rice Injury Rating†*	*Grain Yield Unhulled (kg/ha)*
Dowco 221							
(2.5)	0.75	5	0	13.9	0.1	±	5300
		10	0	19.6	0.8	±	5270
Dowco 221							
(1.7)	0.51	5	0	1.7	0.1	+	5180
+	+	10	0	4.4	0.3	+	5100
MCPA-ethyl							
(0.8)	0.21						
Dowco 221							
(2.5)	0.75	5	0	0.6	0.1	+	5100
+	+	10	0	7.5	0.0	+	5300
MCPA-ethyl							
(0.8)	0.24						
Dowco 221							
(2.5)	0.75	5	0	4.3	0.1	++	4950
+	+	10	0	8.9	0.2	++	4930
2,4-D IPE							
(0.8)	0.24						
Dowco 221							
(3.0)	0.75	5	0	1.2	0.6	+++	4650
+	+	10	0	1.6	0.3	++	4830
2,4-D IPE							
(2.0)	0.50						
Weedy control	—	—	53.0	51.3	7.9	—	5220

*BG = Barnyard grass. BL = Broadleaf weeds — *Monochoria vaginalis, Rotala indica* and others. Sedges = *Cyperus* spp. and *Eleocharis acicularis*.

†± very slight injury, + slight and transient, ++ moderate, +++ severe.

(with the exception of 25 kg/ha for Dowco 221 3.0% plus 2,4-D IPE 2.0%). At the time of the first application, all weeds were just emerging and at that of the second, barnyard grass had reached the 1.8-leaf stage.

The results of weed count made on 29 July showed good herbicidal effects, although the results against broadleaf weeds were slightly erratic. On the other hand, some rolled or sutured leaves and suppression of tillering of the rice plants were observed in all mixture treatments. Those abnormalities were overcome by the end of July in the plots treated with the formulations containing MCPA-ethyl, but the recovery in 2,4-D IPE treatments was apparently slower and the grain yields in such plots were also adversely affected.

This experiment was conducted when the daily average temperature was 22° C. Another similar experiment carried out at Saga in the same year when the daily average temperature was 28° C suggested that 2,4-D IPE worked slightly better in combination with Dowco 221 than did MCPA (Y. Fujii, pers. comm.). This observation is also consistent with the statistics on the actual use of phenoxy herbicides in Japan, namely, a much larger quantity of MCPA than of 2,4-D is used in cooler temperature areas such as Hokkaido and Tohoku districts compared with the southern districts (Anon., 1970a). It was suggested from this experiment that those herbicides which had been successfully developed in tropical countries did not always perform successfully in Japan.

Summary of JAPR Co-operative Field Tests (1969 and 1970)

Based on the above results, co-operative field tests were carried out throughout the country by arrangement of the JAPR in 1969 and 1970. The experimental conditions designed in 1969 were to broadcast Dowco 221 2.5% plus MCPA-ethyl 0.8% granular formulation at rates of 30 to 40 kg/ha at 4 and 10 days after transplant, respectively. The results were summarized and indicated that the formulation gave excellent control of barnyard grass without exception, but the control of broadleaf weeds was erratic. Also, some reduction of rice stand as in the previous experiment was observed, especially in the cooler temperature areas (Anon., 1969).

In 1970 again, the JAPR co-operative field trials were conducted with Dowco 221 2.5% granular and Dowco 221 2.5% plus MCPA-ethyl 0.6% granular. The results are summarized in Table 4.

TABLE 4: SUMMARY OF JAPR CO-OPERATIVE FIELD TESTS OF GRANULAR FORMULATIONS CONTAINING DOWCO 221 IN 1970

Test Location	*Soil Type* and Vertical Leakage of PaddyWater*	*Days after Trans-plant*	*Rate (kg/ha)*	*Herbicidal Efficacy† Grass*	*BL*	*Rice Injury Rating‡*	*Grain Yield (% of Hand-weeded)*
I. Dowco 221 2.5% Granular							
Toyama	AL-L	4	30	E	P	—	103
	20 mn/day	11	30	E	P	—	100
		11	40	G	P	—	97
JAPR	AL-CL	5	30	E	P	—	96
	5	10	30	G	P	—	94
		10	40	E	P	—	98
Wakayama	DL-CL	4	30	E	P	—	96
	4	11	30	E	P	—	93
		11	40	E	P	—	100
Kumamoto	AL-CL	5	30	E	P	—	108
	10	10	30	E	P	—	104
		10	40	E	P	—	105
Kagoshima	VOL-SL	5	30	G	P	++	92
	40	11	30	F	P	++	90
		11	40	F	P	++	89
II. Dowco 221 2.5%/MCPA-ethyl 0.6% Granular							
JAPR	AL-L	5	30	E	G	+	94
	5	10	30	G	G	+	106
		10	40	G	G	+	96
Wakayama	DL-CL	4	30	E	P	—	94
	4	11	30	E	P	—	93
		11	40	E	P	—	100
Hiroshima	TF-L	4	30	E	E	+	101
	S	11	30	E	E	+	101
		11	40	E	E	++	95
Kumamoto	AL-L	5	30	E	P	++	96
	10	10	30	E	P	++	94
		10	40	E	P	++	94
Kagoshima	VOL-SL	5	30	F	F	+	97
	40	11	30	P	P	++	96
		11	40	F	F	++	96

*AL, alluvial; DL, diluvial; VOL, volcanic ash; TF, tuffs; C, clay; L, loamy; S, sandy.

†E, excellent (less than 6% of weedy control); G, good (6-20%); F, fair (20-50%); P, poor (more than 50%).

‡— no injury; + slight and transient; ++ moderate.

The results obtained from Kagoshima were somewhat inconsistent with others, but the reasons were considered to be due to the uniqueness of the soil and to water leakage.

Based on all the results so far discussed, the JAPR evaluation committee issued a recommendation that Dowco 221 alone could be used in Japanese paddy fields where only gramineous weeds were a problem with the restriction that it should not be applied to the fields having more than 5 mm per day of water leakage.

As to the Dowco 221 plus MCPA mixture, it was concluded by the committee that more work was needed to secure stable control of broadleaf weeds without causing phytotoxic effect on rice plants.

FUTURE

As already discussed, a broad-spectrum product is essential for large-scale practical use in Japanese paddy fields. Work with Dowco 221 up to 1970 has not yielded a broad-spectrum, commercially marketable, combination product. In 1971, a new approach is being taken with the objective of identifying a companion product to add to Dowco 221 to provide a safe, effective broad-spectrum product for rice weed control.

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HE-314 (TOPE): A NEW HERBICIDE FOR WEED CONTROL IN PADDY RICE

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INTRODUCTION

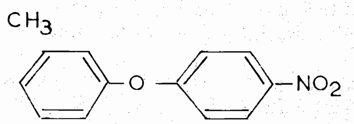
HE-314 is a new herbicide developed by Rohm and Haas Co., Philadelphia, U.S.A. It was introduced to Japan in 1965, and thereafter its herbicidal activity has been tested by many experimental stations.

Chemically speaking, HE-314 belongs to the group of diphenylether herbicides, but the test results indicated that its herbicidal activity was different from that of other members of the group, and that it could be used for practical weed control, especially in paddy rice. Its registered common name is Tope.

In this paper, according to the test results performed in Japan, the herbicidal characteristics of HE-314 and the recommendation for its practical use are described.

GENERAL PROPERTIES

The chemical structure of HE-314 is shown by the following formula:



The water-solubility of HE-314 is a little higher than that of other diphenylether herbicides such as nitrofen and chlornitrofen.

HE-314 is formulated as an emulsifiable concentrate containing 25% active ingredient for weed control in paddy rice. For the tests described in this report, the EC formulation was used in most cases. But a granular formulation containing 10% a.i. is also available.

The acute oral LD_{50} of HE-314 technical is 1,700 mg/kg body-weight to mice and 2,000 mg/kg body-weight to rats.

BASIC HERBICIDAL PROPERTIES

WEED CONTROL SPECTRUM

An experiment was carried out to study the response of the principal weed species in Japan to HE-314. 2 to 4 kg a.i./ha of

the chemical was applied using post- or pre-emergence treatment. Application in both cases, whether applied on upland or under paddy conditions, depended on the various stages of weed growth.

As indicated in Table 1, HE-314 has herbicidal activity against a wide range of weeds although a few kinds of weed such as *Eleocharis* were resistant to the chemical.

TABLE 1: SENSITIVITY OF PRINCIPAL WEEDS TO HE-314
(S — sensible, M — intermediate, R — resistant)

Weeds	*Sensitivity in the Case of* *Pre-em. Treatment*	*Post-em. Treatment*
Echinochloa crus-galli (barnyard grass)	S	S
Digitaria adscendens (crabgrass)	S	S
Eleusine indica (goose grass)	S	S
Alopecurus aequalis (foxtail)	S	S
Poa annua (annual bluegrass)	S	S
Cyperus microria (umbrella sedge)	S	S
Eleocharis acicularis (spikerush)	M	R
Cyperus serotinus	S*	S*
Monochoria vaginalis (konagi)	S	M
Dopatrium junceum	S	S
Rotala indica (toothcup)	S	S
Lindernia procumbens (false pimpernel)	S	M
Polygonum persicaria	S	S
Callitrichoe verna (water starwort)	S	S
Elatine triandra (waterwort)	S	S
Sagittaria pygmaea (arrowhead)	R	R
Potamogeton distinctus (bog pondweed)	M*	M*
Portulaca oleracea (purslane)	S	S
Amaranthus ascendens (liquid amaranth)	S	S
Chenopodium album	S	S
Chenopodium album var. *controbum*	S	S
Commelina communis (dayflower)	R	R
Stellaria media (chickweed)	S	S
Stellaria alsine (bog stitchwort)	S	S
Erigeron philadelphicus (fleabane)	M	M
Erigeron annuus (annual fleabane)	M	M
Capsella bursa-pastoris	S	M
Rorippa atrovirense (yellow cress)	S	M

*Persistence during short period.

In general, according to quantitative investigations, HE-314 seems to have selective herbicidal action depending on its application technique and the environmental conditions. The intensity of its action is highest on annual broad-leaved weeds and higher on gramineous weeds, when applied to the soil as a pre-emergence application and sprayed on the foliage as a post-emergence treatment. On the other hand, the degree of herbicidal effect was observed in the following descending order: gramineous weeds, annual broadleaved weeds, and spikerush when applied under submerged conditions.

Mode of Action and its Relation to Environment

HE-314 is essentially a contact herbicide, although some experimentation has indicated a tendency to translocate. Barnyard grass treated with HE-314 on the young foliage turns to a yellowish brown from the base of the leaf blade to the sheath. Then it begins to wilt and die. This process seems to be slower than with nitrofen and propanil.

HE-314 acts not only as a pre-emergence herbicide, but also as a post-emergence one. It seems to perform best when applied post-emergence, especially under irrigated conditions. The tests reported by Hayasaka (1967) on the effect of pre- and post-emergence application under both upland and irrigated conditions, indicate that percentage control by HE-314 applied at pre-emergence under irrigated conditions is much higher than that under upland conditions, namely from 94 to 97% down to 65 to 84%, while the effect of nitrofen is not affected by water conditions. The report also showed that irrigation water intensified the activity of HE-314 applied at post-emergence while it made propanil activity weaker.

In a study of the influence of light on the herbicidal action of several diphenylether herbicides, Matsunaka (1967) reported that HE-314 does not need light for its action while nitrofen does.

While nitrofen usually attacks only the coleoptile or young shoots of weed seedlings, HE-314 attacks both these and young roots. When applied to a water-culture of rice plants, the chemical inhibits rooting and root development. However, it does not show such injuries when applied into the water of irrigated paddy fields.

Selectivity and Factors Affecting it

The most interesting property of HE-314 is that it has high herbicidal selectivity between rice and barnyard grass, the most important weed in rice. Test results on this selectivity are shown in Fig. 1. The chemical was applied on 3-leaf rice plants and 3- to 4-leaf barnyard grass at various dosages. In a lay-by treatment

(a), the chemical was poured into the irrigation water. But in the spray treatment (b), it was sprayed on to the foliage after the water was removed. In every treatment, the growth of barnyard grass was inhibited according to the dosage rate. But the growth of the rice plant was not affected with the chemical under a definite dosage.

The degree of selectivity varies with the growth stage of the plants. This is shown in Fig. 2. This is the result of a test in which rice and barnyard grass of 5 different leaf-ages, 0 (just after germination) to 4 leaves, were treated with HE-314 under irrigated conditions. It was observed that the growth of rice was not affected by the treatment at any stage, but that the effect of

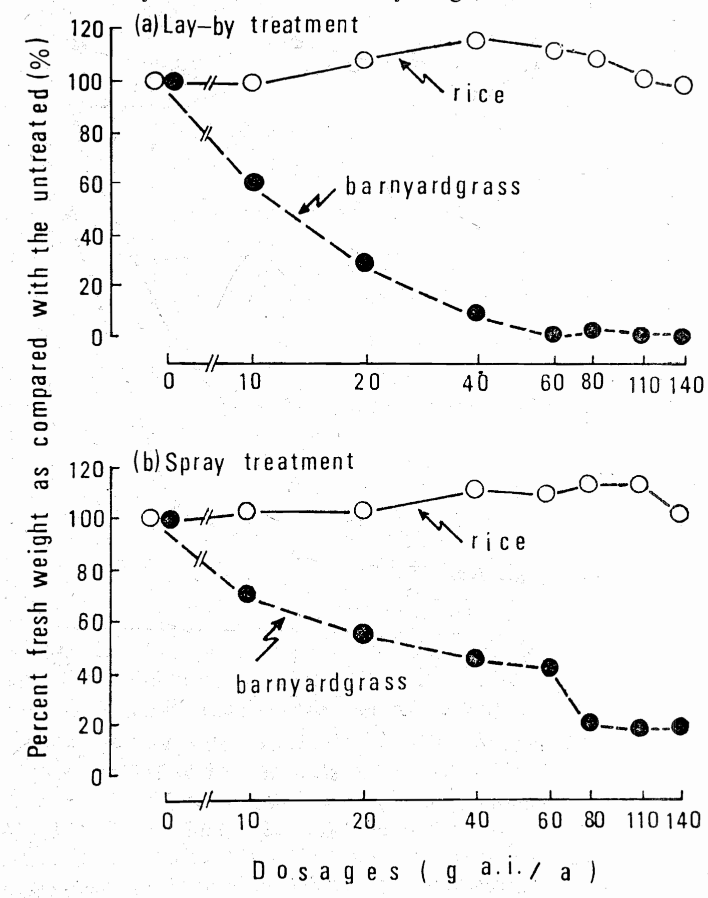


Fig. 1: Selectivity of HE-314 between rice and barnyard grass.

HE-314 to barnyard grass decreased according to the leaf-age at the application time. For getting the best selectivity of HE-314, it is desirable to apply before the 2-leaf stage of growth.

In the case of a post-emergence application for irrigated rice, the herbicidal effect of HE-314 is influenced by the depth of irrigation water at the time of application. As shown in Fig. 3, which is the result of a test with difficult conditions for herbicidal activity, the growth of barnyard grass is much more depressed under deeper water conditions.

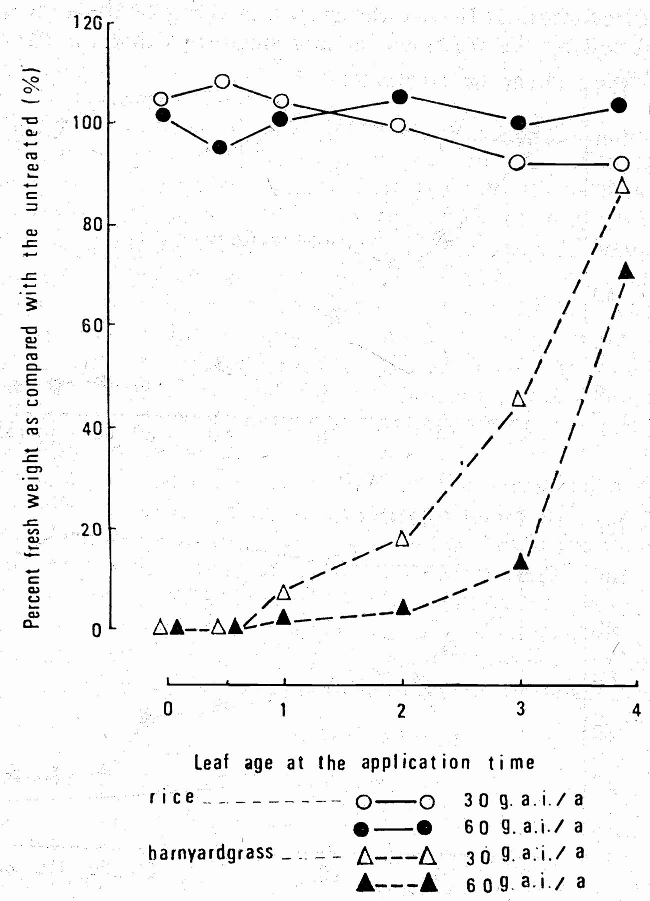


Fig. 2: Variation in selectivity of HE-314 influenced by leaf-ages of treated plants.

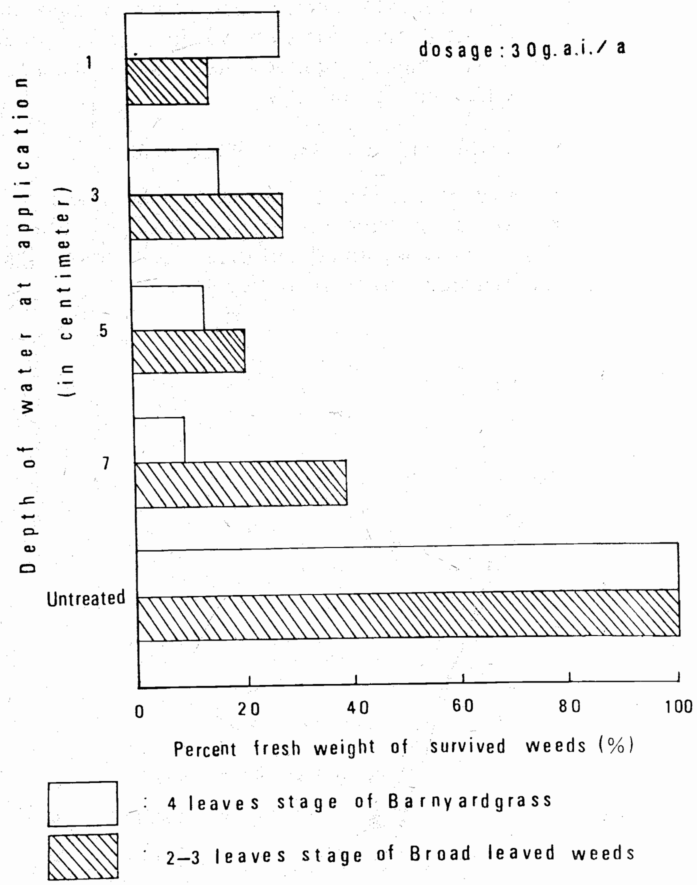


Fig. 3: Influence of water level at application time.

