When the seedling reached 5-7 leaf stage after 2-4 weeks, single seedling was transplanted into separate 5 cm x 5 cm pot containing prepared soil. After transplant, the pots were put in a shady and cool place for several days to protect the seedling from strong sunshine. When the seedlings recovered, the pots were put under normal sunlight again. The pots were watered on time everyday and the other unnecessary weeds were pulled out.

Herbicide application

When the seedlings grew to 11-13 leaf stages, the herbicide was applied.

Uniformity testing of herbicide application

To ensure the uniformity of herbicide application, a pre-experiment was first conducted with blue ink instead of glyphosate. The experimental operator should be invariable in order to ensure the reliability of the experiment. Nine 12 cm x 12 cm petri dishes were put evenly in one square meter area and 100 ml dilutions including 1 ml, 2 ml and 4 ml blue ink with distilled water were added to sprayer and sprayed evenly in the one square meter area respectively. Every treatment was replicated three times. The liquid in every petri dish was collected and added water to 10 ml respectively. The absorbency of this liquid was measured in wavelength of 310 nm (it had been tested that the blue ink had the biggest absorbency on this wavelength). The result was analyzed by SPSS to estimate the uniformity of herbicide application.

Method of herbicide application

The herbicide was applied by manual sprayer. The doses of glyphosate were 0, 35, 70, 140, 280, 560, 1120, 2240, 4480, 8960 g ai ha^{-1}. Spray volume was 100 ml. The operator did the same way as the former experiment. After spraying, the foliage was allowed to dry and plants were placed into a plastic tray full of water in greenhouse. The plant could get water through the hole at the bottom of the pot.

Observation of herbicide injury, standard non-linear regression analysis and account of ED50, ED90
The plants were maintained in the greenhouse after application. The first observation was conducted at 3 days after application and herbicide injury rate was recorded based on visual assessment. The same work was consistently conducted every four days until the injury symptom did not develop further. At 7-12 days after herbicide application, fresh and dry weight above ground was weighed as well when the rate herbicide injury had remarkable difference between the different doses. Data from all experiments were fitted to a log –logistic regression model (Seefeldt et al. 1995).

$$Y=C+(D-C)/(1+\exp(b*\ln(x/ED50))$$

Where Y represented herbicide injury rate, fresh or dry weight, C was the mean response at very high herbicide rates (lower limit), D was the mean response when the herbicide rate was zero (upper limit), b was the slope of the line at the ED50, ED50 was the herbicide rate at the point of inflection halfway between C and D, X was the herbicide dose. To estimate the parameters of the log-logistic response curve, a non-linear regression routine was used with the SAS software system. The value of ED5a0, ED90 was calculated by Log-logistic dose response regression equation. The glyphosate resistance of *C. canadensis* population collected from Nanjing were conducted two times. The best method would be confirmed by comparing the rate herbicide injury, fresh and dry weight.

The standard of the herbicide injury rate based on visual assessment
ck: no symptom

1. Young leaf wilted slightly, or had no symptom. The whole plant wilted slightly (the color of leave dark green, and the leave drooped).

2. Young leaf wilted and drooped, the whole plant wilted. The top of leaf curled and etiolated. Some of leaves had yellow or brown spots.

3. Young leaf curled and etiolated, some leaves were abnormal. The whole plant etiolated. 40%-70% of leaves were dead.

4. Young leaf was curled and abnormal badly. The whole plant etiolated badly. 70% of leaves were dead.

5. The whole plant wilted badly. 95% of leaves died, or the whole plant was dead.

RESULTS AND DISCUSSION

Method for culturing horseweed seedlings

By using the method described in 1.2.1, the seed of horseweed population germinated and seedlings grew very well.

Transplant

By using the method described in 1.2.2, the transplanted seedling of horseweed population had high rate of survival (above 80%).

Uniformity testing of herbicide application

Results of the variance analysis indicated no difference between the nine points in different concentrations. It showed that the spraying method used here satisfied the requirement of experimental precision for herbicide application.

Establishment of the best testing method

The responses of the *C. canadensis* population to increasing dose of glyphosate are shown in Table 2. The non-linear model provided a good description of the relationship among fresh weight, dry weight, or herbicide injury rate and glyphosate doses, obtained R^2 values of 0.90 or higher. The results showed that the quality of fit of the model was very well. But from the two-time test results, it could be found that the value of the ED50 of repeat 1 / ED50 of repeat 2 and ED90 of repeat 1 / ED90 of repeat 2 herbicide injury rate had the least value among the three observation methods. The reason was that the leaves of horseweed population treated with glyphosate withered, etiolated, and rotted unevenly and, thus it was difficult to test fresh and dry weight accurately. Moreover, fresh weight was influenced greatly by moisture. In general, the method of herbicide injury rate was easy to operate, less influenced by moisture, and it could be made at any moment during testing process. Therefore it was confirmed that the method of herbicide injury rate was the best one among three observation methods to test the glyphosate resistance of *C. canadensis* population. This method can be easily replicated.

Table 1. The uniformity test of herbicide application.

Location	Dilution multiple		
	100	50	25
1	0.157 Aa	0.299 Aa	0.561 Aa
2	0.157 Aa	0.297 Aa	0.56 Aa
3	0.157 Aa	0.297Aa	0.561 Aa
4	0.157 Aa	0.301 Aa	0.561 Aa
5	0.157 Aa	0.298 Aa	0.562 Aa
6	0.154 Aa	0.304 Aa	0.563 Aa
7	0.156 Aa	0.303 Aa	0.562 Aa
8	0.155 Aa	0.302 Aa	0.562 Aa
9	0.160 Aa	0.303 Aa	0.561 Aa

Table 2. Comparing the two-time response results to different glyphosate doses of horseweed population from Nanjing by three observation methods.

Method	Repeat1	Repeat2	ED50 1/ED50 2 $ED90_1/ED90_2$
Fresh	$Y=0.012833+0.875334/(1+(X/6.8615)^{16.9705}$	Y=0.007071+2.003243/(1+(X/2.1414)8.4393)	R of ED50=2.82
	ED50=391.19	ED50=138.4841	R of ED90=1.69
	ED90=1041.37	ED90= 616.595	
Dry	$Y=0.1415/(1+(X/7.0404)^{15.6533})$	Y=0.0023+0.298943/(1+(X/2.1534)8.1763)	R of ED50=3.29
	ED50=467.8	ED50=142.3639	R of ED90=1.93
	ED90=1351.49	ED90= 699.5198	
Rate	$Y=1/(1+(X/2.7292)^{6.8818})$	Y=0.0286+0.6857/(1+(X/2.2415)7.0039)	R of ED50=1.26
	ED50=219.78	ED50=174.3813	R of ED90=1.17
	ED90=2336.06	ED90=1994.803	

Note: Fresh= Fresh weight-dose response curve; Dry=Dry weight –dose response curve; Rate = Rate Herbicide injury

Herbicide resistance test in weeds is a bioassay method. Like other bioassay methods, the first and important step is to obtain seedlings in the same growing period (Song et al. 2004). In this experiment, the seedlings were obtained successfully by culturing in greenhouse and transplanting in 5-7 leaf stage.

The method of herbicide spraying is very important in this experiment. If possible, an advanced equipment for application should be used to ensure the uniformity of spray pressure, herbicide concentration and spray speed. However, if the advanced sprayer is not available, a manual sprayer may be used instead only when the operator is the same person, and exercised many times as described in this paper.

The experiment may be the first attempt to investigate the method for testing the glyphosate resistance in China. It was confirmed that the method of herbicide injury rate as percent visual control was the best among three observation methods (herbicide injury rate, fresh weight and dry weight) to test the glyphosate resistance of horseweed population. The experiment could be repeated very well. It is somewhat different from other reports about glyphosate-resistant test methods that the method of herbicide injury rate as percent visual control was more reliable than that of fresh and dry weight (Pratley 1999; Mark and VanGessel 2001; Perez and Kogan 2003).

The method has been applied to test 27 horseweed samples during past two years. Satisfactory results were obtained.

LITERATURE CITED

Fu D Y. 2002. Second chance of glyphosate. Pesticide, .41(10): 1-5.

Lee LimJung, Ngim J, Lee LJ. 2000. A first report of glyphosate-resistant goosegrass (*Eleusine indica* (L) Gaertn) in Malaysia, Twenty-five years of increasing glyphosate use: the opportunities ahead, London, UK, 23 February 1999. Pest Management Science, 56(4): 336-339.

Perez A, Kogan M. 2003. Glyphosate-resistant *Lolium multiflorum* in Chilean orchards. Weed Research, 43:12-19.

Powles S.B., Lorranine-Colwill D.F. and Dellow J.J. 1998. Evolved resistance to glyphosate in rigid ryegrass (*Lolium rigidum*) in Australia. Weed Science, 46(5):604-607.

Pratley J, Urwin N, Stanton R, Baines P, Broster J, Cullis K, Schafer D, Bohn J, Krueger R. 1999. Resistance to glyphosate in *Lolium rigidum.* I. Bioevaluation.Weed Science, 47(4): 405-411.

Ren B F. 1998. Research proceedings of glyphosate. Pesticide, 37(7): 1-3.

Seefelde S., Jensen J.E. and Fuerst E.P. 1995. Log-logistic analysis of herbicide dose-response relationships.Weed Technology, 9:218-227.