Behaviour in Soil and Irrigation Water

From the standpoint of practical use, it is important to understand the behaviour of a herbicide in the soil and the irrigated water. The persistence of HE-314 as indicated by germination inhibition at four different levels of top soil is shown in Fig. 4. It indicated that the amount of translocation through soil of HE-314 is very small, and HE-314 exists for a relatively long period near the soil surface where it acts upon weeds.

The persistence of HE-314 applied into irrigation water of a paddy field is shown in Fig. 5. It is calculated on the basis of percentage inhibition to rooting of the rice plants. In irrigation water, the activity of HE-314 nearly disappears 8 days after application. However, it persists for over 30 days on the surface of the paddy field. This figure includes also the persistence of the chemical applied on to upland soil.

USES SUGGESTED BY BASIC PROPERTIES

Based on the above properties, it is apparent that HE-314 is a post-emergence herbicide suitable for weed control in paddy rice culture, particularly in transplanted cultures, including irrigated nursery beds and irrigated direct-sown rice.

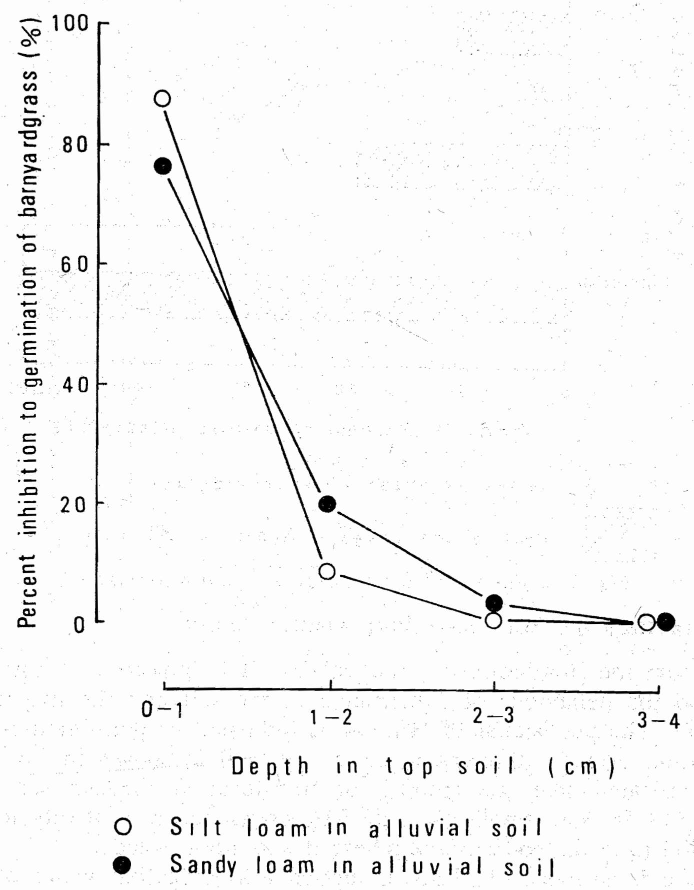


Fig. 4: Translocation of HE-314 in soil.

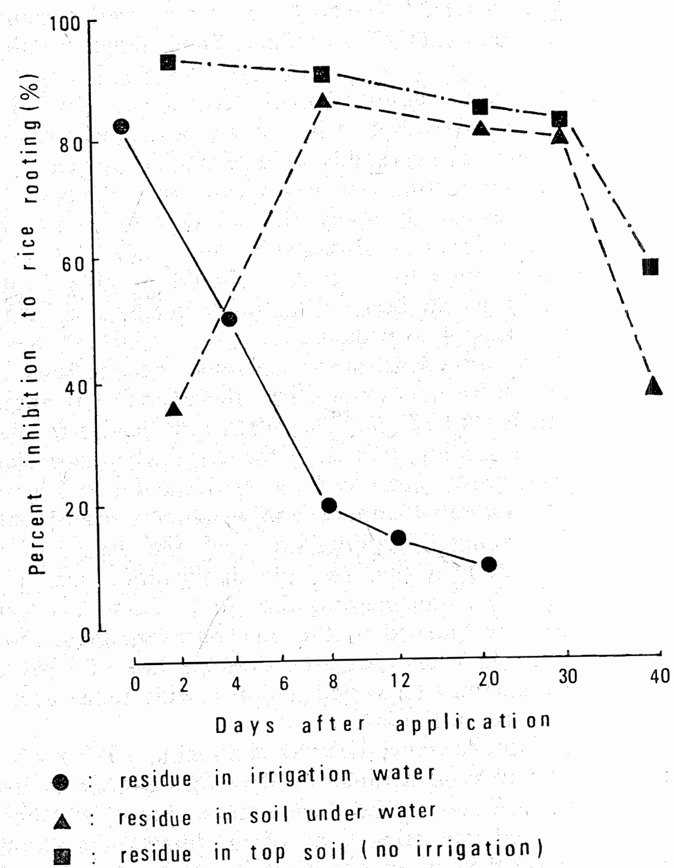


Fig. 5: Persistence of HE-314 in water and soil.

As a pre-emergence herbicide in paddy rice culture, HE-314 cannot be said to be an economical herbicide from the standpoint of its dosage as compared with nitrofen. Studies on pre-emergence application on upland crops are in progress.

Its utilization on forest nursery beds of pine or cedar, for example, appears to be hopeful.

RECOMMENDATION FOR PRACTICAL USES IN PADDY RICE

In 1968, the EC formulation of HE-314 was registered by the Ministry of Agriculture and Forestry in Japan for weed control in certain rice cultures. It was released commercially under the name of "Attackweed EC". It can be used for weed control in transplanted culture, hand or machinery, and irrigated direct-sown culture.

The usual method of application of "Attackweed EC" is to drop or pour the chemical diluted in water at a definite ratio into the irrigation water of the paddy field. For this purpose, it is convenient to use a watering can or a low-pressure sprayer. It is not absolutely necessary to apply the solution uniformly into water, because the chemical diffuses in the water after being applied. The paddy field to be treated should be able to hold irrigation water. To get the best results, the water level should be maintained for at least 4 to 6 days.

For watered nursery beds in transplanted rice culture and direct-sown rice culture under irrigation, the chemical is applied at a dosage of 16 to 24 l EC/ha. The application has to be made 10 to 16 days after seeding, that is, at the stage when rice plants and barnyard grass grow, respectively, to 1 to 2 and 1 to 3 leaves.

In ordinary transplanted culture and machinery transplanted culture, in which younger seedlings are used, the dosage of the chemical is 12 to 20 l EC/ha, and the application time is set during the period from transplanting time to 12 days after transplanting. It should be finished by the time barnyard grass grows to the 2-leaf stage. In every case, the dilution rate of "Attackweed EC" into water may be varied within a wide range according to the application technique.

The granular formulation of HE-314 containing 10% a.i. was registered as "Attackweed Granule". This formulation is used for the same purpose as the EC formulation except in nursery beds. In transplanted rice using hand or machinery, the granule is applied up to 10 days after transplanting at the dosage of 30 to 50 kg/ha. For weed control in direct-sown rice culture, the granule is applied 9 to 14 days after sowing at a dosage of 40 to 50 kg/ha. In every application, the paddy field should be watered and the water reduction has to be limited within 2 cm/day.

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THE CONTROL OF WEEDS IN IRRIGATED, TRANSPLANTED RICE WITH TAVRON G

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Summary

The combination of Dowco 221 3% and 2,4-D isopropyl ester 2% as found in Tavron G has proved very effective for the control of grasses, broadleaf weeds and sedges in irrigated, transplanted rice in the Philippines. Added features of Tavron G for weed control include its low toxicity — with ordinary precautions, it presents no hazards to fish, animals or wildlife; in addition, it has a short residual life — it does not accumulate in the soil because of its rapid degradation in both soil and water. Yield data obtained in the use of Tavron G compared with the control and other commercially available herbicides have consistently shown the superiority of the product. Yield increases were found not only at IRRI, but also in areas outside of IRRI. Field demonstration plots also yielded added valuable information supporting the increase in yield obtained by using Tavron G. Good weed control rating as well as non-phytotoxicity to rice at the rate and time it is used are well documented.

INTRODUCTION

The tremendous impact brought about by the "green revolution" in the production of rice in the Philippines has not only appreciably increased the food supply, but has also resulted in a greatly heightened awareness of the value of agricultural inputs. Farmers have now increased their dependence on the use of good seeds of the high-yielding varieties, fertilizers, herbicides, and insecticides in order to maximize their yield.

In the production process, one of the problems faced by the farmer is that of weeds. Weeds increase the cost of production. Grasses, sedges and broadleaved weeds are perennial problems in rice paddies, competing with rice for nutrients. Proper control of weeds means healthier crops, greater grain yield, and more profit.

The common method employed by farmers to control weeds in irrigated transplanted rice is hand-weeding. In some areas, especially during the rainy season, weeds are controlled to a certain extent by flooding the paddies. These two methods of weed control are inadequate and ineffective. Hand-weeding alone or one application of a phenoxy acid such as 2,4-D or MCPA followed by one hand-weeding has been common practice in some areas.

The use of chemicals alone for weed control has been adopted in many areas in the world, and it has been found economically feasible also in the Philippines.

This paper reviews the extensive tests of Tavron G in transplanted irrigated lowland rice in the Philippines.

WEED COMPETITION IN TRANSPLANTED RICE

Pancho (1964) reported that there are 196 common weed species in the rice fields of the Philippines, belonging to 120 genera and 34 families. Pancho *et al.* (1969) reported that 88 species are very common, 29 of them being found in the lowland rice paddies. The degree of competition offered by an individual weed species is dependent on its growth rate and habit. *Echinochloa crus-galli,* tall and fast-growing, intercepts more light and absorbs more nutrients than the short, stubby and slow-growing species such as *Monochoria vaginalis* and *Rotala indica* (Arai, 1967). Smith (1967) reported that one plant of *E. crus-galli,* among three rice plants, reduced rice yield by 57% when all four plants occupied an area of 0.09 m^2. The reduction in grain yields by different weed species was studied during the 1967 dry season by the International Rice Research Institute (IRRI). Compared with a weed-free crop, *M. vaginalis* did not reduce yield while *E. crus-galli* reduced it by 90%. Vega and Obien (1967) reported that UPCA and IRRI tests had shown that weeds reduce rice yield by 24 to 48%. Predominant weed species at the Central Experiment Station of the UPCA reduced grain yield of lowland rice from 30 to 60% (Vega and Punzalan, 1967). Vega and De Datta (1970) stated that weeds can reduce grain yield by as much as 50%. Predominant weeds present in IRRI's experimental fields were: *E. crus-galli, M. vaginalis, Cyperus iria* and *C. difformis* (IRRI, 1968). The common weeds present in MRRTC include *E. crus-galli, Spinochloa zeylanica, E. colonum, Cyperus iria, C. difformis, Scirpus mucronatus* and *Fimbristylis miliacea* (Bueno and Cabanilla, 1970a).

EVALUATION OF DOWCO 221 GRANULE AGAINST WEEDS

The use of Dowco 221 granule alone for weed control was first reported by Geronimo and Hunter (1969). Greenhouse tests conducted in Walnut Creek, California, and field trials in Davis, California, in 1966, provided the first evidence that Dowco

221 had utility as a selective grass control herbicide in rice, particularly transplanted rice. Field tests in 1967 at Wayside, Mississippi, confirmed this and provided the first agronomic demonstration of its value for selective control of annual grasses in transplanted rice. Successful grass control in transplanted rice was also obtained later in 1967 in field tests conducted at Cali, Colombia, and in 1968 in tests conducted at IRRI.

The initial evaluation of Dowco 221 granule alone for grass control in transplanted irrigated rice was done at IRRI from December 1967 to May 1968. Two experiments were conducted at IRRI and one at the Maligaya Rice Experiment Station in Nueva Ecija (De Datta *et al.,* 1969). The data obtained from these experiments, as shown in Table 1, clearly indicate the efficacy of Dowco 221 alone for the effective control of grasses in lowland rice fields. In the 1968 tests, various rates of Dowco 221, from 0.45 to 2.2 kg a.i./ha gave yield increases of from 734 to as high as 5699 kg/ha over the control (unweeded). These data alone indicate the importance of the grass weeds.

In the 1969 crop year, Dowco 221 was evaluated at the rate of 0.75 kg a.i./ha in three experiments during the dry season and in two during the wet season. The dry season tests were conducted in three areas outside of IRRI. Again, it can be clearly seen from the yield data that Dowco 221 granule is effective

TABLE 1: EFFECTS OF DOWCO 221 GRANULE ON GRAIN YIELD OF IR-8 COMPARED WITH THE CONTROL. APPLIED 4 DAYS AFTER TRANSPLANTING (IRRI, 1968, 1969)

Season	*Rate Used (kg a.i./ha)*	*Yield (kg/ha)* Dowco 221	*Yield (kg/ha)* Control	*Yield Increase (kg/ha)* Dowco 221/Control
1968:				
Dry	0.45	5797	1624	4173
Dry	1.00	7134	1624	5510
Dry	2.20	7323	1624	5699
Dry	1.00	8032	6373	1659
Dry	1.00	5841	5107	734
Dry	1.75	7656	4588	3068
Wet	1.00	6792	4328	2464
1969:				
Dry	0.75	5945	2251	3694
Dry	0.75	7192	4301	2891
Dry	0.75	9388	6079	3308
Wet	0.75	5454	4088	1356
Wet	0.75	5299	4000	1299

against grass. The yield increase over the control ranged from 1299 to 3694 kg/ha.

It was in these series of experiments on Dowco 221 alone that De Datta *et al.* (1969) concluded its ineffectiveness against broadleaves and sedges. Geronimo and Hunter (1969) pointed out that Dowco 221 is only highly active against germinating seeds and emerging seedlings of grasses.

EVALUATION OF TAVRON G AGAINST WEEDS IN TRANSPLANTED RICE

Granular formulations appear slightly more effective than emulsifiable formulations and the addition of a phenoxy such as 2,4-D isopropyl ester can provide broadleaf weed control without adversely affecting grass control or crop safety.

De Datta *et al.* (1969) reported the selective control of annual grassy weeds in transplanted tropical rice with Dowco 221. They found that applications of Dowco 221 at rates as low as 0.75 kg a.i./ha with MCPA or 2,4-D applied at the same time gave similar grass and sedge control and better broadleaf weed control than Dowco 221 alone. The addition of the phenoxy herbicides not only increased the weed control spectrum of Dowco 221, but also it may have supplemented its grass control activity. Vega (1969) also reported that Dowco 221/2,4-D IPE combination is capable of controlling grass weeds as well as broadleaf weeds and sedges.

Likewise, Bueno and Cabanilla (1970a) at MRRTC confirmed earlier tests on the effectiveness of Tavron G against weeds found in lowland rice. M. M. Guantes (pers. comm.) used Tavron G for the control of weeds in transplanted rice in comparison with other commercially available herbicides. His study was conducted at the Central Luzon State University Farm in Nueva Ecija.

The technical representatives of Dow Chemical Pacific Ltd. conducted farm demonstrations throughout the country from October 1969 to April 1970. A total of 150 demonstration plots were set up. In addition, Tavron G was included in the 1970 Rice Mini-Kit project of the National Food and Agricultural Council. All these tests and demonstrations confirmed the efficacy of the product, and was responsible for the marketing of Tavron G in the 1970 wet season in the Philippines.

EVALUATION OF TAVRON G AT IRRI

The IRRI has conducted extensive experiments on the use of Tavron G for weed control in transplanted rice. Table 2 shows

the comparative grain yield of rice in areas treated compared with the control. Many other promising candidate materials were included in the tests conducted at IRRI during the 1968 and 1969 crop season.

In the 1968 crop season, three experiments during the dry season included Tavron G, as well as two during the wet season. Table 2 clearly shows the advantage derived from its use. Yield increases ranged from 978 to 3384 kg/ha over the control.

In the 1969 crop season, more extensive tests were conducted, not only at IRRI but in three other locations — in co-operation with the experiment stations of the Bureau of Plant Industry. In the 9 tests (5 dry seasons and 4 wet seasons) yield increases were again attained in all the Tavron G-treated lots compared with the control or unweeded areas, ranging from 1789 to 4562 kg/ha.

TABLE 2: COMPARATIVE GRAIN YIELD OF RICE USING TAVRON G (IRRI, 1968, 1969)

Season	Location	*Yield (kg/ha)* Control	*Yield (kg/ha)* Tavron G	*Yield Increase* Tavron G/Control
1968:				
Dry	IRRI	5107	6508	1401
Dry	IRRI	5107	6242	1135
Dry	IRRI	3400	6784	3384
Wet	IRRI	3838	4816	978
Wet	Iloilo	4328	6572	2244
1969:				
Dry	Maligaya	2251	6378	4107
Dry	Bicol	4301	7416	3115
Dry	Musuan	6079	10303	3224
Wet	IRRI	4055	6096	2041
Wet	IRRI	4055	5984	1829
Wet	IRRI	4088	6670	2582
Wet	IRRI*	4000	5789	1789
Dry	IRRI	1578	7730	6152
Dry	IRRI	1578	6140	4562
1970:				
Dry	MRRTC†	968	5152	4184

*All tests used IR-8 varieties except this entry where IR-77 was used.
†Data from Bueno and Cabanilla (1970a).

EVALUATION OF TAVRON G IN FARMERS' FIELDS

A nationwide campaign of demonstration plots was launched in October 1969 to April 1970 to show the use of Tavron G for weed control in transplanted rice. As in all pesticide usage trials and when introducing a new product, some criteria were used in selecting farmer-co-operators. Some of the criteria used were:

(1) Farmers aware of the new agricultural inputs like fertilizer, insecticides and herbicides.

(2) Areas located near the road — for plot signs to be seen by more farmers.

(3) Farmers with a good water supply.

(4) Good land preparation.

All of the above criteria were easily met and a total of 150 demonstration areas were set out. The area of each test ranged from 700 to 3000 m^2. The wide range is indicative of how much the farmer is willing to co-operate.

TABLE 3: COMPARATIVE GRAIN YIELD OF RICE (cavans/ha) IN FIELD DEMONSTRATION PLOTS USING TAVRON G. CENTRAL LUZON, WET SEASON 1969-70*

Location	Variety	Computed Yield Tavron G	Computed Yield Control	Increased Yield Tavron G/Control
Nueva Ecija				
1. Gapan	IR-8	47.0	73.5	26.5
2. Gapan	Intan	60.0	70.0	10.0
3. Cuyapo	IR-171	159.0	171.0	12.0
4. Gapan	IR-5	22.0	50.0	28.0
5. San Isidro	IR-5	69.0	77.0	8.0
6. Sto. Domingo	IR-20	70.0	85.0	15.0
7. Laur	C4-63	96.0	104.0	8.0
Bulacan				
8. San Miguel	Wag-wag	44.5	55.0	10.5
9. Pulilan	IR-5	33.0	57.0	24.0
10. Calumpit	Wag-wag	80.0	95.0	15.0
11. San Miguel	Intan	44.0	65.5	21.5
12. San Miguel	Intan	53.0	65.5	12.5
13. San Miguel	Intan	62.5	77.5	15.0
14. San Miguel	Intan	50.0	66.0	16.0
Tarlac				
15. Sta. Ignacia	IR-8	42.0	53.0	11.0
Pampanga				
16. Apalit	Wag-wag	82.0	110.0	28.0

*Data from tests conducted by technical representatives of Dow Chemical Pacific Ltd, Manila, Philippines.

During the crop season, three calls were made by Dow representatives. During these calls, the Tavron G sign was put up, farmers' reactions to the treatment asked, and degree of weed control in both treated and control (usually hand-weeded or rotary-weeded) areas evaluated; the final call was made to obtain the yield data.

Table 3 shows the comparative yield data obtained from 16 farmers in 4 provinces in Central Luzon.

The yield increase resulting from the use of Tavron G ranged from 8 to 28 cavans/ha, with a mean of about 15 cavans/ha. Of the many reasons given by farmers to explain their inability to obtain good effects from the treatment, the most critical was water management.

TAVRON G IN THE RICE MINI-KIT PROJECT

The Rice Mini-Kit was developed in the Philippines as a simple, yet an incredibly powerful extension teaching vehicle. Its primary purpose is to increase awareness of and to speed up adoption of the new high-yielding varieties by the one million farmers of the Philippines. A mini-kit is a package that contains seed, fertilizer, insecticide and herbicide sufficient for 50 m^2. All the agricultural inputs are included in the official Philippine recommendations. There were 850 mini-kits issued during the dry season and 1,000 for the wet season 1970. Tavron G was included in both the 1970 and 1971 dry season tests.

EVALUATION OF TAVRON G ON DIFFERENT RICE VARIETIES

With the gradual increase in the availability of granular herbicides for transplanted rice, the varietal reaction to herbicide is important. Likewise, with the development of more and more high-yielding varieties and the subsequent approval of new seeds by the Seed Board, some problems on the toxicity of herbicides to the new varieties might occur. In anticipation of such problems eight varieties recommended by the Seed Board were planted at MRRTC (dry season, 1970) to check the effects of Tavron G on yield and weed control, and to determine toxicity ratings.

Table 4 summarizes the yield of eight varieties treated with Tavron G and with 2,4-D IPE granule. Most varieties treated with Tavron G gave significantly higher yields than when treated with 2,4-D IPE, and all varieties treated with Tavron G yielded significantly higher than the control, ranging from 31 to 85 cavans more per hectare.

Tavron G and 2,4-D IPE have the highest weed control ratings compared with other herbicides, and are considered least toxic to all the eight varieties, having toxicity ratings of slight to moderate effect (Bueno and Cabanilla, 1970b).

TABLE 4: MEAN GRAIN YIELD OF 8 VARIETIES OF RICE USING TAVRON G AND 2,4-D GRANULE. MRRTC*, DRY SEASON, 1970 (BUENO AND CABANILLA, 1970)

(All varieties used recommended by the Seed Board)

Varieties	*Days to Maturity*	*Yield (cavans/ha)* Control	2,4-D	Tavron G	*Yield increase (cavs)* Tavron G/ 2,4-D	Tavron G/ Control
BPI-76 (NS)	125	82.17	121.16	133.68	12.52	51.51
BPI-1-48	110	50.54	77.99	88.87	10.88	38.33
BPI-9-33	115	21.40	63.37	77.52	14.15	56.12
C4-63	130	86.98	104.67	118.06	13.39	31.08
C4-137	137	101.84	134.66	147.69	13.03	45.85
IR-8	128	89.40	144.82	150.48	5.66	61.08
IR-5	138	88.73	144.52	154.26	9.74	65.53
IR-20	118	41.73	124.71	127.63	2.92	85.90

LSD (5%) between treatments mean = 11.68.

*MRRTC — Maligaya Rice Research Training Center, Bureau of Plant Industry, Munoz, Nueva Ecija.

WATER MANAGEMENT FOR GRANULAR HERBICIDES (IRRI, 1969)

Certain water management practices must be strictly observed if granular herbicides are to be effective against weeds in transplanted rice.

In the Philippines, most rice is grown in fields where the water level cannot be controlled. It is, therefore, important to know how granular herbicides perform under variable water levels. A field experiment was conducted during the 1969 dry season to study the water management requirements for two granular herbicides for transplanted IR-8. Table 5 shows the water management treatments used in the experiment. Granular formulations of EPTC/MCPA and Dowco 221/2,4-D IPE were applied before and after weeds emerged. Although the highest yield in this experiment was obtained with Dowco 221/2,4-D IPE under continuous flooding with 5 cm water, only 5 to 10 days of flooding were necessary to obtain adequate weed control by the two herbicides.

Without continuous flooding and weed control, the grain yield was less than 250 kg/ha. On the other hand, with continuous flooding with 5 cm water and without weed control, the grain yields varied from 3,000 to 4,000 kg/ha. These data suggest that a water depth of 5 cm helped weed control substantially although it did not eliminate the weeds completely.

The superiority of Dowco 221/2,4-D IPE over EPTC/MCPA in controlling weeds (average of all water management treatments) after their emergence is apparent from the grain yield data in Table 6. This additional quality of Dowco 221/2,4-D IPE may prove to be an advantage in many areas where farmers may decide to control weeds chemically just after the weeds have emerged.

TABLE 5: EFFECTS OF WATER MANAGEMENT PRACTICES ON WEED CONTROL BY TWO GRANULAR HERBICIDES (IN kg a.i./ha) APPLIED BEFORE WEEDS EMERGE (EARLY) AND AFTER WEEDS EMERGE (LATE) FOR TRANSPLANTED IR-8. IRRI, 1969 DRY SEASON

(Early — 4 days after transplanting. Late — 10 days after transplanting)

*Water Management**	*Grain Yield (kg/ha)* EPTC 1.75/MCPA 0.7 early	late	Dowco 221 0.75/ 2,4-D IPE 0.5 early	late
5 cm (0-m)	8098	5097	8791	8094
2-3 cm (0-m)†	7922	—	7895	—
Untreated controls				
5 cm (0-m)	3248		4452	

*For each water management treatment, the first figure indicates the depth of water and the second in parentheses indicates corresponding period of flooding in days; m = maturity.

†Standard practice at IRRI.

TABLE 6: WEED CONTROL (MEASURED BY YIELDS OF TRANSPLANTED IR-8) BY TWO GRANULAR HERBICIDES APPLIED BEFORE WEEDS EMERGED (EARLY) AND AFTER WEEDS EMERGED (LATE)

(Early — 4 days after transplanting. Late — 10 days after transplanting)

Treatment (kg a.i./ha)	*Grain Yield (kg/ha)* Early	Late
EPTC 1.75/MCPA 0.7	7436	4447
Dowco 221 0.75/2,4-D IPE 0.5	7730	6140
Untreated control	1578	
Statistical analysis	s.e.	LSD 5% (kg/ha)
Two herbicide means at the same time of application	302	603
Two time-of-application means of the same herbicide	399	797

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RICE WEED CONTROL RESEARCH IN FIJI

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Summary

Dryland Rice: Propanil at 3.36 kg/ha has been proved effective but has some drawbacks which could be overcome by use of a pre-crop and weed emergence herbicide. Rates of applications of phenoxy herbicides on dryland rice are critical. 2.4,5-T ester up to 1.12 kg/ha has been found to be safe when applied at the maximum vegetative growth phase of rice.

Wetland Rice: Grasses are not a serious problem in wetland transplanted rice when land preparation is adequate. MCPA or 2,4-D at 0.9 to 1.12 kg/ha applied 3 to 4 weeks after transplanting gave good control of sedges and dicotyledons common in wetland rice. Where direct-sowing is practised, barnyard grass (*Echinochloa crus-galli*) is a problem and propanil is used to control this weed. Chemical ploughing where the situation demands can be carried out with reasonable success.

INTRODUCTION

Rice is one of the important crops of Fiji. Total annual production during 1968 and 1969 was estimated at approximately [illegible]8,000 tonnes of paddy. The present production is not enough to meet the national requirements and rice worth over $F1.5 million is imported annually.

About 50% of the area under rice is cultivated by dryland methods. Dryland rice in Fiji has been defined as direct-sown, non-puddled and non-irrigated rice (Rhodes 1968a).

Weeds are one of the reasons for reduced yields obtained from dryland rice. This is well known and needs no more emphasis. The traditional and recommended weed control practice in Fiji with the normal tall, leafy, lodging-susceptible varieties is to drill at 0.46 m apart and inter-row cultivate, usually by horse-drawn cultivator. This practice has been found satisfactory and does not require a high cash input (Yelf and Rhodes, 1964). It is common in the wet zone, very weak or no dry season, areas; in the dry zone, good wet season, strong dry season, most of the dryland rice is grown as a subsistence broadcast catch crop in rotation with sugar cane. The short-duration varieties commonly grown are not of a high yield potential and the use of propanil for general weed control is extremely limited or negligible. MCPA or 2,4-D is most often used for the control of dicotyledons. Sensitive plant (*Mimosa pudica*) is not controlled effectively at the rates now normally used for general weed control in rice. However, it may be possible to control this weed at higher rates of application or with stronger herbicides like 2,4,5-T, but these rates or chemicals may result in phytotoxicity.

The introduced dwarf or semi-dwarf, lodging-resistant rice varieties have clearly established the suitability of closer spacing to obtain maximum yields (Dept. of Agric., 1968, 1969). Use of weedicides is required under such conditions since inter-row cultivation is not possible and it is uneconomical to hand-weed.

About half the rice in Fiji is grown as a wetland crop, which has been defined as rice grown on puddled soil usually but not necessarily with water retaining bunds (Rhodes, 1968b). Most of the rice grown under wetland conditions is rainfed. The potential for irrigation and double-cropping is excellent and, with the success achieved on small pilot schemes, larger irrigation schemes involving over 2,400 ha are planned under the current development plan covering the period 1971-75. With the proposed irrigation scheme areas, double-crop rice farming will increase considerably. It is the aim to raise annual paddy production to 36,000 tonnes in order to achieve self-sufficiency by the end of the current development plan period.

Grass weeds are not a serious problem in transplanted, wetland rice where preparation is adequate (Patel and Rhodes, 1969). Sedges and dicotyledons like pickerel weed (*Monochoria hastata*), bundaya (*Melochia corchorifolia*) and sesbania (*Sesbania aculeata*) are most important. These weeds are easily controlled by MCPA or 2,4-D at 0.9 to 1.12 kg/ha applied 3 to 4 weeks after transplanting.

Broadcasting is practised in irrigated areas and is becoming more popular. Barnyard grass (*Echinochloa crus-galli*) is the main problem in the irrigated areas and propanil is used for its control with good results.

It is very difficult, if not impossible, to prepare boggy fields with heavy machines. Where double-cropping with irrigation is practised, drainage must be efficient, otherwise such lands can present difficulties in preparation. However, in a situation where it would be difficult to prepare the fields mechanically, it is possible to carry out chemical ploughing and plant a crop instead of losing a season.

MATERIALS AND METHODS

All rates stated in this paper refer to the active material.

A list of the common weeds of rice in Fiji is given in Appendix 1.

Experiment 1. Weed Control in Dryland Rice

Variety IR-8, spacing — 23 cm rows. Soil type — Rewa clay loam (Twyford and Wright, 1965). All herbicides were applied in water at 450 l/ha with a knapsack sprayer. The main weeds present were jungle rice (*Echinochloa colonum*), tar weed (*Cuphea carthagenensis*), goat weed (*Ageratum conyzoides*), sensitive plant and wild cape gooseberry (*Physalis angulata*). Herbicide treatment details are shown in Table 1. For propanil applied as split applications, the first application was when weeds were at the 1-leaf stage and subsequent applications at 4 to 6 days interval. For trifluralin (all rates) followed by 2,4,5-T ester treatments, trifluralin was applied post-planting, pre-crop-emergence, while 2,4,5-T ester was applied later as a post-crop-emergence spray.

Experiment 2. Effects of Phenoxy Herbicides Applied During the Maximum Vegetative Growth Phase of Rice on Dryland Rice Yield and Weed

Variety IR-8, drilled at 23 cm rows. Soil type — Rewa sandy clay loam. All herbicides were applied post-crop-emergence in water at 450 l/ha with a knapsack sprayer. The main weeds present in the experimental area were jungle rice, goat weed, sensitive plant and tar weed. The herbicide treatments are given in Table 2.

Experiment 3. Effects of Phenoxy Herbicides Applied Near the Panicle Initiation Stage on Dryland Rice Yield and Weed Control

Variety IR-8, drilled at 23 cm rows. Soil type — Rewa sandy clay loam. 2,4,5-T ester at various rates tried was applied post-crop emergence in water 450 l/ha. Main weeds present were jungle rice, sensitive plant and goat weed. Treatments are shown in Table 3.

Experiment 4. Chemical Ploughing for Transplanted, Irrigated Rice

Variety BG 79, transplanted at a random spacing. Soil type — Tokotoke clay. Weed growth on the experimental area consisted of barnyard grass, sedges, pickerel weed and a few rice plants. All herbicides were applied two weeks before transplanting, in water at 900 l/ha. Treatments are shown in Table 4.

RESULTS AND DISCUSSION

DRYLAND RICE, EXPERIMENT 1

Results are given in Table 1.

TABLE 1: WEED CONTROL IN DRYLAND RICE
(Weed control rating: 0 = No control, 10 = 100% control)

Treatment* (kg/ha)	Yield Padi (kg/ha)	Weed Control Rating 64 days after sowing Grasses	Dicots	Dry wt of Weeds/m^2 at Harvest (g)
A propanil 3.36	3189	9.1	8.4	17.74
B propanil 3.36 + surfactant	3489	9.5	8.1	50.05
C propanil 2.24/MCPA 1.12	2857	7.1	8.5	111.84
D propanil (split application) 1.68 + 1.68	3403	9.8	9.2	36.70
E propanil (split application) 1.12 + 1.12	3305	8.9	8.2	60.28
F propanil (split application) 0.56 + 0.56 + 0.56	3285	9.1	8.5	48.22
G MCPA 1.12	2248	0.00	5.75	253.92
H trifluralin 0.56 f.b. 2,4,5-T ester 1.12	3058	9.3	3.0	42.63
I trifluralin 1.12 f.b. 2,4,5-T ester 1.12	3189	9.6	3.6	5.17
J trifluralin 1.68 f.b. 2,4,5-T ester 1.12	3338	9.8	4.0	3.23
K nitrofen 2.24	1574	5.3	3.0	599.12
L OCS 21693 3.36	1412	4.8	2.1	469.41
M Hand-weeded once	2877	8.0	7.0	160.80
N Hand-weeded twice	3114	8.0	7.1	93.00
O Unweeded control	878	0.0	0.0	585.56
SE±	198			60.28

*Treatments A to G applied post-crop-emergence and H to L pre-crop-emergence after drilling.

Propanil at 3.36 kg/ha applied when weeds are at the 2- to 3-leaf stage and growing actively has been found effective against both common grasses and dicotyledons, except wild cape gooseberry. Split applications of propanil have shown good results but this practice is not advised since it increases labour costs considerably. With the risks of rain shortly after application and/or periods of prolonged wet weather, successful application of split treatments can be difficult to achieve in practice.

Propanil and MCPA in mixture at 2.24 and 1.12 kg/ha respectively, applied when weeds were at the 2- to 3-leaf stage and growing actively gave poor grass weed control. This confirms that, to obtain good control of grass weeds, the recommended rate of 3.36 kg/ha should not be reduced when applied alone or in combination with MCPA and perhaps other, similar herbicides.

Some disadvantages of propanil for weed control in dryland rice have been noted and these are:

(1) Reduced effectiveness when rainfall occurs shortly after application.

(2) Weeds soon pass the optimum stage for spraying over periods of prolonged wet weather and both these situations are quite common in the tropics.

A more effective pre-crop and pre-weed-emergence herbicide which will provide effective and long-term weed control under a wider range of climatic/weed growth conditions is therefore required. Such a chemical would probably greatly extend chemical weed control in Fiji rice growing. Trifluralin at all rates has given good control of grass weeds but was poor against dicotyledons. Nitrofen was observed to be effective in a previous trial (Rhodes, 1968a; Patel and Rhodes, 1969) but did not give similar results in the trial reported here. Nitrofen and OCS 21693 were both found to give poor control of sensitive plant. Trials will be continued with new chemicals to identify an effective pre-emergence herbicide for weed control in dryland rice under local conditions.

EXPERIMENT 2

TABLE 2: EFFECTS OF PHENOXY HERBICIDES APPLIED DURING THE MAXIMUM VEGETATIVE GROWTH PHASE ON DRYLAND RICE YIELD AND WEED CONTROL

Treatment (kg/ha)	Yield Padi (kg/ha)	Dry wt. of weeds/m^2 taken at Harvest (g)
MCPA 1.12	2130	131.86
MCPA 1.68	2171	114.42
2,4-D amine 1.12	2542	97.41
2,4,5-T ester 0.56	2483	94.18
2,4,5-T ester 0.84	2578	94.72
2,4,5-T ester 1.12	3031	58.66
Hand-weeded, once only	2092	93.11
Unweeded control	956	400.42
±SE	242	22.07

Results are given in Table 2. MCPA gave poor control of goat weed while the effect on sensitive plant was very little. 2,4-D at 1.12 kg/ha and 2,4,5-T at both 0.56 and 0.84 kg/ha were good against goat weed and effectively suppressed sensitive plant. 2,4,5-T at 1.12 kg/ha gave good control of all broadleaved weeds including sensitive plant. From the results, it is apparent that rice tolerates the phenoxy herbicides well during its maximum vegetative growth phase, normally 5 to 6 weeks after sowing.

EXPERIMENT 3

TABLE 3: EFFECTS OF PHENOXY HERBICIDES APPLIED NEAR THE PANICLE INITIATION STAGE ON DRYLAND RICE YIELD AND WEED CONTROL

Treatment (kg/ha)	*Yield Padi (kg/ha)*	*Dry wt. of weeds/m² taken at Harvest (g)*
2,4,5-T ester 1.12	2308	63.83
2,4,5-T ester 2.24	2152	44.56
2,4,5-T estcr 3.36	1876	47.15
Hand-weeded	2345	69.32
SE±	148	12.70

The results in Table 3 clearly demonstrate the phytotoxic effect of 2,4,5-T ester at 3.36 kg/ha on rice yield. In fact, this effect (chlorosis and yellowing) was observed in all the treatments, though at the 1.12 kg/ha rate recovery was effective and crop yield was comparable to the control. The absence of any significant difference in the degree of weed control between the treatments, measured as dry weight of weeds at harvest, emphasizes this phytotoxic effect on rice yield. Results of a second trial (Dept. of Agriculture, 1969) where propanil was applied as a blanket treatment when weeds were at the 2- to 3-leaf stage and phenoxy herbicides (MCPA at 1.12 and 1.68 kg/ha, 2,4-D amine at 1.12 kg/ha and 2,4,5-T ester at 0.56, 0.84 and 1.12 kg/ha), applied near the panicle initiation stage, showed that all herbicides were phytotoxic to rice but that the plants recovered and none of the treatments reduced crop yield.