Song X.L., Ma B., Huangfu C.H. and Qiang S.H. 2004. Bio-assay of herbicide. Weed Science in China, (3):1-5

Van Gessel M.J. 2001. Glyphosate-resistant horseweed from Delaware.Weed Science, 49: 6, 703-705;

Xiang W.S. 1998.Transgenic crop of glyphosate resistance. Journal of Agricultural University of Northeast, 29(1): 92-98.

Mark and VanGessel. 2001, Rapid publication glyphosate-resistant horseweed from Delaware, Weed Science, 49: 703-705.

Perez A. and Kogan M. 2003. Glyphosate-resistant lolium multiflorum in Chilean orchards. Weed Research 43: 12-19

Pratley J. 1999. Resistance to glyphosate in *Lolium rigidum.* Bioevaluation. Weed Science, 47:405-411

Integrated Weed Management

Impact of weedy rice infestation on rice yield and influence of crop establishment technique

M. Azmi[1] , Muhamad, H.[2] and D.E. Johnson[3]
[1]Malaysian Agricultural Research and Development Institute (MARDI)
Locked Bag 203, 13200 Kepala Batas, Seberang Perai.
Fax. No.: 04-5751725, azmiman@mardi.my
[2]MARDI Station, 45500 Tg. Karang, Selangor, Malaysia
[3]IRRI, DAPO Box 7777, Manila, Philippines

Abstract: Weedy rice (*Oryza sativa* complex) is one of the most serious threats to rice production in Malaysia. First observed in Sekinchan, Selangor in 1987, it has now spread throughout the major rice-growing regions in Peninsular Malaysia and is a cause of concern. Assessments of yield losses were undertaken and it was found that for every 10 panicles m^{-2} of weedy rice recorded approximately 30 g grain m^{-2} of rice was lost. Infestations ranged from 0 to 134 panicle m^{-2} of weedy rice. While weedy rices are morphologically variable, their close similarity and relation to the cultivated crop necessitates the integration of weed control measures focusing on cultural control measures.

A field scale, exploratory study evaluated the impact of water seeding (pre-germinated rice seeds broadcast onto standing water) and mechanical transplanting on areas previously cropped by wet seeding (pre-germinated rice seeds broadcast onto puddled soil) as per local practice. In the area where water seeding had been practiced the population of weedy rice declined by more than 90% after two seasons. Likewise, where mechanical transplanting was practiced, infestations declined to about 35% of previous levels. In the water seeding and transplanted crops the decreased weedy rice infestations were associated with increased rice yields.

Key words: Weedy rice, direct-seeded rice, water seeding, wet seeding, mechanical transplanting

INTRODUCTION

Direct seeding (DS) has replaced the traditional manual transplanting of rice in the main rice production areas of Malaysia. Field scale direct seeding began in the Muda area in 1977 (Ho 1982) and thereafter expanded rapidly. In 1990, this method accounted for 70% of the main season crop area and 80% of the second. Currently, all rice production areas in Peninsular Malaysia are direct seeded. Seeding with pre-germinated seed is the preferred method and this requires effective water management for good crop establishment. DS is normally undertaken either by hand broadcasting or using motorised blower. Currently, weedy rice is a major constraint to DS rice production. The term "weedy rice" refers to easy shattering weedy forms of rice that infest rice fields, and these are particularly problematic in direct-seeded areas (Azmi and Abdullah 1998). Broadcast seeding and the use of combine harvesters are thought to be the main cause for the rapid spread of infestations. Serious crop losses occur as weedy rices compete strongly with the cultivated rice but, due to shattering, weedy rice does not contribute to the harvest yield. In Muda area, shattering of weedy rice grain was observed to be 10-20 days before maturity of the rice variety MR 84 (Watanabe 1995). Watanabe et al. (1996) also reported that in rice crops with about 35% weedy rice infestations the rice yield was reduced by 50-60%. With a more serious infestation, yield loss of 74% was recorded in direct- seeded rice (Azmi and Abdullah 1998). Further, most weedy rice variants have grains with purple to reddish seed coat or pericarp, as in red rice grain (Diarra et al. 1985), which reduces the value of the crop. Weedy rices have also been observed in Vietnam (Chin et al., 2000), Philippines (Baltazar and Janiya 2000) and Sri Lanka (Marambe and Amarasinghe 2000). The common denominator for this increasing spread in tropical Asia is intimately linked with the increasing use of direct-seeded rice culture in the region (Moody 1994).

This paper reports the results of studies carried out to determine 1) the rice yield losses caused by different infestations of weedy rice and 2) the effect of mechanical transplanting and water seeding on established populations of weedy rice in a field scale, exploratory study.

MATERIALS AND METHODS

Yield loss study

The objective was to determine the effect of various densities of weedy rice infestation on rice yields of DS rice. Two heavily infested rice fields that had been in regular rice production were selected in Sungai Panjang, Selangor. Each field was 1.2 ha in size and in off season 2004 was sown with different rice varieties namely MR 220 and MR 211. In randomly placed quadrats, the number of weedy rice panicles were counted before crop harvest and subsequently rice yield recorded from the same. Twenty eight quadrats were taken from each field.

Impact of mechanical transplanting and water seeding

This study was conducted in Sawah Sempadan, Selangor beginning in the main season 2002 to the off -season 2004. Two fields (L76 and L65) that had been in regular cultivation of wet seeded rice and heavily infested with weedy rice were selected for this study. Both fields were used for rice production in the main season of 2002, and this was direct, wet sown at a seed rate of 150 kg ha^{-1}. The density of weedy rice in each field was estimated each season from fifty quadrats (1m x 1m) at heading stage of the crop commencing in main season 2002. The quadrats were systematically placed at the same location on each occasion to allow a comparable estimation of weedy rice panicles m^{-2}.

In the off season 2003, main season 2003 and off season 2004 the fields were prepared as per the schedule and operations described in Table 1. The crop in L76 was established by mechanical transplanting and L65 was water seeded. For water seeding, 200 kg ha^{-1} of pre-germinated seeds were broadcast into 5 -10 cm depth of water in fields flooded two days earlier. In the transplanted field 15 day old seedlings were planted at 30cm spacing and 18 cm inter rows and the field flooded two days later. Variety MR 220 was used in both fields. In the water seeding field, weeds other than weedy rice were controlled by a tank mix of quinclorac (200 g a.i. ha^{-1}) and pyrazosulfuron (12 g.i. ha^{-1}) applied at 12 DAS, followed by metsulfuron/bensulfuron (20 g ai ha^{-1}) at 30 DAS. Water depth was maintained at 5-10 cm from sowing until 2 weeks before harvesting. In the case of transplanted field, quinclorac (200 g a.i. ha^{-1}) was applied at 12 days after transplanting (DAT) followed by metsulfuron / bensulfuron (20 g a.i. ha^{-1}) at 30 DAT. Fields were flooded at 3 DAT and the flood maintained as in water seeded field. In off-season 2004, the fields were sown with pre-germinated broadcast seed after draining the field. Fields were inundated 12 DAS and flooding was maintained until 2 weeks before harvesting.

Table 1. Land preparation for evaluation of water seeding and transplanting to control weedy rice, Sawah Sempadan, Selangor, off-season 2003 and main season 2003.

DAH	Operation	Remarks
0	Clean drains	For better water control.
0-1	Cut stubble	Rotary cutter attached to 4-wheel tractor is used for this operation. Straw and stubble spread evenly.
1-3	Burning	To destroy weedy rice seeds on the soil surface and to promote new emergence of weedy rice from seed bank.
11-13	1st tillage (dry) (shallow rotovation to 7.5 cm depth)	Control of established weeds and encourage germination of weedy rice.
21-23	2nd tillage (wet) and minor levelling	To destroy and encourage germination of weedy rice seeds.
38-40	Final tillage	Rotovation of flooded soil ("puddling") to eliminate emerged weedy rice and for land smoothing.

DAH = days after harvesting;

RESULTS AND DISCUSSION

The density of weedy rice panicles in the MR220 field ranged from 0 to 121 panicles per m^2 (Figure 1) with a mean number of 40.4 (SD ±42.4). In the second field, the range was from 0 to 134 panicles per m^2 (Figure 2) with a mean of 42.9 (SD ±41.7). The relationship between the weedy rice population and the yield of rice was similar for the two fields with increasing numbers of weedy rice panicles being associated with a rice yield decline equivalent to about 30 g grain per m^2 of for every 10 panicles per m^2 of weedy rice present.

In the second study, field L76 recorded a marked reduction in the weedy rice infestation after two consecutive seasons of transplanting and the weedy rice panicle density was reduced to about one third that in the first season (Figure 3). In the fourth season however, after reversion to wet broadcast seeding, weedy rice density had increased significantly compared to the previous transplanted crop. Rice yields increased significantly from 4093 kg ha^{-1} in main season 2002 to 7100 kg ha^{-1} in main season 2003, though they decreased in the fourth season. Similarly, Kim et al. (2000) recorded more than 90% reduction in weedy rice occurrence by machine transplanting in Korea over three years of trial. In field L65, water seeding too had a marked effect on the weedy rice population and crop yield (Figure 4). The weedy rice panicle numbers fell to less than 10% of the original number after two consecutive seasons and the rice yield almost doubled over the same period. Furthermore, after reversion to wet broadcast seeding in the fourth season, weedy rice population increased significantly and again grain yield of the crop was reduced.