From the results of these trials, the importance of proper rate and time of application of the phenoxy herbicides is apparent. It seems that the application of 2,4-D or 2,4,5-T should not exceed 1.12 kg/ha. The most suitable time of application is during the maximum vegetative growth phase of the rice.

2,4,5-T up to 1.12 kg/ha has been found safe and has given good control of most of the dicotyledons including sensitive plant. However, in the light of toxic impurities found in most of the 2,4,5-T formulations and their possible danger to man, it may not be advisable to recommend it on rice.

WETLAND RICE

Transplanted Wetland Rice

As stated previously grass weeds are not a serious problem in wetland transplanted rice. MCPA or 2,4-D is used at the rate of 0.90 to 1.12 kg/ha for the control of sedges and common dicotyledons, 3 to 4 weeks after transplanting.

On the proposed irrigation scheme areas, double-cropped rice planting will increase considerably. Investigations on controlling weeds in transplanted irrigated rice with granular herbicides like 2,4-D IPE, EPTC/MCPA, trifluralin/MCPA, molinate, benthiocarb, butachlor, nitrofen, etc., are being carried out.

Direct-sown Wetland Rice

Broadcasting is practised in irrigated areas and is becoming popular. Barnyard grass is the main problem in irrigated areas. Propanil is used for control with good results. Molinate incorporated before broadcasting at the rate of 3.36 kg/ha has given good control of barnyard grass but was not effective against sedges and common dicotyledons. Future trials with granular herbicides like 2,4-D IPE, benthiocarb, molinate and nitrofen for weed control in direct-sown irrigated rice are planned.

EXPERIMENT 4

TABLE 4: CHEMICAL PLOUGHING FOR TRANSPLANTED IRRIGATED RICE

Treatment (kg/ha)	*Yield — Padi (kg/ha)*
Ploughing, harrowing (normal practice)	3388
cacodylic acid 3.36	3134
DSMA 4.48	2852
MSMA 4.48	2559
amitrole 4.48	2484
paraquat 0.56	2315
SE±	262

From the results (Table 4) it appears that reasonable yields can be obtained with this practice instead of losing a season's crop. Transplanting is advisable since it is doubtful whether broadcasting will give a good, even stand on a soil surface covered with dead vegetation. The addition of minimum tillage after chemical treatment of the land can result in a seedbed suitable for direct-sowing. The cultivation would bury dead vegetation and incorporate the basal dose of applied fertilizers normally recommended.

ACKNOWLEDGEMENT

I wish to thank Dr J. B. D. Robinson, Chief Research Officer, Department of Agriculture, Fiji, for his help in the preparation of this paper.

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APPENDIX I

Common Weeds Found in Rice in Fiji

	Scientific Name	*Common Name*
WETLAND RICE		
	Ischaemum rugosum	muraina grass
	Echinochloa colonum	jungle rice
	Echinochloa crus-galli	barnyard grass
	Melochia corchorifolia	bundaya
	Sesbania aculeata	sesbania
	Monochoria hastata	pickerel weed
	Cyperus pilosus	sedge
	Cyperus iria	sedge
	Cyperus miliaceae	sedge
	Cyperus polystachyos	sedge
	Fimbristylis dichotoma	sedge
DRYLAND RICE		
	Ischaemum rugosum	muraina grass
	Echinochloa colonum	jungle rice
	Echinochloa crus-galli	barnyard grass
	Setaria pallidifusca	cat's tail grass
	Cuphea carthagenensis	tar weed
	Ageratum conyzoides	goat weed
	Mimosa pudica	sensitive plant
	Physalis angulata	wild cape gooseberry
	Cassia tora	Kaumoce

A SIMPLIFIED APPLICATION METHOD FOR WEED CONTROL IN PADDY FIELDS WITH RP 17623 (G-315)

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INTRODUCTION

RP 17623 is a new herbicide developed by Rhone-Poulenc of France. It was introduced into Japan under the code number G-315 in 1968, and since then basic studies and application tests have been conducted. The results from various national and prefectural agricultural experiment stations in Japan, the research station of Nissan Chemical Industries, and other research facilities reveal that G-315 has many excellent qualities for use as a herbicide in paddy fields. Academic interest in the herbicide has also developed, since, despite a wide disparity in chemical structure, its mode of action closely resembles that of nitrofen and chlornitrofen which are both currently popular herbicides in Japan for paddy fields. As is widely known, diphenylether compounds, which have a substituent in the ortho position of one phenyl ring, like nitrofen and chlornitrofen, are active only in the light. It is also well known that nitrofen and chlornitrofen do not control all weeds. Resistant weeds are chickweed (*Stellaria media*) and *Bidens pilosa*. Also, they sometimes cause characteristic browning of the leaf-sheaths of paddy rice (Matsunaka, 1969a, b, 1970). G-315 has all these characteristics and is supposed to have the same mode of action as nitrofen and chlornitrofen (Matsunaka, 1970).

Excellent results have been obtained from soil incorporation treatment in paddy fields, a new application method which is arousing a keen interest in Japan. Table 1 shows field test data on G-315 obtained by agricultural experiment stations and other official research facilities in various parts of Japan in 1970. It shows effective control of paddy field weeds, and increased grain yields when G-315 2% granule (1.0 kg a.i./ha) or 10% emulsifiable concentrate (0.8 kg a.i./ha) was applied by soil incorporation.

Treatment by soil incorporation in paddy fields differs greatly from the same method in dry fields. In paddy fields, it is usual

to make puddlings, before the rice is transplanted, using various implements to level the soil surface. For soil incorporation in paddy fields, it is therefore necessary to apply the herbicide at or before puddling and allow the puddling operation to incorporate the chemical in the soil. If the herbicide is properly incorporated, the following advantages can be expected because the herbicide-treated layer is thicker than that resulting from the usual soil surface procedure:

TABLE 1: HERBICIDAL EFFECTIVENESS AGAINST PADDY FIELD ANNUAL WEEDS AND GRAIN YIELD EVALUATION USING SOIL INCORPORATION TREATMENT

G-315 Formulation and Test Location	*% Dry Weight of Weeds** *Grasses*	 *Broadleaf*	 *Sedges*	 *Total*	*% Grain Yield†*
G-315 2% granule (1.0 kg/ha):					
Hokkaido	29	35	25	30	100
Iwate	5	3	14	6	105
Akita	63	48	23	52	95
Tochigi	16	2	0	15	98
Nagano	54	12	200	26	100
Niigata	14	14	0	13	—
Shizuoka	31	3	5	12	102
Shiga	0	0	0	0	101
Kyoto	2	0	0	1	114
Osaka	0	0	0	0	111
Tottori	0	0	0	0	100
Shimane	18	3	0	6	100
Ehime	0	0	0	0	103
Kochi	6	0	0	3	100
Saga	0	0	0	0	105
Oita	1	0	0	1	108
G-315 10% E.C. (0.8 kg/ha):					
Hokkaido	2	3	15	3	106
Akita	33	41	2	32	116
Tochigi	25	5	33	23	98
Saitama	3	3	2	3	100
Shizuoka	1	0	5	1	115
Hyogo	10	2	1	2	96
Kagawa	0	0	0	0	97
Oita	2	0	0	1	?

*Per 1 m^2 30 to 50 days after application against dry weight of weeds in untreated control plot.

†Against grain yield of completely weeded plot using control herbicide and hand weeding.

(1) Minimum loss of ingredient by draining of submerged water.

(2) Minimum risk of destruction of the treated layer by footprints and by agricultural implements.

(3) Consistent effectiveness because the herbicide is applied pre-emergence when weeds are most sensitive.

These advantages, however, will be lost if the herbicide is mixed too deep in the soil. As indicated in Table 1, both formulations of G-315 are effective in all but a few cases. In several fields, a small amount of leaf-sheath browning occurred but grain yields were not affected.

Table 1 also shows that the emulsifiable concentrate formulation showed equivalent effectiveness to the granule formulation at a dosage level 20% lower. This formulation would therefore seem to be well suited for use in paddy fields using a simplified method of soil incorporation.

MATERIALS AND METHODS

Experiment 1

Pots of 0.02 m^2 containing alluvium clayish soil were prepared and set amounts of G-315 wettable powder and of nitrofen were incorporated in the pot soil at depths of 0, 2.5, 5 and 10 cm. On the soil surface, 60 seeds of barnyard grass (*Echinochloa crus-galli*) were sown and the pots kept in a greenhouse and flooded with 4 cm water. Three weeks later, the fresh weight of barnyard grass was examined to compare weed control effectiveness of the herbicides, and to evaluate the relationship between effectiveness and incorporation depth.

Experiment 2

In the same manner as in Experiment 1, G-315 (0.5 and 1.0 kg/ha) and nitrofen (4.0 kg/ha) were incorporated into soil at a depth of 2.5 cm, then covered with pure soil layers of 0, 1, 2.5 and 5 cm as illustrated in Fig. 1. The total amount of soil in each pot was equal. Sixty seeds of barnyard grass were sown to each pot covered with 4 cm of water, and after 3 weeks the fresh weight of the weeds examined to determine the maximum effective depth of incorporation as in Experiment 1.

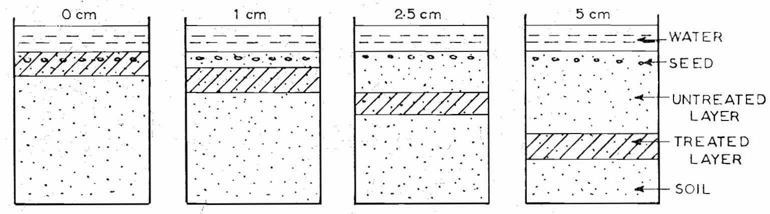

Fig. 1: Technique used to determine the most effective incorporation depth.

Experiment 3

Pots of 0.05 m^2 were prepared as illustrated in Fig. 2 and flooded with 4 cm water. Emulsifiable concentrate and granules of G-315 1.0 kg/ha were then applied, the 15% emulsifiable concentrate by pipetting to the water surface without dilution and the 2% granule by hand scattering and mixing thoroughly in the soil to a depth of 10 cm using a large spatula. Water was allowed to leak from the pots so that the soil surface was exposed 2 days after application. After the water leaked out, 50 cm^2 × 10 cm of soil was sampled by inserting a thin-walled stainless steel pipe twice per pot. Each soil sample was divided into 2 cm layers and each layer transferred to a small pot and thoroughly mixed. Thirty seeds of barnyard grass were then sown in each pot and after 2 weeks' growth under flooded conditions in a greenhouse the fresh weight of the weeds recorded.

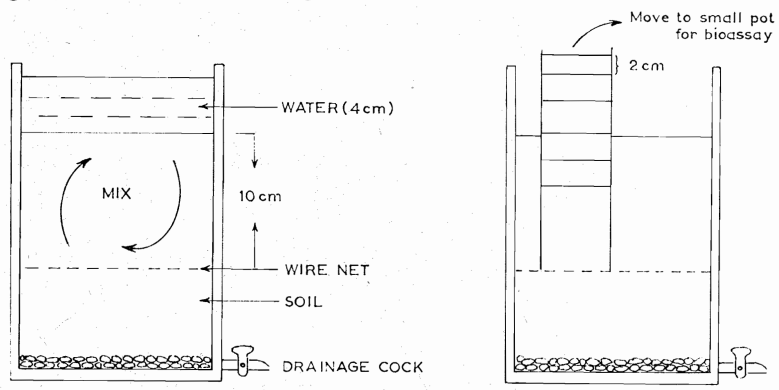

Fig. 2: Bioassay method to determine the distribution of active ingredient of G-315 granule or emulsifiable concentrate applied by soil incorporation treatment in flooded paddy fields.

As the emulsifiable concentrate might remain in water after puddling, 5 ml/pot of pot water was sampled with a pipette 30 minutes after puddling and the G-315 content was determined by gas chromatography.

Experiments 1 and 2 were replicated three times and Experiment 3 twice.

Experiment 4

A method to apply the emulsifiable concentrate directly from glass containers was evaluated in a field test. A 500 ml bottle was designed to broadcast the concentrate from its cap in fine droplets when shaken. The cap had 3 holes of 2.2 mm diameter, each allowing about 5 ml of concentrate to be scattered over a 3 to 5 metres width with each firm shake. The bottle was designed for easy handling (Fig. 3). Fine droplets of the concentrate scattered on the water surface are evenly dispersed and the subsequent puddling provides for even mixing of the herbicide in the soil surface, so that consistent weed control can be expected. This was confirmed by farmers' field tests in which G-315 was

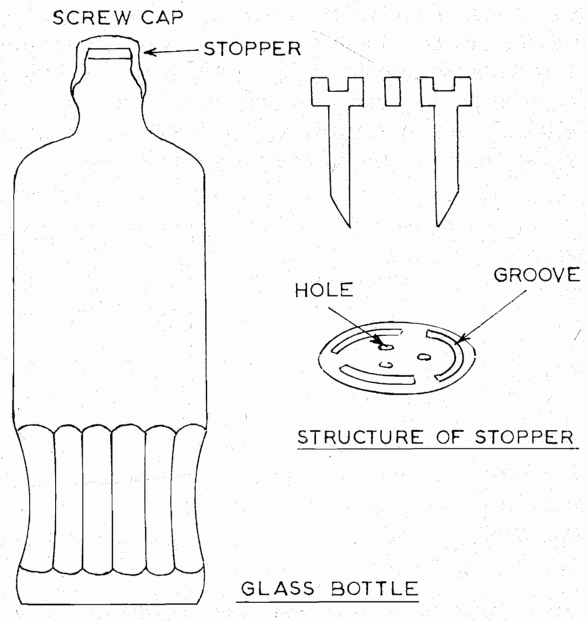

Fig. 3: Design of glass container of G-315 emulsifiable concentrate which can be applied directly without equipment.

applied directly from the bottle to the paddy fields immediately before the final puddling. The final puddling was prior to rice transplanting and was for fertilizing or soil surface levelling. Puddling implements, water depth, etc., varied according to individual situations in these tests.

RESULTS AND DISCUSSION

Figure 4 indicates the results of Experiment 1. The herbicidal activity of G-315 against barnyard grass was far greater than that of nitrofen. At a much lower dosage, G-315 was equal to or superior to nitrofen. Both compounds, however, showed reduced herbicidal activity when mixed deeper into the soil. Shallow incorporation of herbicide is not therefore to be recommended, as in the paddy fields weeds do not germinate at one time as in pot tests and many factors vary to cause fluctuations in the herbicidal effect. At the same time, conditions should be avoided where the herbicide is brought to a depth where no herbicidal activity is apparent.

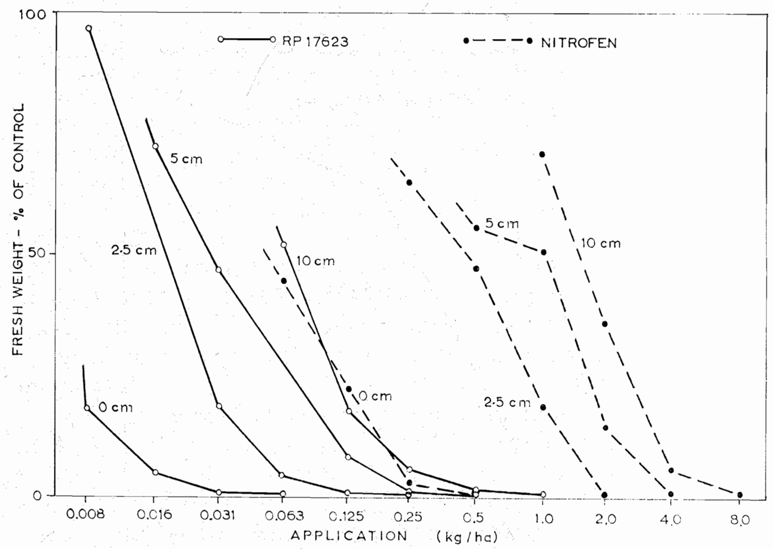

Fig. 4: Effect of various depths of soil incorporation on herbicidal activity of G-315 and nitrofen. Data are presented as a percentage of the untreated control based on the mean fresh weight of barnyard grass tops per pot.

Experiment 2 was conducted to find the depth where G-315 would act most effectively. The results are shown in Fig. 5. Where the treated layer was 1 cm below the soil surface, G-315 indicated high herbicidal activity against barnyard grass, but at 2.5 cm the herbicidal activity was slight, and at 5 cm no activity was observed. Nitrofen at 4.0 kg/ha was not effective at all, even at 1 cm below the soil surface. Judging from these results, and the fact that weed seeds are considered to germinate 1 to 2 cm below the soil surface, proper incorporation depth of G-315 is assumed to be 2 to 3 cm.

Is it really practical to treat such a shallow layer of soil? To confirm this, Experiment 3 was carried out. As shown in Fig. 6, G-315, both granular and as an emulsifiable concentrate, was contained mainly in the top 2 cm of soil. The granular type sometimes exhibited high herbicidal activity even below 2 cm, so it was concluded that it was mixed fairly deeply in the soil. On the other hand, the emulsion type was found at 2 to 4 cm, but was scarcely detected below this depth, and barnyard grass was almost unaffected. As mentioned above, in paddy fields it is desirable

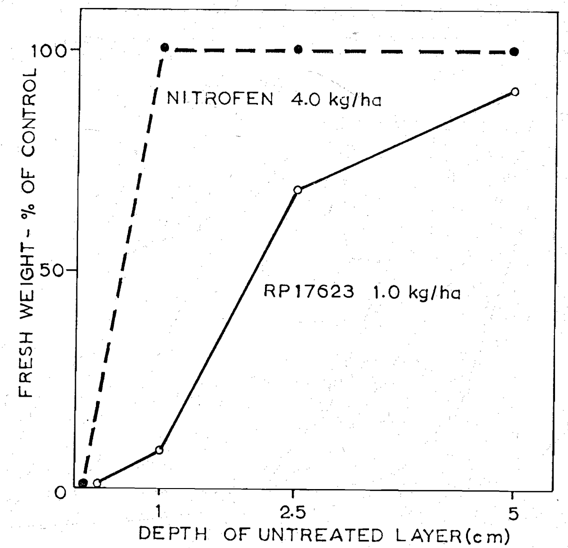

Fig. 5: Effect of distance between the soil surface and the treated soil layer on the herbicidal activity of G-315 and nitrofen. Data are presented as a percentage of the untreated control based on the mean fresh weight of barnyard grass tops per pot.

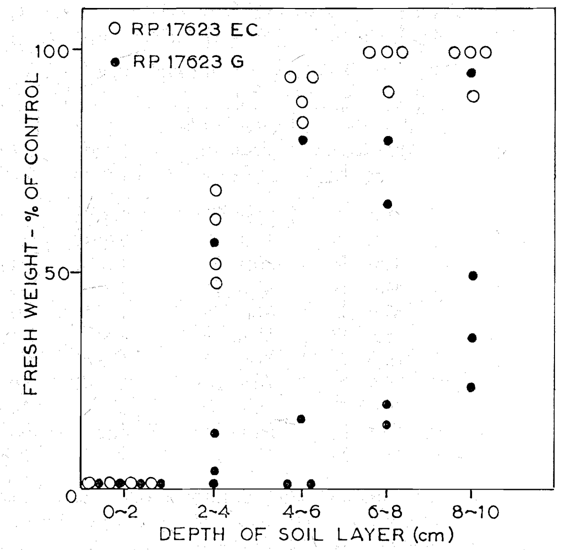

Fig. 6: Herbicidal activity in soils from various depths after incorporation treatment of G-315 granule and emulsifiable concentrate in flooded conditions. Data are presented as a percentage of the untreated control based on the mean fresh weight of barnyard grass tops per pot.

to mix G-315 to a depth of 2 to 3 cm. Efficient soil incorporation is possible if an emulsifiable concentrate formulation is applied at or before normal puddling work.

In this experiment, the concentration of G-315 in water 30 minutes after puddling was very low — less than 0.1 ppm for granules and about 0.3 ppm for the emulsion. The results of the analyses indicate that, even if G-315 is applied as an emulsion, the greater part of it is quickly incorporated into the soil. It is assumed that the emulsion sinks with the fine soil particles after puddling.

The results of Experiment 4, the field tests of the glass dispensers, are given in Table 2. The herbicidal effect and phytotoxicity were evaluated by 11 farmers in comparison with a commercially-available granular herbicide that they applied in other paddy fields. The application method was given a favourable evaluation by all the farmers, as it enabled them to spray the herbicide very easily and uniformly in about 5 minutes per hectare. None of them commented that G-315 was inferior to the standard herbicide, and 8 of the 11 rated it far superior to other herbicides.

TABLE 2: RESULTS OF SOIL INCORPORATION OF G-315 EMULSIFIABLE CONCENTRATE IN FARMERS' PADDY FIELDS

(Both weed control and phytotoxicity judged by each farmer)

Farmer	*Field Area (m^2)*	*Rice Variety**	*Application Date*	*Rice Transplanting Date*	*Weed† Control*	*Phytotoxicity*
1	130	Nih	Jun. 7	Jun. 8	Ex.	Slight
2	70	Toy	Jun. 19	Jun. 20	Same	No
3	100	Nih	Jun. 2	Jun. 3	Ex.	Slight
4	130	Nih	May 21	May 25	Ex.	No
5	110	Nih	May 22	May 23	Ex.	No
6	100	Nih	May 17	May 19	Ex.	No
7	150	Nih	May 21	May 24	Good	No
8	75	Sai	Jun. 27	Jun. 28	Good	No
9	120	Sai	Jun. 27	Jun. 28	Ex.	Moderate
10	70	Sas	Jun. 26	Jun. 26	Ex.	No
11	70	Nih	Jun. 25	Jun. 26	Ex.	Slight

*Nih, Nihonbare; Toy, Toyonishiki; Sai, Saitamamochi; Sas, Sasashigure.
†In comparison with a commercially-available granular herbicide that each farmer applied in other paddy fields.

As far as phytotoxic effects are concerned only one case was observed in which rice growth was temporarily retarded, and this had no influence on grain yields.

Soil incorporation of G-315 in rice paddy fields can therefore be said to have shown excellent results in practical applications.

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PROPERTIES AND MODE OF ACTION OF BENTHIOCARB, A SELECTIVE HERBICIDE FOR RICE FIELDS

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Summary

Benthiocarb gives good control of paddy field weeds, especially barnyard grass (*Echinochloa crus-galli*) and slender spike-rush, inhibiting the growth of germinating weeds at the pre-emergence to early post-emergence stage. Rice is sensitive to benthiocarb at the germinating stage, but is not affected after the 1-leaf stage. Single and combination commercial formulations of benthiocarb are available in Japan.

INTRODUCTION

Benthiocarb has been developed since 1965 by the Kumiai Chemical Industry Co. Ltd., being registered in 1969 as a rice herbicide, and commercialized in 1970 under the trade name of "Saturn". It was first marketed in combination with simetryn ("Saturn-S", 7% benthiocarb plus 1.5% simetryn) for transplanted rice and was used over about 10% of the total area of rice culture in 1970. Its use is increasing with the introduction of new products, "Saturn" (10% granular formulation of benthiocarb and 50% emulsifiable concentrate) and "Saturn-M" (7% benthiocarb plus 6% chlornitrofen). The application of benthiocarb to direct-sown rice or upland crops is developing in Japan, Italy, U.S.A. and other countries.

Benthiocarb is a colourless, clear liquid, with a molecular weight of 257.8, and a boiling point of 126 to 129° C/0.008 mg Hg. It is soluble in organic solvents, and slightly soluble in water (20 ppm at 20° C). Its acute oral LD_{50} is 560 mg/kg for mice and 920 mg/kg for rats. Fish toxicity for carp (TLM 48 hr) is 3.6 ppm by 50% EC (equals 1.8 ppm by active ingredient).

Among a thousand benzylthiolcarbamate derivatives tested, benthiocarb proved the most effective and selective for rice and barnyard grass. For example, in substitution of the benzene ring with chlorine atom, 4-chloro-(benthiocarb) was found to be the best. Non-substituted or 2-substituted compounds were effective against barnyard grass, but were very toxic to rice. Dichloro- or trichloro-derivatives were less effective and non-selective. Substitution of the *p*-position with other groups than chlorine decreased activity or selectivity. As for substitution of carbamoyl nitrogen by alkyl groups, di-ethyl substitution was the best.

WEED SPECTRUM AND SELECTIVITY

Benthiocarb is especially effective against barnyard grass (*Echinochloa crus-galli*), slender spike-rush (*Eleocharis acicularis*), and tama-kayatsuri (*Cyperus difformis*). It is also effective against konagi (*Monochoria vaginalis*) and other broadleaf weeds common in paddy fields.

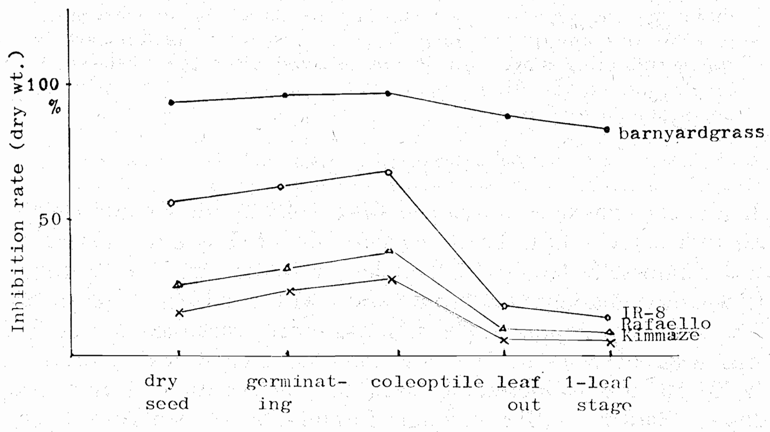

Fig. 1: Inhibition of rice and barnyard grass by benthiocarb in relation to their growth stages. Dosage was 400 g/ha in each pot.

Benthiocarb controls barnyard grass from its germination to the 2-leaf stage under flooded conditions. Rice is sensitive to benthiocarb before the coleoptile stage, but is not affected after that stage. Of the several rice varieties examined, Japonica was more resistant than the other varieties, though, as shown in Fig. 1, growth stage is a dominant factor in the resistance of rice to benthiocarb (Nakamura *et al.*, 1969; Shigematsu *et al.*, 1971).

UPTAKE, TRANSLOCATION AND MODE OF ACTION

Benthiocarb is more effective when applied over the barnyard grass seeds than when applied under the seeds (Nakamura *et al.*, 1969).

Tests with dark-grown and over-elongated barnyard grass indicated that benthiocarb is taken up more from the mesocotyl than

TABLE 1: INHIBITION OF BARNYARD GRASS BY BENTHIOCARB AND CHLORPROPHAM BY CONTACT METHOD

(Barnyard grass seedlings were wrapped with absorbent cotton and supplied with benthiocarb solution or water)

	Treated Area	*Inhibition Rate of Shoot Growth (%)* 3	10	30	100 ppm
benthiocarb	mesocotyl	78	81	87	98
	root	16	32	60	62
chlorpropham	mesocotyl	62	65	78	100
	root	32	58	62	87

from the roots (Table 1) (Kimura *et al.*, 1970). Translocation studies using ^{14}C-methylene labelled benthiocarb are being conducted.

Benthiocarb inhibits the Hill reaction of isolated spinach chloroplast 50% at 3×10^{-4} M, but does not inhibit the photosynthesis of intact rice or barnyard grass nor affect the respiration of excised roots of rice or barnyard grass. However, it does inhibit the synthesis of gibberellin-induced α-amylase in the aleurone layer of barnyard grass 50% at 5×10^{-5} M and that of rice at 7×10^{-4} M (Ichizen and Matsunaka, 1971). The inhibition of protein synthesis must be involved.

Benthiocarb acts synergistically with simetryn only for barnyard grass and not for rice under flooded conditions. The reason for this action has not yet been explained (Ichizen *et al.*, 1969).

RESIDUES IN RICE AND SOIL

So far no residue has been detected in rice grain (Yamada and Tamura, 1971), and paddy soil analyses have shown no or little residue of benthiocarb.

Decomposition of benthiocarb must be microbial, as it does not decrease in autoclaved soil (Yamada and Tamura, 1971).

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MINIMAL AND ZERO TILLAGE TECHNIQUES AND POST-PLANTING WEED CONTROL IN RICE

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Summary

Trials comparing conventional cultivation techniques in wet padi culture with minimal and zero tillage techniques using paraquat for pre-crop planting weed control are described. Good crop establishment and growth were achieved under minimal and zero tillage techniques and the yields were found to be similar to those obtained under a conventional tillage technique. Yields increased with increasing levels of nitrogen from 0 to 90 kg/ha, but the response to added nitrogen was similar with all three tillage techniques evaluated. Application of liquid or granular formulations of MCPA 4 days after transplanting gave better control of post-planting weeds and higher yields than application of a similar rate at 20 days after transplanting.

INTRODUCTION

The importance of rice to South Asian countries, an area with nearly 55% of the world's people and net growth in population of over 2% per annum, is well known. To meet the constantly increasing demand for rice, considerable thought has been and is being given to ways and means of increasing its production. It can be argued that greatly improved efforts of recent years to increase rice production have by and large been successful. Use of new varieties, either developed by the International Rice Research Institute (I.R.R.I.) or introduced by the National Department of Agriculture, is commonplace, standards of crop husbandry have improved, and the farmers in some parts are able to grow two crops of rice a year instead of the customary one crop. Whilst rice production has risen, a great deal of further progress still needs to be made. There are large areas in many countries where low productivity of labour used in pre-planting land preparation, seedbed establishment, and transplanting and post-planting weed control are proving to be major constraints in achieving the maximum potential of newer technology.

The technique used for land preparation in various countries varies widely from simple manual slashing, followed by flooding

for 2 to 3 weeks to rot the weeds before incorporation into the soil, to sophisticated mechanical ploughing or rotovation. However, for various reasons, in the majority of cases, the land is still tilled using laborious and time-consuming manual and/or animal power. The functions of these extensive cultivations appear to be (a) creation of suitable tilth or soil structure, (b) incorporation of plant residue, and (c) weed control. In this context it is of interest to note that Russell, as early as 1945, following extensive cultivation experiments, showed that agricultural crops are far more sensitive to weeds than they are to tilth. Recent developments in the field of chemical weed control have made it possible to control weeds without cultivation, thus enabling examination of the effects of cultivation independently of weed control.

The earliest attempts to use chemicals in place of ploughing were in removing low quality weed species from stands of high quality forage plants from areas of grazing land located on terrain where most tillage systems were either impractical or impossible. During 1950-55 attempts were made to establish crops like wheat, oats, flax, maize and soya bean, either without cultivation or with a minimum of disturbance. Chemicals used in these studies included TCA, dalapon, amitrole, cacodylic acid, dinoseb, MCPA, 2,4-D, and 2,4,5-T.

The effectiveness of these chemicals varied with the composition of weeds; in addition they were mainly slow acting and in many cases left toxic residues in the soil which would affect the main crop planted soon after spraying. However, the discovery of paraquat, a chemical with a very rapid action, wide spectrum and no residue in the soil, stimulated considerable interest in no-tillage work after a lapse of several years. Work aimed at replacing some or all cultivation by using paraquat in crops like wheat, barley, oats, kale, soya bean, flax, jute and padi was undertaken in many parts of the world.

One of the earliest and simplest applications of paraquat as an aid to cultivation in padi culture was in Malaysia where weeds were first desiccated by an application of paraquat then burnt off after 3 to 5 days, after which the field was flooded and padi seedlings immediately transplanted. This early work has now been considerably expanded and results from some of the trials are presented here.

Interaction of chemically aided cultivation techniques with post-planting weed incidence was also studied. In situations where the use of paraquat did not obviate the need for post-planting weed control, trials were undertaken to establish the most cost-effective recommendations. Results from these trials are also discussed in this paper.

MATERIALS AND METHODS

Trials were carried out on typical sites of single- and double-cropped padi. A randomized block or a split plot design was used with 3 or 4 replications. Plot size varied from site to site but the minimum size used was 4.5 × 9.0 m.

CONVENTIONAL METHOD OF LAND PREPARATION

In the trials programme one of the following two methods was compared with the minimal or zero tillage technique:

Traditional Method: Weeds were first slashed with a "tajak" (a scythe-like tool) followed by flooding for a period of 2 to 3 weeks to facilitate decomposition, then by a second slashing to control regenerating weeds, followed by incorporation of the dead vegetation into the soil. This usually required 1 or 2 rounds of harrowing, followed by levelling and transplanting. With this method the total time taken from the start of cultivation to planting usually varied between 4 and 5 weeks.

Mechanical Method: This method involved an initial rotovation, invariably under flooded conditions, using either a tractor-mounted or a pedestrian rotovator, followed by a second rotovation after an interval of 10 to 12 days. One or two rounds of harrowing were followed by levelling and transplanting. The total time taken under this system varied between 15 and 25 days.

CHEMICAL METHOD OF LAND PREPARATION

Two chemically assisted methods of land preparation were tested — a minimal tillage technique where only one cultivation was used to incorporate desiccated vegetation into the soil, and a zero tillage technique where no cultivation at all was carried out.

In most minimal tillage trials, paraquat alone at 0.56 kg/ha, or, when broadleaved weeds occurred, a tank mixture of 0.56 kg/ha paraquat and 0.56 kg/ha MCPA, was used to control weeds before cultivation and planting. In zero tillage trials, with a view to obtaining complete control of ratooning rice and some grass species, a sequential treatment of dalapon at 1.68 kg/ha followed 3 days later by paraquat at 0.56 kg/ha was also used. The chemicals were applied in 450 l/ha using a shoulder-mounted Birchmeirer "Senior" hand-pumped sprayer fitted with a red (078) "Polijet" nozzle. Paraquat was applied as "Gramoxone" and MCPA as "Agroxone" 4, a formulation containing equal amounts of Na and K salts.

In minimal tillage plots, chemical spraying was followed 3 days later by flooding for 3 to 5 days, then incorporation of desiccated weed either manually or using a rotovator, and finally levelling and transplanting. In zero tillage plots, spraying was followed by flooding after a wait of 3 days; transplanting was carried out 3 to 4 days after flooding.

Regular tiller counts and plant height measurements were taken from 10 randomly selected plants per plot. Weed cover before and during crop growth, and after harvesting, was measured with a point quadrat. For estimating yield, whole plots were harvested after discarding 0.3 to 0.6 m of the border area. Contributions of the main components of yield were also assessed.

In all trials full manurial and crop protection programmes were followed.

Two methods of planting rice were used. One involved the conventional method of sowing a nursery followed by transplanting 20-day-old seedlings into the field. In the second method, pre-germinated seeds were broadcast in the field.

RESULTS

MINIMAL TILLAGE

Data from several trials where the minimal tillage technique was compared with conventional methods are presented in Table 1. In all cases, provided recommended levels of nitrogenous fertilizer were applied, no significant differences in yield were observed between plots cultivated using either a conventional or a minimal tillage method.

Tiller numbers, panicle numbers per hill, 1000 grain weight, and percentage of ripened grain were found to be similar under minimal and conventional tillage systems (Table 2).

More recent work has shown that, even if flooding is carried out within one day after spraying, herbicidal activity is not adversely affected.

Yields from transplanted and broadcast padi following minimal tillage were found to be similar (Table 3).

TABLE 1: GRAIN YIELD (kg/ha) OF TRANSPLANTED WET PADI UNDER CONVENTIONAL AND MINIMAL TILLAGE
(Name of the variety in this and subsequent tables given within parentheses below each trial number)

Treatment (kg/ha)	*KKP.5* (Ria)	*KKP.6* (Bahagia)	*KKP.7* (Malinja)	*BP.1* (Mashuri)	*BP.2* (Malinja)	*BP.3* (Malinja)	*PDP.2* (Ria)	*PLP.1* (Peta × T. Rotan)
Conventional tillage:								
Traditional method	7171	—	—	2900	2598	3385	—	3938
Mechanical method	6692	7090	3931	—	—	—	5699	—
Minimal tillage:								
paraquat 0.56	6592	6671	—	3032	2979	3517	—	—
paraquat 0.56/MCPA 0.56 ...	—	7172	4193	3110	—	3302	5657	3913
LSD 5%	482.3	1068.7	582.4	463.6	604.8	507.5	586.2	459.5
1%	655.9	1455.9	781.8	658.0	860.5	721.4	811.9	635.6

TABLE 2: EFFECT OF MINIMAL TILLAGE ON TILLER NUMBERS, PANICLE NUMBERS, % RIPENED GRAIN, AND 1000 GRAIN WEIGHT OF TRANSPLANTED PADI

Treatments (kg/ha)	*KKP.6* Tiller Nos./Hill 30*	Tiller Nos./Hill 60*	Panicle Nos./Hill	% Ripened Grain	1000 Grains Weight (g)	*BP.3* Tiller Nos./Hill 30*	Tiller Nos./Hill 60*	Panicle Nos./Hill	% Ripened Grain	1000 Grains Weight (g)
Conventional tillage:										
Traditional method	—	—	—	—	—	9.57	13.40	10.38	68.60	45.26
Mechanical method	18.4	24.9	17.8	85.95	45.51	—	—	—	—	—
Minimal tillage:										
paraquat 0.56	20.0	25.0	16.8	89.59	46.20	9.23	15.25	10.35	69.95	45.65
paraquat 0.56/MCPA 0.56 ...	19.3	23.1	16.0	90.41	45.36	9.43	13.47	10.57	69.48	45.41
LSD 5%	2.01	3.03	2.39	11.86	1.78	1.90	2.15	1.67	3.13	0.99

*Days after transplanting.

Zero Tillage

Data obtained from two trials where zero tillage technique was compared with the minimal and a conventional tillage technique show that the differences in yield following all three land preparation techniques were not significant (Table 4). However, in trial BP.2, 1.79 kg/ha dalapon followed 3 days later by 0.56 kg/ha paraquat gave the best control of ratooning and volunteer rice plants and the yield was observed to be highest with this treatment. Differences between treatments in tiller numbers, panicle numbers per hill, percentage of ripened grain, and 1000 grain weight were also found to be non-significant.