Land preparation in the two fields had been identical up to crop establishment. In L65, pre-germinated rice seeds were broadcast directly onto the field flooded to a depth of 5 -10cm. With water seeding the seeds sink to the soil surface from where the coleoptiles grow to emerge from the water surface. As the field remains flooded until a few weeks before maturity many weed species, including weedy rice, are inhibited from germinating by the submersion. Such crop management is dependent on the farmer having access to adequate irrigation water and soil that is relatively impermeable to allow the flood to be maintained. It is also dependent on the flood water being relatively clear, as turbid water is likely to inhibit the emergence of the rice seedlings. Fields need to be well levelled, as if the water is too deep in portions rice seedling will not emerge and if too shallow the weeds and weedy rice will grow. In L76 the rice seedlings were transplanted into saturated soil but not flooded soil. This lack of water around transplanting time gave weedy rice an opportunity to emerge and weedy rice seedlings were noted at this stage. Emergence of weedy rice may have been avoided by earlier flooding after transplanting.

Weedy rice is particularly difficult to control due to its close relation to the crop. The severity of infestation depends greatly on the size of the soil seed bank and successful control is likely to be achieved only with integrated measures to reduce the seed multiplication. Cultural practices of uniform burning of rice straw and stubble after harvest, repeated tillage in land preparation as stale seedbed measures contribute to depletion of the seed bank, but success is partly dependant on weather conditions that promote germination of weedy rice from the seed bank. Failure to promote germination of weedy rice during land preparation may lead to severe infestation during crop growing period. Suppression of weedy rice emergence may be achieved by maintaining flood water in the crop, either after water seeding or transplanting, appear to be options permitting higher yields on infested fields.

Partial budget analysis of the two systems showed that net returns per hectare in off season 2003 from water seeding were greater (RM 1420.97 / USD373.94) than with mechanical transplanting (RM 399.52 / USD105.14). These higher returns with water seeding were due to higher yield obtained. In the subsequent season (main season 2003), rice yields obtained from both methods were more than 1 ton ha^{-1} more than that obtained in off season 2003 resulting in much better return. These improved yields were a reflection of the successful control of weedy rice using either water seeding or transplanting.

CONCLUSION

The crop losses attributed to weedy rice in this study are substantial. Our estimates suggest that, at the yield levels being achieved in the study area, infestations represented by about 35 weedy rice panicles per m^2 will cause a yield loss of about 1 t rice grain ha. The subsequent study indicates that these losses in Malaysia may be reduced through cultural measures. Integrated measures based on either water seeding or mechanical transplanting techniques appear to provide valuable alternatives to the usual wet seeding practice and these led to improved weedy rice control on infested areas. Further studies are however required in order to validate these initial findings.

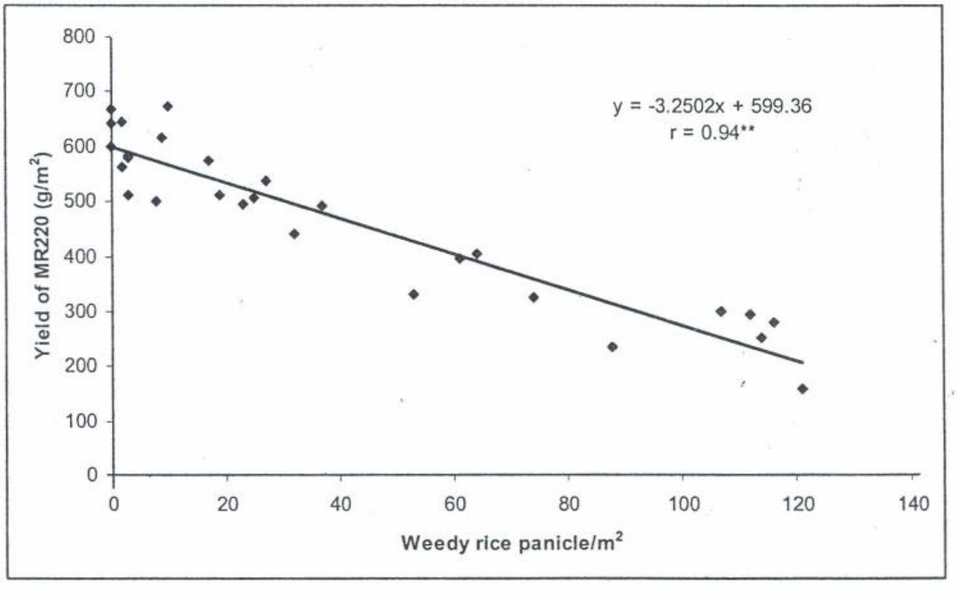


Figure 1. Relationship between number of panicles of weedy rice m^{-2} and grain yield m^{-2} of MR 220, off season 2004.

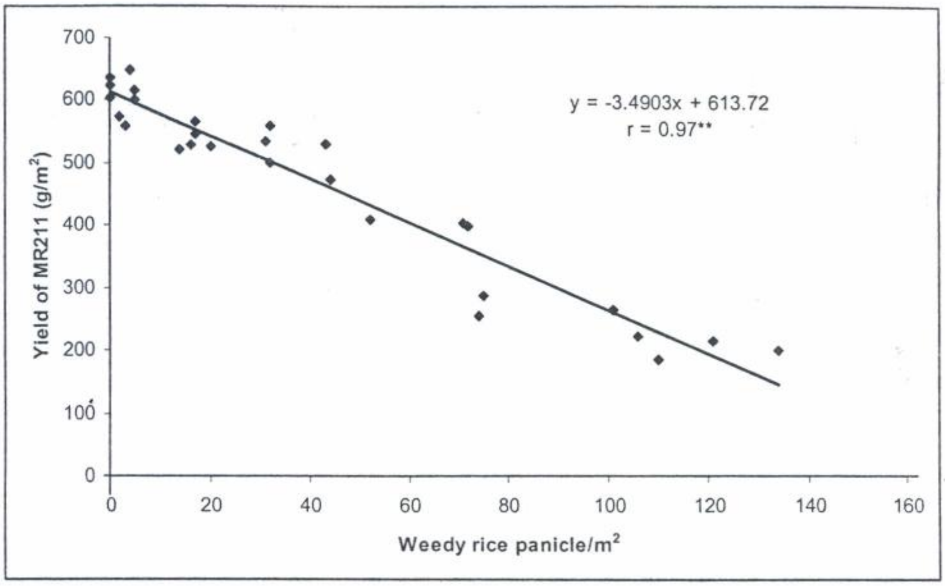


Figure 2. Relationship between number of panicles of weedy rice m^{-2} and grain yield (g m^{-2}) of MR 211, off season 2004.

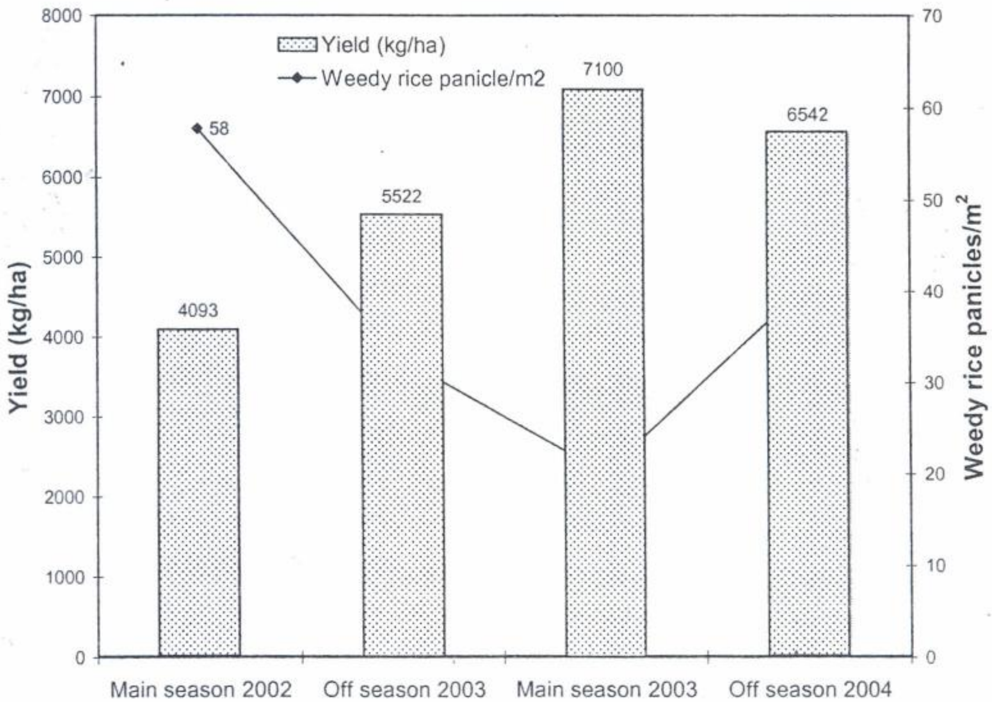


Figure 3: Effect of different establishment methods on weedy rice and rice yield in (L76 – transplanting in 2003) over four consecutive seasons (see text for details of crop management). SED for weedy rice panicle numbers ± 5.9.