Long-term Effect of Various Tillage Techniques and Fertilizer Level on Weed Population and Yield

Initial trials were followed by several long-term trials comparing normal, minimal and zero tillage techniques on different soil types. Each tillage was evaluated at three levels of nitrogen (0, 45 and 90 kg/ha) using an Indica variety. P and K rates were kept constant (at 67.2 and 33.6 kg/ha, respectively) for all treatments. Results obtained over four seasons are presented below:

Weed Population: The incidence of weeds in the growing crop has generally been less following the use of minimal than after conventional cultivation. In the absence of perennial weeds, a similar trend was noted with zero tillage also. However, when paraquat-resistant (perennial) grasses were present, continuous use of zero tillage resulted in rapid regeneration and on some sites an increase in resistant weeds over four seasons. This trend was particularly noticeable in pre-plant weed assessments (Tables 5 and 6).

Yield: Yields increased significantly with increasing level of nitrogen with all three tillage systems. However, no significant differences were observed between various tillage techniques (Table 7). Yield response to added nitrogen during the first season was found to be linear in all cases. From the second season onwards, some of the treatments showed a curvilinear response.

Post-crop Planting Weed Control

Weed stands before planting tended to contain mixtures of grasses, sedges and broadleaved species. The main weeds were:

TABLE 3: GRAIN YIELD (kg/ha) OF TRANSPLANTED AND BROADCASTED WET RICE UNDER CONVENTIONAL AND MINIMAL TILLAGE TECHNIQUES

Treatment	*Yield (kg/ha)* *KKP12*	*KKP17*
Normal tillage:		
Transplanted	4969	3942
Broadcasted	6219	4455
Minimal tillage:		
Transplanted	4967	4381
Broadcasted	6141	4796
LSD 5%	558	685

TABLE 4: COMPARISON OF ZERO TILLAGE WITH CONVENTIONAL AND MINIMAL TILLAGE METHODS. GRAIN YIELD (kg/ha) OF TRANSPLANTED PADI

Treatment (kg/ha)	*Yield (kg/ha)* *BP.2*	*TGP.2*
Conventional tillage	2598	4226
Minimal tillage:		
paraquat 0.56/MCPA 0.56	2979	4313
Zero tillage:		
paraquat 0.56/MCPA 0.56	2498	4241
dalapon 1.79 → paraquat 0.56 (3 days later)	3062	—
LSD 5%	605.4	559.2

TABLE 5: PRE-CULTIVATION WEED POPULATION PERCENTAGE WEED COVER, FOLLOWING CONTINUOUS CROPPING IN RICE USING CONVENTIONAL, MINIMAL AND ZERO TILLAGE TECHNIQUES

Treatment	*1st Season* *G*	*S + B*	*2nd Season* *G*	*S + B*	*3rd Season* *G*	*S + B*	*4th Season* *G*	*S + B*
KDP Series:								
Normal tillage	10.0	49.0	2.0	37.0	8.0	80.0	33.0	47.0
Minimal tillage	2.0	56.0	8.0	29.0	21.0	59.0	39.0	51.0
Zero tillage	5.0	54.0	16.0	16.0	29.0	54.0	50.0	40.0
PHAP Series:								
Normal tillage	0.0	76.0	1.0	54.0	6.0	39.0	8.0	46.0
Minimal tillage	0.0	69.0	17.0	47.0	7.0	27.0	18.0	40.0
Zero tillage	0.0	75.0	20.0	37.0	26.0	14.0	23.0	5.0
T7P Series:								
Normal tillage	7.0	31.0	3.0	48.0	3.0	9.0	7.0	46.0
Minimal tillage	4.0	33.0	3.0	49.0	0.0	16.0	6.0	45.0
Zero tillage	3.0	35.0	1.0	36.0	6.0	15.0	5.0	54.0

G = Grasses. S + B = Sedges and broadleaved species.

TABLE 6: POST-PLANT WEED POPULATION IN RICE FOLLOWING CONVENTIONAL, MINIMAL AND ZERO CULTIVATION TECHNIQUES — PERCENTAGE WEED COVER AT 3 WEEKS AFTER TRANSPLANTING

Treatment	*1st Season* *G*	*S + B*	*T*	*2nd Season* *G*	*S + B*	*T*	*3rd Season* *G*	*S + B*	*T*	*4th Season* *G*	*S + B*	*T*
KDP Series:												
Normal	0.0	31.0	31.0	1.0	32.0	33.0	1.0	24.0	25.0	4.0	1.0	5.0
Minimal	6.0	13.0	19.0	1.0	9.0	10.0	3.0	15.0	18.0	1.0	2.0	3.0
Zero	25.0	2.0	27.0	2.0	9.0	30.0	11.0	16.0	27.0	24.0	2.0	26.0
PHAP Series:												
Normal	0.0	3.0	3.0	0.0	2.0	2.0	0.0	9.0	9.0	0.0	15.0	15.0
Minimal	0.0	3.0	3.0	0.0	2.0	2.0	1.0	6.0	7.0	0.0	3.0	3.0
Zero	0.0	6.0	6.0	29.0	2.0	31.0	14.0	1.0	15.0	6.0	1.0	7.0
T7P Series:												
Normal	1.0	44.0	45.0	2.0	16.0	18.0	10.0	47.0	57.0			
Minimal	0.0	44.0	44.0	0.0	17.0	17.0	0.0	44.0	44.0			
Zero	0.0	7.0	7.0	1.0	9.0	10.0	0.0	16.0	16.0			

G = Grasses. S + B = Sedges and broadleaved species. T = Total weed stand.

TABLE 7: GRAIN YIELD (kg/ha) OVER VARIOUS SEASONS OF TRANSPLANTED RICE UNDER CONVENTIONAL, MINIMAL AND ZERO TILLAGE TECHNIQUES

Treatments (kg N/ha)	*KDP Series Seasons*				*PHAP Series Seasons*				*TTP Series Seasons*			
	1st	*2nd*	*3rd*	*4th*	*1st*	*2nd*	*3rd*	*4th*	*1st*	*2nd*	*3rd*	*4th*
Conventional												
0	3286	2707	2483	2754	3933	3191	3498	2448	3027	2378	3177	2183
45	3743	3491	2876	3459	4308	3646	3895	2764	3732	3006	3326	2690
90	3882	3605	2997	3289	4713	3693	3717	3028	3996	3572	2708	2352
Mean	3637	3268	2785	3167	4318	3510	3703	2747	3585	2985	3070	2408
Minimal												
0	3584	3154	2955	3119	3921	3173	3527	2397	3723	2293	3156	2036
45	3758	3416	3005	3432	4219	3731	3631	2877	3998	3135	3348	2341
90	3902	3814	2882	3488	4580	3633	3619	2815	4030	3678	3444	2836
Mean	3748	3461	2947	3346	4240	3512	3592	2696	3917	3035	3316	2404
Zero												
0	3519	3219	3011	3219	4087	3213	3656	2468	3731	2196	3220	2577
45	3529	3487	2992	3192	4338	3680	3601	2916	4072	3487	3624	3106
90	3867	3447	2972	3219	4810	3323	3466	2774	4275	3550	3049	3342
Mean	3638	3384	2992	3210	4412	3405	3574	2719	4026	3078	3298	3008
LSD 5%	392	315	267	440	426	367	386	394	543	588	449	377

Grasses: *Isachnae globosa, Leersia hexandra, Ischaemum timorense, Leptochloa chinensis, Echinochloa colonum.*
Sedges: *Scirpus grossus, S. juncoides, Eleocharis* sp., *Cyperus* sp., *Fimbristylis milicea, Leporonia articulata.*
Broad-leaved weed species: *Monochoria vaginalis, Limnocharia flava, Jussiaea repens.*

As indicated earlier, in all minimum trials weed incidence after planting was lower than with conventional tillage. This difference was much more marked in plots treated with a mixture of paraquat and MCPA at 0.56 kg/ha used to obtain better control of a mixed weed stand before planting. However, in spite of reduced weed population with minimum tillage, the need for post-planting weed control was not completely eliminated. Consequently trials were undertaken to establish the most cost-effective post-planting herbicide recommendation.

In most situations, the post-planting weeds were observed to be predominantly sedges and broadleaved species and some annual grasses. Based on recent findings of the I.R.R.I. (Moomaw *et al.*, 1968; De Dalta and Laesina, 1969) that the phenoxy herbicides applied 4 days after transplanting (before weed emergence) control annual grasses, broadleaved weeds and sedges, an initial trial compared MCPA application 4 and 21 days after transplanting. Results presented in Table 8 show that MCPA

TABLE 8: WEED COVER AT VARIOUS INTERVALS FOLLOWING MCPA SPRAY AT 4 AND 21 DAYS AFTER TRANSPLANTING (DAT)

Treatment	*% Weed Cover (DAT)* 4	21	39	46
Conventional:				
Hand-weeding — 30 DAT	—	13	5	7
MCPA — 4 DAT	—	3	3	4
MCPA — 21 DAT	—	42	12	8
No weeding	—	39	98	100
Minimal tillage: (paraquat 0.56 kg/ha)				
Hand-weeding — 30 DAT	—	22	6	8
MCPA — 4 DAT	—	3	2	3
MCPA — 21 Dat	—	42	16	13
No weeding	—	33	85	98
Minimal tillage: (paraquat 0.56 + MCPA 0.56 kg/ha)				
Hand-weeding — 30 DAT	—	19	5	10
MCPA — 4 DAT	—	3	3	5
MCPA — 21 DAT	—	25	5	6
No weeding	—	23	64	85

application 4 days after transplanting gave better control than a similar application 21 days after transplanting.

In further trials carried out in the Philippines, where post-crop planting weed populations tend to be more varied than in Malaysia, it was confirmed that MCPA 0.8 kg/ha applied 4 days after transplanting gives better control of weeds and higher yields than application at 20 days after transplanting — the traditional application time — and equal weed control to 2,4-D, EPTC/MCPA and trifluralin/MCPA (Table 9). Granular formulations of MCPA were found to be as effective as liquid sprays of MCPA and 2,4-D IPE granules (Table 10).

TABLE 9: POST-PLANTING WEEDS (TIME TO HAND-WEED IN hr/ha) AND GRAIN YIELD (kg/ha) OF TRANSPLANTED IR 5 UNDER VARIOUS HERBICIDE TREATMENTS APPLIED TO DRAINED PADDY

San Leonardo 1969. Wet Season

Treatment (kg/ha)	*Time of Application (DAT)*	*Weeds in Crop*	*Yield*
No weeding	—	—	3235
Hand-weeding	—	130.2	4706
MCPA (EC) 0.8	4	36.2	4852
MCPA 0.8	20	60.1	3917
MCPA 0.8 + 0.8	4 & 20	18.2	4668
2,4-D IPE (EC) 0.8	4	34.1	4899
EPTC 2/MCPA 0.6	4	46.3	4475
trifluralin 0.7/MCPA 0.45	4	32.2	4692
LSD 5%/1%		26.3/36.1	226/308

TABLE 10: PRODUCTIVE TILLERS PER HILL AND GRAIN YIELD (kg/ha) UNDER VARIOUS LIQUID AND GRANULAR FORMULATIONS OF MCPA APPLIED 4 DAYS AFTER TRANSPLANTING

Cabaruan Guimba 1970. Wet season

Treatment (kg/ha)	*Productive Tillers*	*Grain Yield*
2,4-D IPE (granules) 0.8	9.4	5070
MCPA (EC) 0.8	10.7	5292
MCPA (limestone chips granules) 0.8	10.1	5378
MCPA (extruded clay granules) 0.8	10.2	5256
Control — no weeding	9.2	4754
LSD 5%/1%	Not sig.	318/429

DISCUSSION

Good padi establishment and yield have been obtained following minimal or zero tillage systems. This confirms the findings of other workers that in wet padi culture the main reason for extensive pre-plant cultivation is the elimination of weeds (Mabayyad and Buenacosa, 1967; Mittra and Pieris, 1968). If weeds can be eliminated chemically, as has been achieved under the two chemical systems of land preparation developed in the present study, the need for cultivation also is reduced or completely eliminated.

The minimal tillage system tried so far includes the use of chemical, flooding and cultivation, and no attempt has been made to evaluate the role of each of these treatments. Nevertheless, the fact that good weed control and yields were obtained even when flooding was carried out one day after spraying seems to suggest that paraquat initiates the process of weed control (and decomposition) which is subsequently completed by flooding and cultivation. This supposition is further supported by the work of Mittra and Pieris (1968) in Ceylon which indicated that paraquat cultivation and flooding had complementary effects on weed control.

Zero tillage makes it possible to plant the next crop soon after harvesting by eliminating lengthy pre-crop planting cultivation and thus flexibility is lent to the cropping schedule and multi-cropping is facilitated. However, long-term use of the zero tillage technique may lead to establishment of perennial weeds.

Plant growth data available over four seasons indicate that plant growth continues to be normal as confirmed by similar yields under the three cultivation systems at any given rate of nitrogen application. Response to nitrogen rates, as expected, was linear under all cultivation systems.

Although the minimal tillage plots showed a reduced post-planting weed incidence, the need for post-plant weeding was not completely eliminated. In most situations, post-planting weeds were sedges and broadleaved weed species which germinate with the crop and a timely application of MCPA provided complete control. Recent findings of the I.R.R.I. that application of short-chain alkyl ester or Na/K salts of 2,4-D or MCPA in liquid or granular form prior to weed emergence (3 to 5 days after transplanting) can control seedling grasses as well as sedges and broadleaved weed species were confirmed both in Malaysia and in the Philippines (Novero and Elias, 1969). Application of

MCPA 4 days after transplanting in liquid or granular form to 20-day-old seedlings gave better control of weeds and higher yields than application 21 days after transplanting. As both 2,4-D and MCPA can persist in the soil over short periods and are readily absorbed by germinating seedlings, the limited number of formulations evaluated were found to be equally active. MCPA and 2,4-D are among the least expensive and most widely used chemicals for post-emergence control of broadleaved weeds and sedges (Moomaw *et al.*, 1966; Moomaw *et al*, 1968). Results presented here have confirmed that these compounds can also be used safely to control annual grasses, in addition to broadleaved species and sedges, before their emergence in transplanted wet padi.

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EMERGENCE ASPECTS OF WEED SEEDLINGS AND THEIR SIGNIFICANCE IN WEED CONTROL

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INTRODUCTION

To develop efficient weed control in arable as well as unarable lands, it is important to establish the ecological nature of the principal noxious weeds as a community or as individuals, that is, their life history, germination physiology of their seeds, emergence and growing behaviour of seedlings, their competition with crops and so on. Emergence behaviour is particularly important and knowledge of it can greatly assist in improving weed control measures in arable lands. However, only a few scientific studies in weed emergence have so far been conducted (Arai, 1962; Dawson and Burns, 1962; Chancellor, 1964a, b; Wiese and Davis, 1967; Robocker, 1970).

Between 1963 and 1966 several experiments were conducted on the emergence history and emergence depth of several important weed species. In this paper, some experimental data are presented and their significance in weed control considered.

EMERGENCE HISTORY

MATERIALS AND METHODS

The term "emergence history" refers to the varying numbers of weed seedlings emerging with time. The experiments used six principal annual weeds of lowland fields in Japan as follows:

Echinochloa crus-galli (Gramineae) — barnyard grass
Monochoria vaginalis (Pontederiaceae) — konagi
Dopatrium junceum (Scrophulariaceae) — abunome
Rotala indica (Lythraceae) — toothcup
Cyperus microiria (Cyperaceae) — umbrella sedge
Fimbristylis littoralis (Cyperaceae) — hideriko

The seeds of these weeds were mixed with silt-loam soil, made free of other weed seeds by previous heating and were placed in a framed field 50 × 50 cm² in area and 10 cm deep. Three series of soil-water conditions were prepared:

(1) A submerged soil-water condition, created by holding irrigation water at a depth of 3 cm above the soil surface.

(2) A saturated condition, created by keeping the soil water at the soil surface level, using a glass tube fixed to the outside of a framed field for maintaining control of the underground water level.

(3) A dry condition, created by holding the underground water level 20 cm beneath the soil surface by means of a glass tube.

The weed seeds were sown on three dates: May 7, July 28 and August 1, corresponding to early, ordinary and late season culture of rice in southern Japan, respectively.

Results

1. *Period of Emergence*

Emerged seedlings were picked at 5- or 6-day intervals and the numbers of each species counted. However, the data from the late sowings were rejected, because germination was too low owing to the adverse effects of high temperatures (about 35° C) on the metabolic activity of seed organs and/or secondary dormancy of the seed embryo.

Echinochloa crus-galli: The seeds emerged essentially within a relatively short period, showing a peak 15 to 30 days after sowing. The remaining seeds emerged little by little until late October. The emergence pattern differed somewhat according to the season; in an ordinary season a steeper peak occurred earlier after sowing than in an early season. On the other hand, there was little difference in emergence patterns under the three soil-water conditions, though there was earlier emergence under submerged rather than dry conditions. The relatively low variation in the emergence patterns of this grass indicated a wide adaptability to the environment, and it will therefore be difficult to control effectively in most rice fields.

Monochoria vaginalis: The majority of these weed seedlings emerged within an extremely short period under submerged conditions, showing the steepest peak at the 15th to 25th day after sowing; under other soil-water conditions, the weed showed a trend of gradual emergence, especially under dry conditions. A difference between seasons, however, hardly existed. The large variation in the emergence pattern of this weed under various soil-water conditions is typical of hydrophytic seed.

Dopatrium junceum: Seasonal variation of the emergence of this weed was very similar to that of *M. vaginalis,* except for one ordinary season under dry soil-water conditions, probably as a result of some unknown experimental error.

Rotala indica: This weed is also regarded as a representative hydrophytic weed in rice fields. Its emergence pattern, however, showed a somewhat different trend from those of the broadleaved weeds already mentioned. It did not show a steep peak, but rather a gradual one. Such an emergence pattern increases the difficulty of control, and accounts for the presence of this weed in rice fields after use of a herbicide with a short residual activity.

Fimbristylis littoralis: The period of emergence of this weed was the longest of all those examined, emergence continuing without a clear peak until the end of the experiment. Accordingly, where its infestation is serious, this weed is likely to be very hard to control with a single application of a herbicide. Fortunately, it is usually scarce in rice fields where deep submergence is practised.

Cyperus microiria: This weed had a trend of early emergence, with a peak about the 30th day after sowing under submerged and saturated conditions in a normal season. In dry soil conditions and other planting seasons, its emergence pattern was found to be very gradual, similar to *F. littoralis.* This weed would also appear difficult to control under the conditions of dry soils or lower temperatures that are usually found in early season planting.

In general, therefore, the experiment demonstrated that there are distinct differences in the emergence pattern of the several kinds of weeds used.

2. *Variation of Cumulative Emergence*

The numbers of seedlings picked every five or six days were recorded for each species and by successive addition gave cumulative totals of the numbers of seedlings that emerged. From the total final number cumulative emergence percentages (CEP) could be derived.