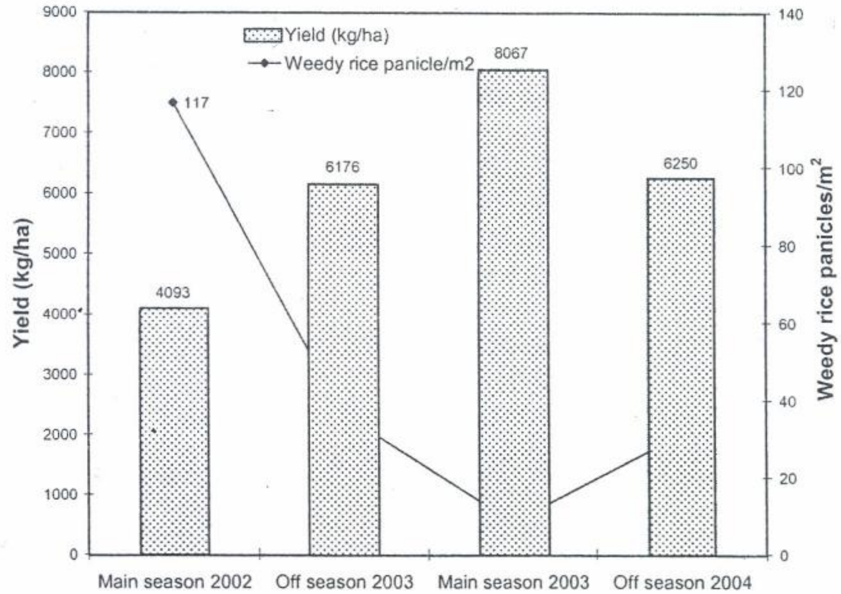


Figure 4: Effect of different establishment methods on weedy rice and rice yield in (L65 – water seeding in 2003) over four consecutive seasons (see text for details of crop management). SED for weedy rice panicle numbers ± 6.4.

ACKNOWLEDGEMENTS

The authors are grateful to Messrs. Chew See Eng, Nur Khairani, Saharuddin Shari and Abdul Hamid for helping to conduct weed surveys and implementing the experiments, and to Violeta "Beng" Bartolome for assistance with the statistical analysis. The project was funded by MARDI under the R-IE032-0903 Research Grant, Ministry of Science, Technology and Environment, Malaysia and International Rice Research Institute (Kod 80202).

LITERATURE CITED

Azmi, M. and Abdullah, M. Z. (1998). *A manual for the identification and control of padi angin (weedy rice) in Malaysia*. MARDI Publication, Serdang. pp. 18.

Azmi, M. and Baki, B. B. (1995). The succession of noxious weeds in tropical Asian rice fields with emphasis on Malaysia rice ecosystems. *Proceedings I(A), 15th Asian Pacific Weed Science Society Conference*. Tsukuba, Japan. 51-67.

Baltazar, A. M. and Janiya, J. D. (2000). Weedy rice in Philippines. *Proceedings of Wild and Weedy Rice in Rice Ecosystems in Asia – a Review* (Baki, B.B., D. V. Chin, and M. Mortimer, Eds). Pp. 75-78.

Chin D. V., Hien, T. V. and Hien T. V. (2000). Weedy rice in Vietnam. *Proceedings of Wild and Weedy Rice in Rice Ecosystems in Asia – a Review* (Baki, B.B., D. V. Chin, and M. Mortimer, Eds). Pp. 45-50.

Diarra, A., Smith, J. R. and Talbert, R. E. (1985). Interference of red rice (*Oryza sativa*) with rice (*O. sativa*). *Weed Science*, 33: 644-9

Ho N. K. (1982). *The Future of Direct Seeding in the Muda Area*. MADA. Pp. 27.

Kim, S. Y., Yang, S., Sung, T. P. and Ho, Y. K. (2000). Cultural management to control weedy rice in paddy field. *Korean J. Crop Sci*. 45(4):232-236.

Marambe, B. and Amarasinghe, L. (2000). Weedy rice in Sri Lanka. *Proceedings of Wild and Weedy Rice in Rice Ecosystems in Asia – a Review* (Baki, B.B., D. V. Chin, and M. Mortimer, Eds). Pp. 79-82.

Moody, K. (1994). Weedy forms of rice in Southeast Asia. Paper presented at the MARDI Workshop on Padi Angin, 18 May 1994, Kepala Batas, Penang, Malaysia, 5p.

Mooroka, Y. and Jegatheesan, S. (1996). Introduction. Recent advances in Malaysian rice production - direct seeding culture in the Muda area. MADA/JIRCAS. Pp. 3-20.

Watanabe, H. (1995). Weedy rice problems in Southeast Asia and control strategy. *Proc. of 15th Asian-Pacific Weed Science Society Conf.*, p. 68 - 80. Tsukuba, Japan: Asian Pacific Weed Science Society

Watanabe, H., Azmi, M. and Md. Zuki, I. (1996). *Ecology of Major Weeds and their Control in Direct Seeding rice Culture of Malaysia.* MARDI/MADA/JIRCAS Collaborative Study (1992-1996).

Theoretical considerations in Artificial Neural Networks (ANNs) in predicting rice yield in Malaysia

M. Sorayya[1], B. Mohd. Sapiyan[2], and Baki Hj. Bakar[1]
[1]Institute of Biological Sciences, University of Malaya, Kuala Lumpur, Malaysia
[2]Department of Artificial Intelligence, Faculty of Computer Sciences and Information Technology, University of Malaya, Kuala Lumpur, Malaysia
sorayya@um.edu.my

Abstract: Agronomic practices, edaphic and water regimes and weed management can be manipulated to improve rice yields. Setting a realistic yield goal is one of the critical problems in precision farming. The ANN technique can be used to build a rice yield prediction model for precision farming application. As an automated learning tool, the artificial neural network (ANN) is an attractive alternative for processing massive data generated by precision farming. Precision farming aims to improve cropping efficiency by variable application of treatments such as fertilizers, pesticides, crop management practices, etc, on a point-by-point basis within fields. Factors affecting rice yields, namely, soil, water regime, agronomic practices and weed management, are quite complex, and the assessment and analytical techniques by way of traditional statistical methods are unable to produce accurate results. Therefore, a complete understanding of the relationship between yield and factors or variables that affect yield is critically important in precision farming. An important step in this process would include a search for techniques that are able to identify functional relationships between factors that affect crop yield with high accuracy. Investigation on application of ANN has been carried out in several crops, including corn. These findings will used to develop a theoretical framework in the application of ANNs in predicting rice yield in Malaysia. This paper reviews and discusses the use of Artificial Neural Network (ANN) technique in predicting rice yields in Malaysia.

Key words: Artificial neural networks (ANNs), precision farming, rice yields, agronomic practices, crop management.

INTRODUCTION

Rice is grown on *ca.* 667,000 ha of arable land in Malaysia with an average farm size of 1 – 2 ha (Baki 2005). Because of the small farm size, problems of economy of scale in production and profitability often prevail. A perennial problem faced by rice farmers is weed infestation, and management of rice weeds is a constant battle among farmers, extension agents and policy makers, requiring both inputs and manpower. Such inputs, of course, represent direct monetary loss to rice farmers.

While constant effort is being made to combat the weed menace through research and extension activities, not all farmers are accessible to weed control technologies due to inherent constraints such as low literacy rates, poor communication skills, inaccessibility to credit facilities and effective herbicides, and other control measures, *inter-alia*, among rice farmers. Rice farmers search for effective ways to broaden the increasingly narrow margin of profit between production costs and crop returns. However, unlike their counterparts in many developing economies, Malaysian rice farmers enjoy government support through farm inputs subsidy and premium price support system, besides getting access to credit facilities and extension services.

Weeds remain a universal scourge in rice fields world wide, inflicting yield losses ranging from 10% to 85%. Baki & Azmi (1994) estimated yield loss of *ca.* 15% due to weeds in rice in Malaysia. Weed incidences are a function of several edaphic factors, and agronomic and weed management practices. Quite often, attainable rice yield is influenced by an interplay of rice varieties, fertilizer regimes, agronomic and weed management practices, while the resultant yield loss is a display of the after effect of the degree of weed infestation, species composition, weed control effort, and harvesting technology. In this context, weeds inflict more yield losses in rice fields than any other pests. More need to be done to alleviate rice farmers from facing constant and perennial problems of weeds, and experiencing severe yield losses. The use of integrated weed management (IWM) through high yielding, fast growing, and competitive rice cultivars, judicious herbicide use and water management, efficient agronomic practices, and herbicide-tolerant varieties to control weeds is the right direction in this effort, not only to increase yield but also to protect the environment and ensure sustainability of resources for rice production. Cost-effective methods for managing weeds could help increase yields and preserve profits. There are enough evidences demonstrating the efficient herbicide-based integrated weed management of the weed through precision agriculture to control barnyard grass and other rice weeds (Valverde et al. 2000; Hetherington 2001; Smith et al. 2001; Azmi *pers.comms.*). Yield predictions rely on chartered information in the database in addition to the availability of a robust computer-aided prediction system.

This paper highlights some of the theoretical considerations in artificial neural networks (ANNs) in predicting rice yield in Malaysia.

ARTIFICIAL NEURAL NETWORKS AND YIELD PREDICTION

Prediction of yields of strategic crops such as rice is an important step in national and international economic planning. Recently, the application of Artificial Neural Networks (ANNs) has been developed into a powerful tool that can compute most complicated equations and numerical analyses to the best approximation. The ANNs is a precursor in the effort to develop a weed management decision-support system in rice in Malaysia. We believed that being a fast developing nation with a burgeoning population; Malaysia should take advantage of this powerful technology to enhance productivity of her agriculture sector. We propose a suitable ANNs framework that can be applied for rice yield prediction in Malaysia. If a network that is correctly designed encompasses the relationships between factors affecting crop yield, and with sufficient useful data test to assess the effect of the relevant factors employed, the ANNs can be used as a tool to generate a good model estimate for rice production. Furthermore, using ANNs assessment of factors that strongly affect rice yields can be made. In so doing, the identification and selection of the most influential and consequential of such factors can then be made, ignoring perhaps those irrelevant and insignificant factors, where data gathering are difficult, costly or redundant.

Lately, data mining tools are used in analyzing massive data sets from complicated systems and providing high-quality information (White and Frank 2000). The application of Artificial Intelligence (AI) such as Artificial Neural Networks (ANNs), Fuzzy Systems and Genetic Algorithm is an attractive alternative for building a knowledge-discovery environment for a crop production system, and their applications can model the complex natural processes involved in crop yield predication more conveniently and with great accuracy.

Thai and Shewfelt (1991) and Tumbo et al. (2002) reported that neural networks models out-performed traditional statistical models. Zhang et al. (2002) argued the inherent advantage of neural networks needing no previous knowledge of the system being studied to determine the relationship that exists between the inputs and outputs. Furthermore, neural networks are capable of forecasting data patterns that are too complex for the traditional statistical modeling, as well as being able to detect patterns and trends in any set of data given, including the highly unorganized and variable data sets (Ballard 2003).

Drummond et al. (1995) applied feed-forward, back-propagation ANN for corn and soybean yield predictions based on soil properties, including phosphorus, potassium, pH, organic matter, top-soil depth, and magnesium saturation as inputs, and these were compared with the results of other statistical models. Drummond et al. (1995) compare the performance of different modeling techniques, generating a set of Coefficient of Multiple Determination (R^2) values (Table 1). The R^2 values are a statistical estimate of how well a model fits the actual data. It was evident that the ANN performed better *vis-à-vis* other methods based on the R^2 values, thereby providing a clearer picture in understanding yield variability. However, the network model needed further refinement to increase accuracy as the ANN did not include weather information and other agronomic and soil factors.

Table 1. Comparison for yield prediction for various techniques*

Model	Yield Estimation (1993)		Yield Estimation (1994)	
	R^2	Standard. Error (Mg ha^{-1})	R^2	Standard. Error (Mg ha^{-1})
Multiple Linear Regression	0.21	1.2	0.42	0.26
Stepwise Multiple Linear Regression *(9 soil parameters, 6 best terms)*	0.23	1.19	0.43	0.26
Stepwise Multiple Linear Regression (*6 soil parameter + interactions, Significant terms*)	0.27	1.16	0.57	0.22
Partial Least Squares Regression (*6 soil parameters*)	0.21	1.2	0.41	0.26
Projection Pursuit Regression (*6 soil parameters*)	0.57	0.88	0.73	0.18
ANN (*6 soil parameters*)	0.54	0.94	0.67	0.19

* after Drummond et al. (1995).

Literature search on various non-linear techniques for yield prediction, including neural and fuzzy techniques have been made in this study, and the results are summarized in Table 2.

An ANN trained to relate crop yield to the factors that affect yield could be very useful in setting more realistic target yields within fields for precision agriculture. However, an ANN trained to predict yield accurately in one field might not be accurate in another field. If some unmeasured factors influenced yields, the training process might set weights that compensated for the omissions in the field used for training. If the level of those unmeasured factors differed in another field, the neural network trained in the first field would be inaccurate in the second field. One clear advantage of the ANN is that it may be practical to do initial training on a field with a large database, and then re-train the network for other fields with much smaller databases. The ANN topology could be the same for all fields, but through re-training, ANN weights could be specific to each field. Moreover, the weights for each field could be updated through re-training each time a new crop was harvested. (Liu et al. 2001)

Table 2. Reviews of selected studies.

Focus of the work	Comments	Author
Fuzzy logic expert system to predict corn yields based upon a variety of measured and estimated factors	Method has reported positive success.	Ambuel et al. (1994)
Back-propagation and radial basis function neural networks to estimate crop yields	Data on soil, weather and management factors have been used to estimate yields over a number of years. Their findings were promising, though some over fitting was evident and no validation results were reported.	Liu and Goering (1999)
Yield Prediction involving a large number of variables for one site year of data, *viz.* fertility, satellite imagery and soil conductivity	Limited success	Shearer et al. (1999)
Comparison of back-propagation neural networks and linear methods in accuracy of yield prediction	Reported achieving greater training accuracies compared to liner methods. However, compared with progression pursuit regression (PPR) method, the former method elicited lower training accuracies (Friedman and Stuetzle, 1981).	Sudduth et al. (1996)
Supervised feed-forward neural methods on one site-year of the data set used by Sudduth et al. (1996).	Findings revealed that training accuracies nearly as high as those produced by progression pursuit regression PPR.	Drummond et al. (1998)

PROPOSED FRAMEWORK ARTIFICIAL NEURAL NETWORKS DEVELOPMENT

The objective of this study was to propose a suitable ANN framework that can be used in the selection of the best or most appropriate estimators of rice yield and assessing the performance of a trained neural network in predicting rice yield in Malaysia.

We suggest that the Neural Network architecture is back-propagation, fully connected, feed-forward neural network. Gautam et al. (2003) pointed out that back-propagation architecture is best suited to develop prediction models with noisy data sets and many inputs. This is the case in rice yield prediction as the effort involves massive volume of data and a sizeable number of variables that affects the yield. The back propagation algorithm is a supervised learning method for multi-layer perceptron networks with sigmoid activation units. However, it has generally been recommended for use in the linear function. This is because using linear function has been prove to be better than the non-linear function aimed at solving problems with a non-linear trend.

a) Input factor selection: The number of inputs needed must be determined before developing an ANN. All the important factors should be included in the input layer. The input factors selection was based on agronomic knowledge. Analyzing rice growth and development is the first step in understanding the input factors.

(i) Rainfall. Rice is a semi aquatic plant and does not need standing water for a successful rice crop. However, uncertainty of water supply, either through irrigation or rain, and to reduce weed infestation rice is always cultivated as a crop with standing water. Greatest water use is during the preparation of land, thus land preparation with minimum timing and maximum use of rain water at the correct time of the season is recommended. In cases of zero tillage technology, minimum water use prevails.

(ii) Soil physico-chemical traits and fertilizer application regimes. Invariably, soil fertility and fertilizer regimes are two important factors affecting rice crop growth and yields. Most soils cannot supply all the essential nutrients for continuously cropped soils, so they must be supplemented with fertilizers. The measurement of available P and K and yield goal information are used to make P and K fertilizer recommendations. The present standard recommendation for fertilizer application of 100 kg N: 30 kg P: 30 kg K for rice is too general to be relevant and applicable to all paddy soils in the country (Aris Junus *pers comms.).* This became more irrelevant in marginal paddy soils, namely, the acid sulphate soils in southern district of MADA and the clayey soils of KADA in Keleantan. Further, the government fertilizer subsidy for rice is based on the 100 kg N: 30 kg P: 30 kg K, making it ill-suited for problem and marginal paddy soils prevailing in the country. The edaphic factors such as soil pH, soil types/series, and fertilizer augmentation to enhance fertility will subsequently influence rice yields. Incorporating these factors in yield modeling is essential for accuracy and reliability of the models generated through the ANNs.

(iii) Management and Agronomic Factors. The following management and agronomic factors need to be considered in the development of ANNs. A proper seed selection, preferably the certified seeds from authorized seed supplying company or agency, should be used. In Malaysia, the Department of Agriculture through its Seed Technology and Supplying Unit supply certified seeds, free from weed seeds impurities, diseases and pests to rice farmers at minimal costs. Planting density in the case of transplanted crop, or seeding rates for direct-seeded rice culture matter most in the assessment of standing crops in the field to be assessed or modeled. There are enough information available in the local and international literature on planting density or seeding rates of rice to be put in the database for yield modeling studies (Azmi and Aris Junus *pers comms.*). In Malaysia, crop rotation in paddy fields is not a universal practice among farmers, except for those in the peasantry group, notably in hill paddy. In the irrigated granaries, the weather- and water availability-mediated variability in yields due to seasons represent an important aspect that need to be considered thus appropriately incorporated in the inputs data of the modeling effort. Other random unpredictable and unusual factors, such disease incidences, pest outbreaks, infestation by weeds need to be incorporated as well in the input variables.