The objective in this section is to show what formulae best fit the CEP curve for each weed. The following five formulae were obtained from mathematical consideration of the experimental data:

TABLE 1: TYPES OF CEP CURVES AND PROBABILITY OF ACCURATELY FITTING EMPIRICAL FORMULAE

Season and Soil-water Condition	*E. crus-galli*	*M. vaginalis*	*D. junceum*	*R. indica*	*F. littoralis*	*C. microiria*
Early:						
Submerged	L_1***	H***	H***	L_1**	L_1***	L_1**
Saturated	L_1***	H***	H***	L_1**	S***	L_1**
Dry	L_2***	S**	S	S***	S**	S***
Ordinary:						
Submerged	H***	H***	H***	H**	L_1**	H***
Saturated	H***	H***	H***	L_2***	L_1**	H***
Dry	H***	S_t**	S**	S***	L_1	L_2***

** $P > 0.1$. *** $P > 0.5$.

1. Hypertonic (H) . . . $Y = a - c/X - b$
2. Semi-logarithmic (L_1) . . . $Y = a \log X - b$
3. Double logarithmic (L_2) . . . $\log Y = a \log X + b$
4. Sigmoid (S) . . . $\log(Y/100 - Y) = k(X - X')$
5. Straight (S_t) . . . $Y = a X + b$

In all of the formulae, Y indicates CEP and X is the number of days after sowing. a, b, c, and k are constants. X' is a turning point of increasing velocity in the sigmoid formula. The exactness of fit of the empirical formulae (Noda and Eguchi, 1965) was examined by the χ^2 test. The types of empirical formulae for each weed under different conditions are given in Table 1. The accuracy of fit of the empirical formulae is highly significant in all cases except two — *i.e.,* S-type of *D. junceum* under dry conditions in early season, and L_1-type of *F. littoralis* under dry conditions in a normal season. However, the former showed a sigmoid-like resemblance with respect to the turning of low-high-low in increasing velocity, and the poor fit of the latter might be due to scarcity of values recorded early in the emergence period.

Next, two critical periods in each empirical formula can be taken. One is the time to obtain 10% of CEP, which is considered to be most suitable as an indicator of the initial emergence of seedlings. The other is the time to obtain 80% of CEP, which is approximately the end of the emergence of most of the seedlings. The number of days from sowing to these points were named EP_{10} and EP_{80}, respectively. Generally speaking, the EP_{10} of H-type obtained from the empirical formulae ranged from 0 to 20 days, that of L_1-type from 10 to 30 days, and that of S-type from 35 to 60 days, as indicated in Table 2. Thus, it may be stated that initial emergence is retarded successively in types H, L_1 and S. EP_{10} of L_2 and S_t, however, cannot be estimated exactly, since the data fit to these types was too poor to be considered satisfactory. They would probably be intermediate between L_1 and S types.

The number of days from EP_{10} to EP_{80} means an inverse of increasing velocity during the major periods of emergence, fast or slow emergence, and ranges from 5 to 45 (about 25 average) for H-type, from 40 to 85 (about 70 average) for L and S types as shown in Table 3.

Discussion

The foregoing demonstrates distinct variations in the emergence patterns of different kinds of weeds according to season and soil-water conditions. These are summarized in Table 4.

TABLE 2: NUMBER OF DAYS TO 10% AND 80% EMERGENCE

Season and Soil-water Condition	*Time*	*E. crus-galli*	*M. vaginalis*	*D. junceum*	*R. indica*	*F. littoralis*	*C. microiria*
Early:							
Submerged	EP_{10}	9.9	10.3	20.0	25.1	26.3	13.7
	EP_{80}	58.9	19.3	53.7	88.7	97.1	77.3
Saturated	EP_{10}	10.4	20.3	20.9	29.1	41.2	30.8
	EP_{80}	78.0	51.7	43.9	116.4	108.0	105.7
Dry	EP_{10}	0.?*	49.1	60.0	61.4	62.2	37.2
	EP_{80}	83.0	99.5	109.1	123.8	100.0	95.3
Ordinary:							
Submerged	EP_{10}	9.7	0.3	11.1	9.6	23.5	19.0
	EP_{80}	19.8	7.1	33.1	31.1	68.9	58.6
Saturated	EP_{10}	8.3	9.4	11.7	9.6	20.7	9.9
	EP_{80}	28.4	30.3	53.2	84.1	79.6	37.2
Dry	EP_{10}	0.4	21.4	58.4	57.6	29.1	7.4
	EP_{80}	13.3	96.2	96.3	97.9	81.7	76.9

*A negative value was obtained from an empirical formula, but it should not be regarded as applying in field practice.

TABLE 3: NUMBER OF DAYS FROM EP_{10} TO EP_{80}

Season and Soil-water Condition	*E. crus-galli*	*M. vaginalis*	*D. junceum*	*R. indica*	*F. littoralis*	*C. microiria*
Early:						
Submerged	49.0	8.8	33.7	63.6	70.8	63.9
Saturated	67.6	31.4	23.0	87.3	66.8	74.9
Dry	83.0	50.4	49.1	62.4	47.8	58.1
Ordinary:						
Submerged	10.1	6.8	22.0	21.5	45.4	39.6
Saturated	20.1	20.9	41.5	74.5	58.9	27.3
Dry	12.9	74.8	37.9	40.3	52.6	69.5

TABLE 4: SUMMARY OF VARIATION OF EMERGENCE PATTERN WITH CULTURE SEASONS OR SOIL-WATER CONDITIONS

Weed Species	*Variation with Season*	*Variation with Soil-water*
E. crusgalli	moderate	moderate (or small)
M. vaginalis	small	great
D. junceum	small	great
R. indica	moderate (or small)	moderate
F. littoralis	small	small
C. microiria	moderate	small (or moderate)

Variation with seasons, probably with air and/or soil temperatures, was noted to be high for *E. crus-galli* and *C. microiria*, but very small for *M. vaginalis* and *D. junceum*. Variation with soil-water conditions was high for *M. vaginalis* and *D. junceum*, moderate for *E. crus-galli* and *R. indica* and small for *C. microiria* and *F. littoralis*.

The change of the cumulative emergence percentage was expressed by any of five formulae — hypertonic (H), semi-logarithmic (L_1), double logarithmic (L_2), sigmoid (S), and straight (S_t). However, these could be reduced to three types, H, L, and S, by combining L_1 and L_2 and S and S_t (Fig. 1).

H-type expressed by the hypertonic formula, shows characteristically an early initial emergence with the greatest rate of emergence occurring during the major periods of emergence; it occurs most commonly in paddy fields under deep submergence. Weeds of this type should be relatively easy to control by any control method, provided it is carried out at the proper time.

L-type, expressed by a single logarithmic formula, is characterized by later initial emergence and a slower pattern of progress in emergence than H-type. In general, it is rather difficult to control weeds of this type satisfactorily with a single application of a herbicide, and successive control methods would be necessary.

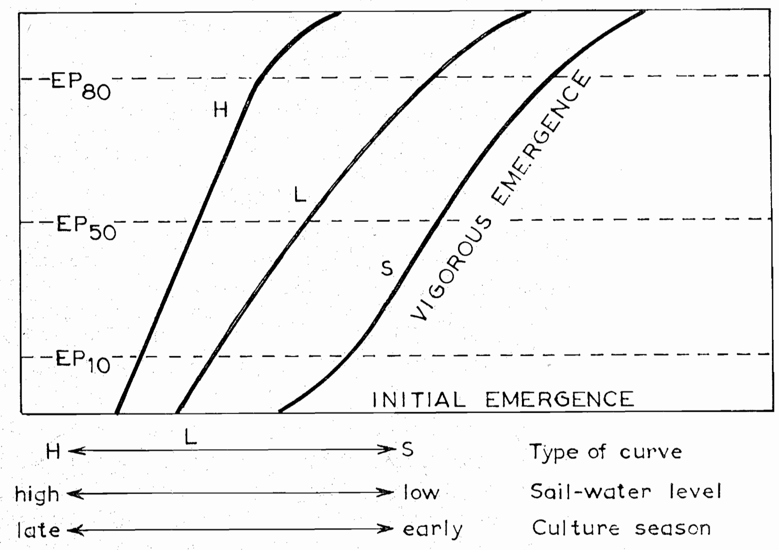

Fig. 1: Model representation of types of cumulative percentage emergence curves.

S-type, expressed by a sigmoid formula, is characterized by a retarded initial emergence. The increasing velocity of CEP, however, increases around mid-emergence. The method of control should be basically similar to that for L-type.

Occurrence of the three types varies with variations in soils, culture seasons, and/or kinds of weeds. To control weeds most efficiently, conditions that give the emergence pattern for H-type weeds are desirable. Thus, land levelling before transplanting and deep flooding are useful means of creating an H-type situation for the majority of paddy weeds.

EMERGENCE DEPTH

MATERIALS AND METHODS

This experiment used the principal weeds of upland and lowland fields in Japan, the 14 species shown below:

Echinochloa crus-galli var. *orizicola* (Gramineae) — barnyard grass
E. crus-galli var. *caudata* (Gramineae) — hairy barnyard grass
Setaria viridis (Gramineae) — green foxtail
S. viridis var. *purpurascens* (Gramineae)
Digitaria adscendens (Gramineae) — crabgrass
D. ischaemum (Gramineae) — smooth crabgrass
Eleusine indica (Gramineae) — goosegrass
Leptochloa chinensis (Gramineae) — sprangletop
Portulaca oleracea (Aizoaceae) — common purslane
Cyperus iria (Cyperaceae) — yellow cyperus
C. difformis (Cyperaceae) — umbrella plant
Fimbristylis littoralis (Cyperaceae) — hideriko
Monochoria vaginalis (Pontederiaceae) — konagi
Lindernia procumbens (Scrophulariaceae) — false pimpernel
Dopatrium junceum (Scrophulariaceae) — abunome

The germination or emergence depth of weed seeds was measured by the following two methods:

Method A

A fixed number of weed seeds, differing according to species, were thoroughly incorporated into the soil in pots 12 cm in diameter by 15 cm in depth for upland conditions, and 10 by 15 cm for submerged conditions. As the seedlings emerged they were sampled cautiously so as not to disturb the soil. The distance between the point of seed attachment and the point along the hypocotyl or shoot at which the seedlings emerged from the soil surface, marked by the beginning of the zone of coloration due to chlorophyll or other pigments, was measured as the emergence depth of seedlings.

Method B

Six different seed placements (0, 2, 4, 6, 8, and 10 cm from the soil surface) were made for each weed species, using pots 10 cm in diameter by 15 cm deep. The number of emerged seedlings was recorded about 20 days later when emergence was complete. The average depth of emergence was obtained from vertical variation in the number of emerged seedlings. The experiments were carried out under natural conditions except that shelter from rain was provided by vinyl covers. The soil was a silt-loam, widely distributed in the lowland fields in Kyushu. Soil moisture in upland conditions was kept adequate, about 33% on dry basis, by maintaining the level of the water table at 13 cm from the soil surface during the experiments. Submerged conditions were created by irrigating to a depth of about 2 cm each day.

RESULTS AND DISCUSSION

1. *Emergence depth*

In general, the depth of emergence was deeper in upland than in submerged conditions, as indicated in Table 5. For instance, *E. crus-galli* var. *orizicola* emerged under upland conditions from 2.34 and 2.45 cm by methods A and B, respectively, whereas under submerged conditions the values were 0.18 and 0.21 cm. Although there is a discrepancy between methods A and B for some weeds, in general this does not seem significant. Genetic differences between weed species appear more distinctly under upland conditions; under submerged conditions, there were only slight differences probably owing to buffering by water.

The data obtained under upland conditions by method A also showed variation in amount of emergence with depth. All of the data showed a skew having the peak in the upper portion of the soil. The deepest was found at a depth of 6 to 7 cm for *E. crus-galli* and *D. adscendens*. The soil depth providing 80% emergence was obtained from a curved line derived from the relationship between emergence percentage of the total number of seeds and soil depth (see Fig. 2).

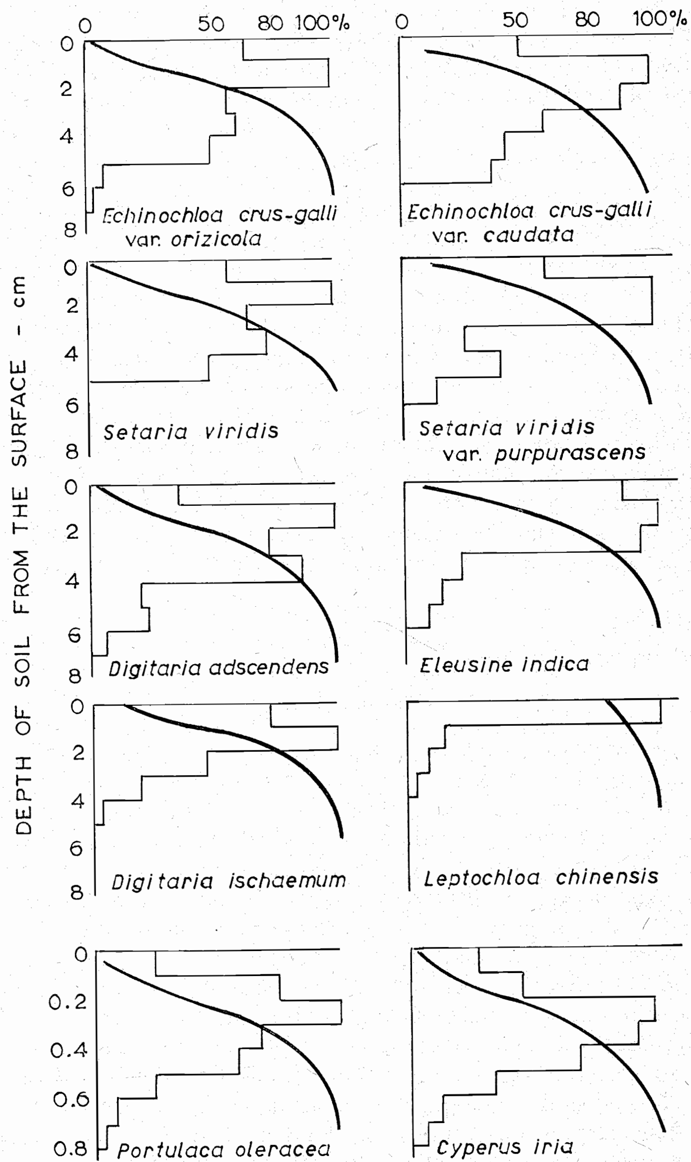

Fig. 2: Variation of seed emergence with depth. Polygons show the index of emergence number when 100 is regarded as the highest. Curves indicate the relation between soil depth and emergence percentage of total number of seeds to emerge.

TABLE 5: EMERGENCE DEPTH OF WEED SEEDLINGS BY RESPECTIVE METHODS

Weed Species	*Emergence Depth by A (cm)*	*Mesocotyl Length (cm)*	*Under-ground Shoot Length (cm)*	*Emer-gence Depth by B (cm)*	*Depth of 80% Emer-gence (cm)*
Upland condition:					
E. crus-galli var. *orizicola*	2.34	2.25	0.10	2.45	3.3
E. crus-galli var. *caudata*	2.56	2.37	0.18	3.37	3.6
S. viridis	2.45	2.42	0.04	3.93	3.2
S. viridis var. *purpurascens*	2.31	2.27	0.05	2.46	2.7
D. adscendens	2.56	2.65	0.02	3.35	3.3
D. ischaemum	1.53	1.35	0.15	2.52	1.9
E. indica	2.21	1.92	0.24	1.41	2.8
L. chinensis	0.51	0.39	0.12	0.06	0.5
P. oleracea	0.25	—	—	0.01	0.35
C. irea	0.35	—	—	0.07	0.36
Submerged condition:					
E. crus-galli var. *orizicola*	0.18	—	—	0.21	
E. crus-galli var. *caudata*	0.12	—	—	0.04	
M. vaginalis	0.12	—	—	0	
L. procumbens	0.19	—	—	—	
D. junceum	0.26	—	—	0?	
C. difformis	0.17	—	—	0.07	
F. littoralis	0.08	—	—	0?	

From the results obtained, the weed species under an upland condition can be considered as falling into the following four groups, ranging from I (deep) to IV (shallow):

I. *E. crus-galli* var. *caudata*
S. viridis
D. adscendens

II. *E. crus-galli* var. *orizicola*
S. viridis var. *purpurascens*

III. *D. ischaemum*

IV. *L. chinensis*
C. iria
P. oleracea

Needless to say, weeds having deeper emergence are, in general, hard to control with soil-applied herbicides in crop lands, and are likely to have the longest period of emergence.

2. *Growing Points of Seedlings*

The distance from the seed itself to the point of seedling emergence at the soil surface was defined as the depth of emergence. However, for grass weeds this distance can be separated morphologically into two parts — underground shoot and mesocotyl (including epicotyl which could hardly be recognized). The main depth of emergence, however, was governed by the length of mesocotyl, and the length of the underground shoot was independent of the mesocotyl length.

The length of the underground shoot refers to the distance of the growing point of grass seedlings from the soil surface, and is related to the efficiency of weed control by the application of foliar applied herbicides. The grass weeds in this experiment could be grouped by length of underground shoot as follows:

Long: *E. indica*

Intermediate: *E. crus-galli* var. *orizicola*
E. crus-galli var. *caudata*
D. adscendens
L. chinensis

Short: *S. viridis*
S. viridis var. *purpurascens*
D. ischaemum

"Long" implies a deeper growing point than "short", and weeds with this characteristic are hard to control with the foliar application of contact herbicides. For example, propanil is very effective in controlling crabgrass and barnyard grass, but selectivity between crabgrass and barnyard grass has often been found in actual application. The lower tolerance of crabgrass to propanil is possibly caused by its shallower growing point compared with that of barnyard grass. An additional difference can be noted in that of barnyard grass. Selectivity of the leaf structure of crabgrass and barnyard grass. Selectivity of green foxtail and wheat with trifluralin is reported as due to the difference in the coleoptile node area (Rahman and Ashford, 1970). The varietal differences of rice to chloropropham have been reported to be due to the development of the first node (Baker, 1960).

3. *Emergence Depth and Seed Weight*

In general, it has been said that weeds with small seeds can only emerge from shallow soil layers while large seeds can emerge

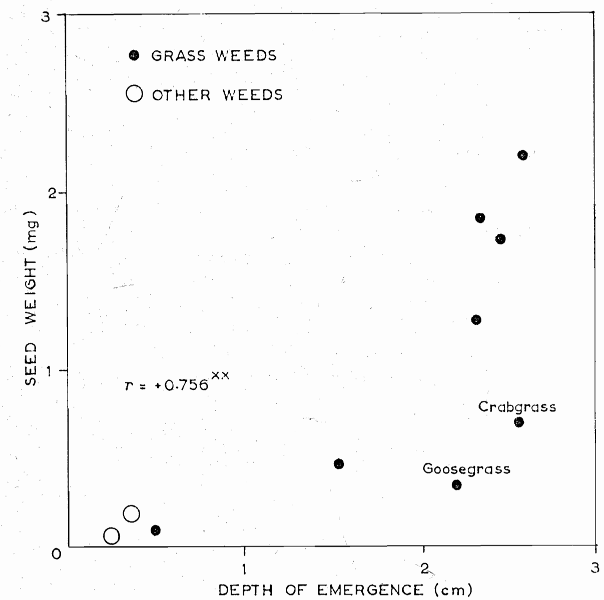

Fig. 3: Correlation between seed weight and emergence depth.

from greater depths of soil (Murphy and Arny, 1939; Hanf, 1950; Dawson and Burns, 1962; Chancellor, 1964b). A relationship of the depth of emergence to seed weight was investigated using various weed species in this experiment. The weight of weed seeds ranged from 2.205 mg for *E. crus-galli* var. *caudata* to 0.00917 mg for *R. indica*. The correlation is not high, showing a coefficient of +0.759 (significant at the 5% level) as indicated in Fig. 3. This shows that the emergence depth is not fully governed by the size of seeds; several other factors exist, such as physiological nature of embryo and endosperm. The depth of emergence appears to be governed also by various environmental factors (Chancellor, 1964b; Wiese and Davis, 1967). This problem, however, will be studied in the future.