Thus before developing the Neural Network, yield will be expressed as a function of factors affecting the yield. Yield = f(SF, WF, MF, AGF, EF)
where:

SF = Soil Factors *(Soil series/type, pH, fertility status).*

AGF = Agronomic Factors *(Tillage (wet/dry); Irrigation; Fertilizer regimes (100: 30 :30 / 80: 20 : 20); Variety (MR84 / MR 220); Seeding rate (90 / 60 / 20 kg); Seeding type (dry , wet)).*

MF = Management Factors *(Weed management, Pest control, Planning density).*

CF = Climatic Factors *(Season, rainfall pattern, density, temperature).*

b) Data Source: The Tanjung Karang Rice Irrigation Project in Northwest Selangor Malaysia (PBLS) was selected for this study. The PBLS has an area of *ca*. 37,340 ha or 9.46% of the total acreage of rice in the Peninsular Malaysia producing no less than 178,074 t of rice (Anon 2002). The average yield is 4.769 t ha^{-1}. The data required for this study need to be collected as there are no sufficient previous data available. The data sets from the 2005 - 2007 cropping season will be used. However, data collection process will be continued in order to achieve a better result. Data collection is carried out by using a survey form that referred in the appendices. The survey form is designed as such where all the factors which are directly and indirectly influence rice yield are collected.

c) Training and Test Set Preparation: Lacroix et al. (1997) reported that data pre-processing can greatly assist ANN learning, and it may sometimes be essential to enable an ANN to detect patterns contained in the learning data set. A test data need to be selected using a sampling method from the data collected from the Tanjung Karang Rice Irrigation. The test set will be withheld from training and will be used only to verify the prediction accuracy of the ANNs. Stratified sampling approach can be used to selected data that will be used as test data set. Others suggested the "split-sample" approach whereby a subset of the data is withheld from training. A measure of the accuracy of prediction on this validation set will then be reported. In small data sets, results can be misleading. More reliable methods of generalization estimation exist, such as cross-validation (Stone 1973). In *k*-fold cross-validation, the data is divided into *k* subsets of equal size. The function approximation technique is then applied k times, each time leaving out one of the subsets, and using only that subset to compute the generalization statistic. Cross-validation has generally been accepted as superior to "split sample" techniques, particularly on small data sets (Goutte 1997). However, in practice the selection of *k* is not an easy task. An extremely large choice for *k* can make the computational problem complicated. An extremely small choice of *k* may cause the generalization estimate to be unreliable. Drummond et al. (1998) reported that acceptable generalization results using a five-fold cross-validation technique on a single site-year of data which can keep the computational complexity of the problem manageable.

d) Planned Network: The transfer function proposed for each neuron in the hidden layer and output layer is sigmoid function. However, the use the linear function will also be considered because it has been proven that using linear function is better than the non-linear function aimed at solving problems with a non-linear trend.

Function approximation is the task of learning or constructing a function that generates approximately the same outputs from input vectors as the process being modeled, based on available training data (Mehrotra et al. 1997). The back-propagation neural network is a universal approximate (Haykin 1994). Given sufficient hidden units, multi-layer feed-forward network architectures can approximate virtually any function of interest to any desired degree of accuracy (White et al. 1992). The network training will use data from the Tanjung Karang Rice Irrigation. The input factors assumed to influence rice yield are cited in text.

e) Parameter selection: For a feed-forward, back-propagation network, the important parameters include initial weights, learning rate, number of hidden elements, and number of training epochs. Trial and error method need to be applied once the network is constructed to select the parameter values that would give the most accurate predictions.

f) Performance Evaluation: After the ANN is trained; its performance needs to be evaluated in several aspects. Evaluation process can be carried out by using the following three approaches: (i) Sensitivity Evaluation, (ii) Genetic algorithm (GA), (iii) Calculating Prediction error and (iv) Root Means Square Error (RMS). For sensitivity evaluation, proposed evaluation can be carried out by looking at the effect of each input factor on output yield. A test example needs to be randomly selected and each input will be varied over its actual range while all other inputs will hold constant. The output yield then can be plotted versus each input factor. Proposed evaluation using GA can be carried out to predict a yield when all the conditions are optimum. A genetic algorithm (GA) can be applied to search the range of each of the input factors to determine the combination that would produce the theoretically maximum yield. GA is an optimization procedure that finds global, not local, maximums. The GA is an adaptive search method that is modeled after the genetic evolutionary process. Briefly, one combination of input variables is a string, and a collection of strings is a population. At each iteration, known as a generation, each of three GA operators, *viz.* reproduction, crossover, or mutation, is applied to each string. The trained ANN performance can also be evaluated by conducting a sensitivity analysis. A base-case yield needs to be calculated with each input factor set at the midpoint of its observed range. Then the first input factor will be incremented by 10% of its range and the yield was calculated while all other input factors were held constant at their range mid-point. The base-case yield was subtracted from the incremented yield to determine the sensitivity of the calculated yield to the first input factor. This process needs to be repeated for each of the other input factors.

The accuracy of the trained ANN can be evaluated by calculating prediction error using the below formula:

$$\text{Prediction error} = \frac{\text{Predicted yield} - \text{actual yield}}{\text{Actual yield}} \times 100\%$$

ANN performance can also be evaluated using the Root Means Square Error (RMSE) in which the accuracy of model is evaluated on the basis of the difference between the actual and estimates. N represents the number of reserved test samples.

$$\text{RMS error} = \frac{\sqrt{\sum^{N} \text{prediction error}^2}}{N}$$

Figure 1 depicts a preliminary diagrammatic representation of the proposed planned back-propagation neural network for calculating rice yield.

The algorithm below summarizes steps that need to be carried out to implement a neural network for rice yield prediction, *viz.* i) select input factor; ii) collect and prepare the data source; iii) train and prepare test set; iv) plan the ANN Network and determine approximating function and function approximation; (v) select parameters; and (vi) evaluate network performance.

The literature search and theoretical considerations in the ANNs for rice yield predictions and modeling can be summarized as follows: (i) neural networks offer a highly structured architecture, with learning and generalization capabilities, and are able to forecast data patterns that are too complex for the traditional statistical models in predicting crop yield; (ii) neural networks application development is a precursor for rice yield predication model in Malaysia; (iii) a neural network framework that is modeled after corn yield prediction model is suggested as a proposed framework in building a rice yield prediction model in Malaysia; and (iv) the neural network can be used to find out factors that effect rice yield.

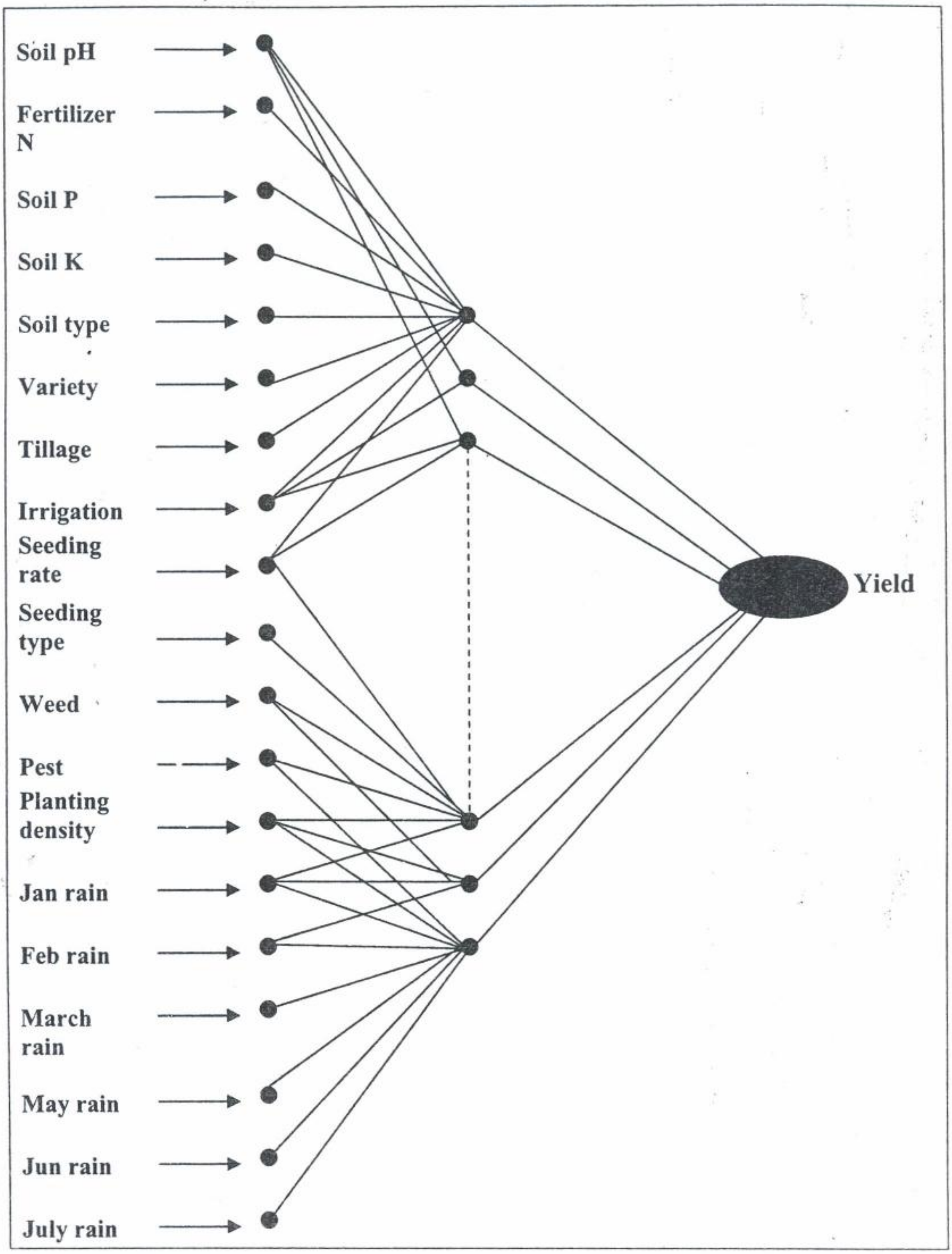


Figure 1. Preliminary diagrammatic representation of the proposed planned back-propagation neural network for calculating rice yield (adapted from Liu & Goering 1999).