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PROMISING NEW HERBICIDES FOR RICE IN JAPAN AND THEIR PROPERTIES

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In 1950, the herbicide 2,4-D was introduced into Japan, thus marking the beginning of what could be called the first period in the history of scientific weed control in Japan. This period, from 1950 to 1958, is characterized by successive development and practice of foliage-treatment herbicides such as 2,4-D, MCPA and MCPB.

The year 1958 marks the discovery of the effectiveness of pentachlorophenol as a soil treatment herbicide that is applied just after transplanting. Greatly aided by its preparation as a granular formulation, the practical use of pentachlorophenol expanded rapidly in transplanted rice throughout Japan. The period of development of pentachlorophenol from 1958 to 1962 can be called the second period in the history of new weed control.

The third period is the result of problems that arose as the use of pentochlorophenol rapidly increased. Pollution from this chemical, probably caused by its essential high toxicity to animals, resulted in the death of fish and shellfish, particularly in 1962 and 1963 in the southern regions of Japan. Therefore, the synthesis and development of a new herbicide having the same effectiveness of pentachlorophenol but without its toxic effect on fish and shellfish, was urgently required. As a result of extensive co-operative experimentation in Japan, several useful herbicides were found. From the initial discovery of these lesser toxic herbicides in 1963 to around 1970 might be called the third period.

At present in Japan, nearly the total area of paddy fields is being treated with herbicides. Herbicides have contributed to rice production in the following ways:

(1) They are an outstanding labour-saving device for weeding, human labour for weeding having been saved by 70%.
(2) They are relieving rice growers of the hard work of hand-weeding during the summer season.

(3) They help in the success of dense-planted rice culture.
(4) They are paving the way to direct-sown rice culture.

The principal herbicides applied in 1969 are indicated in Table 1. Soil-treatment herbicides applied just after transplanting of rice are characterized by the dramatic increase of the diphenylether type such as chlornitrofen and nitrofen. In addition, use of the swep/MCPA combination developed recently in Japan has increased considerably in northern areas. The use of pentachlorophenol and associated herbicides is tending to decline gradually because of their high toxicity to fishes and shellfish. Use of the phenoxy type herbicides, such as 2,4-D and MCPA, which have usually been applied at the tillering stage of rice, has also declined since about 1963 owing to the longer residual activity of other herbicides. On the other hand, there has been a considerable increase in the application of foliage-treatment herbicides after harvest of rice, particularly of paraquat (Table 1).

TABLE 1: PRINCIPAL HERBICIDES FOR RICE IN JAPAN, INDICATED BY AREA TREATED IN 1969

Treatment and Herbicide	*Area Treated (000 ha)*
Soil treatment:	
pentachlorophenol G	931
pentachlorophenol/MCPA G	608
chlornitrofen G	483
nitrofen G	395
swep/MCPA G	129
MCPA/chlornitrofen G	127
pentachlorophenol WP	79
prometryn G	52
pentachlorophenol/fertilizers G	46
pentachlorophenol/dichlobenil/MCPA G	40
MCPA G	34
prometryn/MCPA G	30
Foliage treatment into rice:	
2,4-D ethyl ester G, WP	395
MCPA ethyl ester G, WP	323
2,4-D amine EC	188
2,4-D sodium WP	76
MCPA sodium WP	49
Foliage treatment after rice harvest:	
2,4-D/amitrole WP	54
paraquat EC	50

G = granule
WP = wettable powder
EC = emulsifiable concentrate

Further, according to an estimate on the use of herbicides in 1970, combinations of benthiocarb, newly registered in 1969, have been applied on about 0.30 million hectares of ordinary transplanted rice, an indication of the high potential of this herbicide for rice in the near future.

At present, the most desirable properties of herbicides are a high selectivity, a wide margin of application time, and a broad spectrum of weed control as the culture of rice changes. With these aspects in mind, evaluation tests of new herbicides for rice in Japan have been co-operatively carried out by the National and Prefectural Agricultural Experiment Stations every year, sponsored by the Japan Association for the Advancement of Phyto-regulators. The results of recent experiments indicate that the following herbicides are promising:

Ordinary transplanted rice: Chlornitrofen, nitrofen, benthiocarb, benthiocarb/symetryn, benthiocarb/chlornitrofen, chlorthal/benthiocarb, RP 17623 (G-315), X-52, swep/MCPA.

Machine transplanted rice: Chlornitrofen, nitrofen, benthiocarb, benthiocarb/chlornitrofen, benthiocarb/symetryn, Tope.

Dry-sown rice: Bensulide/prometryn, MO500, benthiocarb, swep.

Water-sown rice: Benthiocarb, benthiocarb/chlornitrofen, benthiocarb/symetryn.

Some herbicidal properties of these herbicides are outlined below.

CHLORNITROFEN (GRANULE)

This is a diphenylether type herbicide developed in Japan, which acts only in the presence of light, and is very effective in controlling annual weeds by pre-emergence treatment. In addition, it is very safe to rice having only a weak action on the roots of rice and little mobility in the soil. Its disadvantages are a narrow margin of application time and no control of perennial weeds such as slender spike-rush (*Eleocharis acicularis*). At present, this herbicide is useful with both ordinary transplanted rice and machine transplanted rice.

NITROFEN (GRANULE)

Initially introduced from the U.S.A., this chemical is the same diphenylether type as chlornitrofen and has very similar herbicidal properties. It has a slightly wider margin of application time, affecting weeds at a more advanced stage, but is likely to cause more severe injury to the leaf-sheath of rice under unusually deep flooding because of its stronger action on foliage. This herbicide also is suitable for both ordinary and machine transplanted rices.

Swep (wettable powder)

This chemical was originally introduced from the United States several years ago, and is characterized by high selectivity of grass weeds. Recently, it has been evaluated for pre-emergence treatment of dry-sown rice to control grass weeds such as barnyard grass and crabgrass which are spreading rapidly in the southern areas of Japan.

Swep/MCPA (granule)

This mixture was developed in Japan. The synergistic action of the two chemicals provides effective control of grass weeds as well as annual broadleaved weeds and slender spike-rush by pre-emergence and early post-emergence treatments. However, as this herbicide has caused rice injury under higher temperatures, its application has been somewhat limited in the southern, warmer areas, being more suitable for ordinary transplanted rice in the cooler areas of Japan.

Benthiocarb (granule)

This thiolcarbamate, recently developed in Japan, may usefully control most of the principal weeds on lowland fields except *Monochoria vaginalis* and *Elatine triandra;* notably it kills slender spike-rush at pre-emergence and post-emergence treatments. High selectivity between rice and barnyard grass and a weak action on the roots of rice make application on rice very safe. The granule is suitable for both ordinary and machine transplanted rice, and its emulsion appears promising on dry-sown rice.

Benthiocarb/symetryn (granule)

A mixture of benthiocarb and symetryn is very effective in controlling a variety of weeds including *Monochoria vaginalis* and *Elatine triandra,* and has a wider margin of application time than benthiocarb alone. However, as symetryn shows considerable variation in herbicidal action under different temperatures, a defect of this herbicide is to cause rice injury at temperatures of 30° C or more immediately after application. Provided temperatures soon after application are not too high, this herbicide can be usefully applied to transplanted and water-sown rice.

Benthiocarb/chlornitrofen (granule)

This mixture of benthiocarb and chlornitrofen is as effective as benthiocarb alone, but also gives more effective control of *Elatine triandra* and other annual broadleaved weeds. It can be used on ordinary and machine transplanted rice, and on water-sown rice.

Chlorthal/benthiocarb (granule)

A mixture of benthiocarb with chlorthal appears to have additive and/or synergistic action, and is characterized by a higher selectivity between rice and barnyard grass and effectiveness to more advanced stages of weeds than other benthiocarb type herbicides. The herbicide has the disadvantage of a short residual life in the soil. It is highly evaluated for post-emergence control of advanced stages of weeds.

X-52 (granule) (2,4-dichloro-3′-methoxy-4′-nitro-diphenylether)

This diphenylether type herbicide, just recently developed in Japan, has essentially the same mode of action as nitrofen and chlornitrofen. However, its higher activity against slender spike-rush which is difficult to control with nitrofen and chlornitrofen and a longer residual activity, might make this herbicide more promising when applied pre-emergence to transplanted rice.

RP 17623 (G-315) (granule)

This new herbicide is characterized by strong activity against a wide spectrum of weeds with very low dosages. The mode of action is similar to that of nitrofen and chlornitrofen, and, although it causes temporary browning of the leaf-sheath of rice under deep flooding, this has no permanent effect. The residual activity in the soil is very long, but the mobility is not great. This herbicide is useful with transplanted rice, particularly by soil incorporation before transplanting.

BUTACHLOR (GRANULE)

This material was recently introduced from the United States, and was evaluated pre-emergence with ordinary transplanted rice, being effective in controlling grass weeds, Cyperaceae, and slender spike-rush. However, it is somewhat poor in controlling broad-leaved weeds. Long residual activity, but little mobility in the soil, are characteristics. On the other hand, mixture with other herbicides effective in killing broadleaved weeds is being studied, and is expected to show promise in rice.

TOPE

This is another diphenylether, its mode of action being somewhat different from that of nitrofen and chlornitrofen, acting under dark as well as light conditions. It is effective in controlling advanced stages of barnyard grass, and has high selectivity between rice and barnyard grass. This herbicide is promising for use with machine transplanted rice.

BENSULIDE/PROMETRYN (EMULSION)

In this mixture bensulide is selectively effective in controlling grass weeds, and prometryn can control most annual weeds. In addition, low mobility in the soil and longer residual activity on the soil surface under upland conditions have been observed. This herbicide, therefore, is suitable for dry-sown rice at pre-emergence.

MO 500 (EMULSION)

This chemical is of the same diphenylether type as nitrofen and chlornitrofen, but is stronger in its action on foliage, has a shorter residual activity and less mobility in the soil. It showed promise for pre-emergence use on dry-sown rice in 1969 experiments.

* * *

Future approaches to chemical weed control in Japan are to develop herbicides having a broad spectrum of weed control, to determine the lower limits of dosage necessary to eliminate damage by weed competition, and to clarify the fate of herbicides applied to crops and soils with particular regard to their residual toxicity to animals.

THE USE OF NITROFEN IN IRRIGATED RICE IN EAST PAKISTAN

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Summary

In this long-term study, it was found that nitrofen is ideally suited as a pre-emergence herbicide for irrigated rice in East Pakistan. The best application time is within 7 days after land preparation to avoid germination of weeds. When applied uniformly in standing water, excellent weed control was obtained irrespective of the rice variety on which it was tested. No adverse effects were observed to fish, wildlife or humans in areas where it was applied, even at rates of 5.88 kg a.i./ha. Optimum weed control was observed in fields where the granular formulation was applied at the rate of 2.74 kg a.i./ha. Avoiding the disturbance of the herbicidal layer for 30 days following application resulted in maximum weed control. However, it is very important that the treated fields are kept in moist conditions, preferably with 5 to 7.5 cm of standing water. It should be noted that no water should be added or withdrawn from the field during the first 4 days following herbicide application to ensure maximum weed control.

INTRODUCTION AND OBJECTIVES

The presence of weeds in rice fields is generally considered the most important cause of reduced rice yield from a given area. This reduction of yield is due to competition of weeds for nutrients and light, and their ability to serve as alternative hosts for insects and diseases. For this reason, herbicides will play an increasingly important role in feeding the people of this earth, especially in the northern hemisphere where rice is the primary food. With the help of pesticides and fertilizers, progressive countries have become self-sufficient and no longer have to depend on others for the provision of their major food supply.

To assist the Government of East Pakistan in producing enough food for its increasing population, the writers co-operated in evaluating nitrofen on a large-scale basis.

East Pakistan's warm climate, abundant rainfall and rich soil allow the production of three crops of rice annually. Cultural conditions of these three East Pakistan rice crops, however, vary considerably:

(1) *Aus Crop.* Little water is available for this crop at planting time (March-May). Seed is broadcast on the dry soil, with germination and early growth depending on rainfall.

(2) *Aman Crop.* This is a monsoon crop and is transplanted during June-July in deep floods (23 to 30 cm). Because of heavy rains, it is impossible to drain the field in this crop.

(3) *Boro Crop.* This crop is transplanted in November-December between the rows of unharvested Aman padi. Land preparation in this crop is good and the floods remain shallow throughout the season.

Nitrofen was developed in Japan in January, 1962, specifically as a herbicide for irrigated rice. Owing to its low fish toxicity to carp (LD_{50}, 3500) and its excellent herbicidal effect as well as safety to rice, the Japanese Government allowed it to be sold in some areas during the 1963 planting season. Generally, a three-year period of testing is required for a rice herbicide in Japan before the Government approves its use. Nitrofen is finding widespread use, specifically in Japan, Korea and Taiwan, as a selective pre-emergence herbicide.

Because of its broad spectrum of weed control, safety to rice, especially to the root system, low human and fish toxicity, relatively long residual activity, and almost complete compatibility with other agricultural chemicals, nitrofen should become one of the most important herbicides for rice in East Pakistan.

The commercial formulation "Tok Granular" ("Nip" in Japan) contains 7% of the active ingredient. This preparation was used in the trials described below.

Because of its efficacy as a rice herbicide, and its low mammalian and fish toxicity, "Tok" is of great interest to the Government of East Pakistan. The actual oral LD_{50} of "Tok" technical to rats is 2630 mg/kg ± 134 mg/kg, which compares very favourably with many other agricultural chemicals.

The Government of East Pakistan, as well as other countries, is evaluating agricultural chemicals with a view to eliminating those products that are toxic to man and wildlife. One insecticide has already been banned, owing to its high fish toxicity. Emphasis is being placed on relatively safe chemicals which preferably can be applied by hand. This emphasis is important because the farmer has practically no application equipment.

MATERIALS AND METHODS

The trials were conducted in various districts of East Pakistan, mainly in the Dacca, Joydebpur and Mymensingh areas in the Aman and Boro rice crop. Both native and improved IRRI varieties (IR-8, IR-9 and IR-20) were used. Fertilizers used on a per hectare basis up to the final land preparation were: Urea, 67.4 kg; triple superphosphate, 134.4 kg; muriate of potash, 33.7 kg.

A total of 8 dosage rates of "Tok Granular" were evaluated in this study, namely, 22.4, 30.2, 33.6, 34.7, 39.2, 44.8, 67.2 and 84.0 kg/ha. The highest rates, 67.2 and 84.0 kg/ha, were used to determine if any fish toxicity would develop. All treatments were replicated four times. Each replicate and treatment was separated by a small levee, preventing water or chemical movement from one plot to the next. The herbicide was applied within seven days after transplanting into uniformly flooded plots. In plots where water percolation and evaporation were high, water was added a few days after transplanting.

Weed counts were taken in some plots. In addition, in some experiments the numbers of tillers were counted and plant heights determined to ascertain any adverse effect on the rice plants. All control plots were hand-weeded since this is the common practice in East Pakistan. Following herbicide application, moist conditions were maintained in all trials. Wherever possible, 5 to 7.5 cm of standing water was kept on the field at all times. No water was added or withdrawn from the field during the first four days following application.

Depending on the soil and land characteristics, the principal weeds encountered in transplanted rice fields in East Pakistan were:

Amaranthaceae:
Alternanthera sessilis
Convolvulaceae:
Ipomoea reptans
Cyperaceae:
Cyperus corymbosus
Cyperus michelianus
Eleocharis obtusa
Fimbristylis miliacea
Scirpus mucronatus

Gramineae:
Leersia hexandra
Parapholis incurva
Marseliaceae:
Marselia quadrifolia
Onagraceae:
Jussiea decurrens
Pontedetiaceae:
Monochoria hastata

RESULTS AND DISCUSSION

Observations showed that, irrespective of the variety, nitrofen has no adverse effect on the rice plant. Plant height and number of tillers as well as grains per panicle and weight of 1000 grains in the treated plots were found to be not significantly different from the hand-weeded control plots. It was observed that, for maximum weed control, the herbicidal layer should not be disturbed for 30 days following application. Table 1 shows that considerable yield increases were obtained from treated fields. The average yield increase was 11.7% over the hand-weeded plots, ranging from 9.2 to 14.9%.

TABLE 1: AVERAGE RICE YIELD FROM PLOTS TREATED WITH "TOK GRANULAR" COMPARED WITH CONTROL PLOTS

Application Rate (kg/ha)	*Treated Plots (kg/ha)*	*Hand-weeded Control Plots (kg/ha)*	*Yield Difference (kg/ha)*	*Yield Increase over Control (%)*
22.4	5718	5234	484	9.2
30.2	4426	3872	554	14.3
33.6	3951	3437	514	14.9
34.7	4702	4243	459	10.8
39.2	5112	4618	504	10.9
44.8	2950	2674	276	10.3
			Average yield increase	11.7
67.2*	1660	1198	462	38.5
84.0*	1843	1475	368	24.9

*These trials were specifically conducted to study the effect of "Tok" on rice and fish.

The experiments showed that the major weeds occurring in the rice fields in East Pakistan can be effectively controlled with 39.2 kg "Tok granular" per hectare (2.74 kg a.i.). The best time for application in the field is within 7 days after land preparation. A delay will result in germination of the weeds and, thus, a reduction in rice yield. The best results were obtained when rice was transplanted the day after land preparation, with herbicide application following 3 to 4 days after transplanting.

At no time during over three years of trials were any adverse effects observed on either rice, fish or humans. Even at rates of 67.2 or 84.0 kg/ha no fish toxicity was observed.

In certain trials where algae were found, it was noted that certain species, especially the blue-green algae, were effectively controlled.

A great benefit of nitrofen is that the time of application is not critical when compared with many other rice herbicides, since it is applied before the germination of weeds. "Tok Granular" is compatible with commonly used fertilizers and insecticides and can be mixed with them, thus reducing the application cost. After application, the granules disintegrate in water and release the active ingredient, which forms a herbicidal layer on the soil surface. This layer kills susceptible seedling plants as they push through the treated soil surface and come into contact with light. This phenomenon has been studied extensively in Japan by Dr Matsunaka, Chief, 6th Laboratory of Plant Physiology, National Institute of Agricultural Sciences, who found that the herbicidal action of nitrofen is photobiochemical in nature.

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