LITERATURE CITED

Ambuel J. R., Colvin T. S. and Karlen D. L. 1994. A fuzzy logic yield simulator for prescription farming. Trans. ASAE, 37(6): 1999-2009.

Anon 2002. Malaysia Agricultural Directory & Index 2001/2002. Agriquest, Kuala Lumpur.

Baki, B.B. 2005. Shaping the Future of Agriculture and Weed Science to Serve Humanity, Unversity of Malaya Press, Kuala Lumpur, 168p. Baki, B.B. & Azmi, M. 1994. Integrated management of paddy and aquatic weeds in Malaysia: Current status and prospects for improvement. Pages 46-77. In: H. Shibayama, K. Kiritani & J. Bay-Peterson, (eds) Integrated Management of Paddy and Aquatic Weeds in Asia. FFTC Book Series No. 45, Taipei, Taiwan.

Ballard R.J. 2003. Forecasting with neural networks – A review. NSSJ, 20(2): 21-29.

Drummond S.T. 1998. Application of Neural Techniques for Spatial Yield Estimation, M.S. Thesis, Computer Engineering and Computer Science Department, University of Missouri, Columbia.

Drummond S. T., Sudduth K. A. and Birrell S. J. 1995. Analysis and correlation methods for spatial data. ASAE Paper No. 95-1335. St. Joseph, Mich.: ASAE

Drummond S.T., Joshi A.and Sudduth K.A. 1998. "Application of neural networks: Precision farming." in Proc. IEEE World Congress on Computational Intelligence, Anchorage, AK, May 4-9.

Friedman J.H. and Stuetzle W. 1981. "Projection pursuit regression," J. American Statistical Association, 76:817-823.

Goutte C. 1997."Note on free lunches and cross-validation," Neural Computation, 9:1211-1215.

Guatam R. K., Panighani, S., Franzen, D. and Sims, A. 2003. Neural network models for soil nitrate prediction using imagery and non-imagery information. ASAE Paper No: 033065. St. Joseph, Mich.: ASAE.

Hetherington S. 2001. *Echinochloa* control in rice in Australia. In Labrada, R. & Kim, U.K. (eds.). Ecology and Management of *Echinochloa* spp. FAO Rome, pages 53-56.

Lamb J.A., Anderson J.L., Rehm G.W. and Dowdy R.H. 1996. "Grain yield stability in continuous corn and corn-soybean cropping systems on a sandy landscape." In Proc. 3rd Int. Conf. On Precision Agriculture, P.C. Robert et al. (ed.), pp 417-424..

Liu J. and Goering C.E. 1999 "Neural network for setting target corn yields." ASAE paper 99-3040, Toronto, Ontario, Canada, July 18-21.

Lacroix R., Dalehi F., Yang X.Z. and Wade K. M. 1997. Effects of data preprocessing on the performance of artificial neural networks for dairy yield prediction and cow culling classification. Trans. ASAE, 40(3): 839-846.

Smith M.C., Valverde B.E. & Merayo A. and Fonseca J.F. 2001. Integrated management of itchgrass in a corn cropping system: modeling the effect of control tactics. Weed Science, 49:123-134.

Shearer S.A., Thomasson J.A., Mueller T.G., Fulton J.P., Higgins S.F. and Samson S. 1999."Yield prediction using a neural network classifier trained using soil landscape features and soil fertility data." ASAE Paper 99-3042, Toronto, Ontario, Canada, July 18-21.

Stone M. 1973. "Cross-validatory choice and assessment of statistical predictions." J. Royal Stat. Soc. Ser. B., 36:111-147.

Thai C.N. and Shewfelt R.L. 1991. Modeling sensory color quality of tomato and peach: neural networks and statistical regression. Trans. of ASAE, 34(3): 950-955.

Tumbo S. D., Wagner, D. G. and Heinemann P. H. 2002. Hyperspectral-based neural network for predicting chlorophyll status *in corn*. Trans. of ASAE, 45(3): 825-832.

Valverde B.E., Riches C.R. & Caseley J.C. 2000. Prevention and management of herbicide resistant weeds in rice: Experiences from Central America with *Echinochloa colona*. Natural Resource Institute- CATIE-Camara de Insumos Agropecuarios de Costa Rica Publication, San Jose, Costa Rica, 123p.

White H., Gallant A. R., Hornik K., Stinchcombe M. and Wooldridge J. 1992. Artificial Neural Networks: Approximation and Learning Theory . Malden, Mass. Blackwell Publishers.

Zhang Q., Yang S.X., Mittal G.S. and Yi S.J. 2002. Prediction of performance indices and optimal parameters of rough rice drying with neural networks. Biosystems Engineering, 83(3): 281-290.

Farmers' participatory studies of integrated weed management systems for intensified lowland rice (*Oryza sativa* L.) in Bangladesh

G.J.U. Ahmed[1], M.K.A. Bhuiyan[1] C.R. Riches[2], M. Mortimer[3] and D. Johnson[4]
[1]Department of Agronomy, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh.
gjuahmed@yahoo.co.in
[2] Natural Resource Institute, University of Greenwich,
Chatham Maritime, Kent ME4 4TB, UK
[3] School of Biological Sciences, University of Liverpool, Liverpool L69 7ZB, UK.
[4] International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines

Abstract: On-farm evaluations of improved weed management options for intensive lowland rainfed rice were conducted in Comilla district in Bangladesh. Trials compared the efficacy of butachlor, pretilachlor, cinmethylin, oxadiazon and mechanical weeding in comparison with current manual farm practices of hand weeding. Results indicated that, in general, herbicide use gave the highest rice yield although mechanical weeding with a push weeder was an effective tool. Studies also indicated that yield differences were evident in response to the availability of water and weed abundance was greatest where farmers had poor control of water. The adoption of herbicides for weed control in rice agriculture in Bangladesh will contribute to improving food security.

Key words: Weed management, water management, lowland rice.

INTRODUCTION

The Comilla district in south-east Bangladesh has long been recognized as being progressive in the adoption of modern agricultural practices for rice production. The triple crop *boro* - T. *aus* - T. *aman* rice system can produce up to 10 tons ha^{-1} per year and is a major cropping pattern in the district, as is double cropping of rice in the *boro-T. aman* seasons. On-farm studies in two villages in the Comilla district indicated that the yield gap due to weed competition in the T. *aman* crop between production under farmer management and the potential yield under weed free conditions averaged 425 kg ha^{1} (Ahmed *et al.*, 2001, 2003). However the gap could be as high as 1 t ha^{-1} with 30% of farmers losing in excess of 500 kg ha^{-1}. Earlier, Mamun (1990) reported that weed growth reduced grain yield by 68-100% in direct seeded *aus* rice, 14-48% for transplanted *aman* rice and 22-36% in *boro* rice. The present on-farm weeding systems are laborious (either manual or by use of a push weeder) and time consuming. The use of push weeders is inefficient under conditions of poor water management and infestation by perennial weeds. Hussain *et al.* (2001) have noted that for food security in Bangladesh rice production needs to be increased from 3 to 5 tons ha^{-1} in the next 20 years against a background of increased labor costs. Improving weed management practices will contribute to this goal. This paper presents results from on-farm trials, in which comparative evaluations were made of the effectiveness of improved weed control practices in intensive lowland rice in Comilla district.

MATERIAL AND METHODS

Experiments were conducted in farmers' fields in four upazillas (administrative unit) of Comilla district. These areas fall into the old Meghna Esturian floodplain agro ecological zone. The soil is mostly non-calcareous grey floodplain type, low in organic matter, acidic in dry conditions but becomes neutral in pH when puddled. Annual rainfall of the area varies between 4000-5000mm. Maximum temperatures are observed in June (35^{0}C), minimum temperatures being in January (15^{0}C). Most precipitation occurs during March to October. Two experiments were conducted in farmers' fields in four upazillas in the *boro* and *T. aman* seasons of 2003.

Experiment 1. Performance of weed management options in two water regimes of *boro* (irrigated) and *T. aman* (rainfed) rice.

Methodology: The following treatments were imposed in plots within farmers' fields in two sites (Chowara and Paruara) in both seasons and at a further site (Zaforganj) in *T.Aman* 2003.

I. Weed control treatments:

1. Butachlor 1.25 kg a.i. ha^{-1} (Machete 5G) + 1 hand weeding
2. Pretilachlor 470 g a.i. ha^{-1} (Rifit 500 EC) + 1 hand weeding
3. Cinmethylin 7.5 g a.i. ha^{-1} (Argold 10EC) + 1 hand weeding
4. BRRI Push weeder + 1 hand weeding
5. Two hand weedings
6. No weeding

II. Water management:

1. Good water management - plots were near the supply area of a tubewell allowing supplemental irrigation to be applied on demand.
2. Poor water management – plots were situated at the periphery of the command area of the tubewell resulting in irregularity of supply.

Six trials were conducted in each location in *boro* (02-03) season under irrigated conditions and in the *T. aman* 03 season under rainfed conditions. Plot size for each treatment was $100m^2$ (20m x 5m) and treatments were arranged randomly separating each plot with a levee. Herbicides were applied with knapsack sprayer at 5 days after transplanting.

Data collection and analysis:
Weed population, weed biomass, yield and yield component data were taken from each plot. Data were analysed by analysis of variance.

Experiment 2. Comparative performance of weed control options in intensive rice systems in on farm-trials.

Field days and training sessions at a regional level were organized in collaboration with farmers, research and extension organizations and private sector companies to implement trials of a range of weed control methods. Farmers elected to implement individual weed management comparisons from the following set of treatments:

1. Pretilachlor 470 g a.i. ha^{-1} + 1 hand weeding
2. Butachlor 1.25 kg a.i. ha^{-1} + 1 hand weeding
3. Cinmethylin 7.5 g a.i. ha^{-1} + 1 hand weeding
4. Oxadiazon 360 g a.i. ha^{-1} (Ronstar 25EC) + 1 hand weeding
5. Push weeder + 1 hand weeding

A total of 80 farmers collaborated in the trial in Burichang, Debidwar, Sadar and Barura upazillas in both *boro* and *T. aman* seasons. In farmers' fields, individual treatment plots were $200m^2$ in area, separated by levees and selected treatments were imposed in addition to conventional farmer practice (either 1 or two manual weedings, as required). Each farm site was considered as a replicate. Data collection and analysis were similar to the previous experiment.

RESULTS AND DISCUSSION

Experiment 1 *Boro* 2002- 2003 season

Table 1 indicates that on-farm water management (as defined above) influenced weed infestation at 45 DAT. Where water supply was assured, in all weeding treatments including farmers practices, lower weed dry matter weight was recorded at both sites confirming the much earlier observation of Smith and Moody (1979). This was despite the fact that much greater inter-farm variation was observed in Paruara. Water management regime and weed management options significantly influenced grain yield (Table 2) and comparatively higher yields were recorded at Chowara. Lower yields were recorded under sites experiencing poor water management, with greater yield differences between good and poor water regimes being evident at Chowara. In this more productive site, there were no significant differences in yield amongst differing imposed weed management treatments.

Experiment 1 *T. aman* 2003

Weed dry matter recorded at 45 DAT differed significantly across the three locations (Table 3). At Chowara, pretilachlor + 1HW gave the highest yield (4.41 t ha^{-1}) followed by plots treated with butachlor + 1 HW. At Paruara and Zaforgonj, herbicide treated plots and those receiving conventional farm practice similar grain yields comparable to that from hand weeded (2HW) plots.

Experiment 2 Weed control options in *boro* 2002-2003 season

Large scale on-farm trials indicated that in the majority of cases a higher yield was obtained from the improved weed management in comparison to current farm practice (Table 4). Similar experiments were conducted in the *T. aman* 2003 season and results showed a similar trend. The cost of weeding by conventional means (two hand weedings @ Taka 2800 ha^{-1}) was higher than when the BRRI weeder and one hand weeded was used (Taka 1680 ha^{-1}). Herbicide treated plots incurred the least weeding cost (Figure 1).

Table 1. The effect of water regime and weed management options on weed dry matter at two sites in *boro* 2002-2003 season. Data are square root of dry weed biomass, gm $^{-2}$ and square root of weed density (plants m^{-2}) at 45 DAT. HW = hand weeding.

a) Weed biomass by individual treatment.

Weeding Treatment	Good water management		Poor water management	
	Paruara	Chowara	Paruara	Chowara
Pretilachlor + 1HW	1.57	2.47	3.06	2.49
Cinmethylin + 1HW	1.46	2.25	2.5	3.29
Butachlor + 1HW	1.36	2.02	1.83	2.03
2 Hand weedings	1.42	1.44	2.18	1.99
BRRI Weeder + 1HW	1.52	2.93	3.50	3.61
Unweeded	2.91	4.16	8.22	6.42
Farmer practice	1.51	1.47	2.80	2.41
LSD ($_{.05}$)	1.337	0.384	1.337	0.384

b) Overall means according to water management

	Weed density		Weed biomass	
	Paruara	Chowara	Paruara	Chowara
Good water management	2.62	6.87	1.68	2.39
Poor water management	4.12	7.76	3.44	3.18
S.E.	0.21	0.06	0.17	0.05
CV (%)	28.40	3.90	29.81	7.83

Table 2. Grain yields in response to water regime and weed management option at two sites in *boro* 2003 season. GWM = Good water management, PWM = Poor water management.

Treatment	Grain yield (t ha^{-1})			
	Chowara		Paruara	
	GWM	PWM	GWM	PWM
Pretilachlor + 1 HW	5.24	4.29	3.23	2.63
Cinmethylin + 1HW	5.32	3.60	4.08	3.45
Butachlor + 1HW	5.08	3.78	4.17	3.90
2 Hand weedings	5.00	3.85	4.00	3.71
BRRI weeder + 1HW	5.14	3.29	3.98	3.57
Unweeded	3.50	2.62	2.34	2.35
Farmers practice	5.31	3.12	4.24	3.99
LSD(.05)	1.015		ns	
CV (%)	5.86		10.90	

Table 3. Effect of weed treatments on weed growth and grain yield in on - farm trials at Chowara, Paruara and Zaforgonj , *T. aman* 2003 season. GY = grain yield. Weed weights are square root transformed.

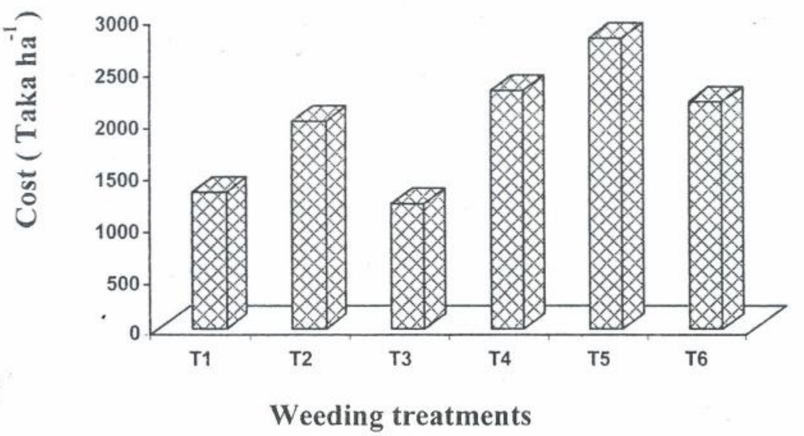
Weeding Treatment	Chowara		Paruara		Zaforgonj	
	Weed wt.(gm-^{2})	GY (t ha^{-1})	Weed wt.(gm^{-2})	GY (t ha^{-1})	Weed wt.(gm^{-2})	GY (t ha^{-1})
Pretilachlor + 1HW	1.47	4.41	1.55	4.44	1.22	4.63
Cinmethylin +1HW	1.63	3.99	1.17	4.55	1.31	4.48
Butachlor + 1HW	1.91	4.16	1.20	4.34	1.33	4.49
2 hand weedings	2.06	4.13	1.28	4.32	1.45	4.62
BRRI Weeder + 1HW	1.47	3.86	1.25	4.27	1.39	4.43
Unweeded	3.20	2.83	4.21	3.00	2.31	2.79
Farmers practice.	1.32	3.94	1.33	4.33	1.58	4.38
LSD(.05)	0.464	0.265	0.337	0.244	0.309	0.175

Table 4. Comparative performance of improved weed management practices in on-farm trials fields in Paruara, and Chowara, *boro* 2003 season. GY = grain yield. For each treatment, T versus FP gives the comparison between farmers practice (FP) and the improved treatment (T).

Treatment	Paruara				Chowara			
	Grain yield (t ha^{-1})		Weed dry matter (g m^{-2})		Grain yield (t ha^{-1})		Weed dry matter (g m^{-2})	
	T	FP	T	FP	T	FP	T	FP
Pretilachlor+1HW	4.55	4.00	4.08	7.23	5.37	4.64	3.83	4.77
Butachlor+1HW	4.70	4.25	2.42	2.66	4.14	4.19	3.27	4.83
Cinmethylin+ 1HW	3.92	3.75	9.89	13.27	4.32	3.96	7.85	9.08
Oxadiazon+1HW	3.42	3.17	2.96	5.35	4.79	4.13	4.93	12.14
BRRI weeder+1HW	4.32	4.15	5.82	3.15	5.21	4.60	1.89	2.01

CONCLUSION

These results confirm that the introduction of herbicides into both *boro* and *aman* transplanted rice in Bangladesh will improve yield and profitability of rice. Herbicide use is increasing by more than 50% per year as farmers seek to mitigate increasingly high labour costs. Workshops to promote these findings have been organized in collaboration with stakeholders involved in supporting rice production by farmers including the Department of Agricultural Extension (DAE), agro-chemical companies, NGO's and research institutions. Accelerating a joint program for rapid dissemination of weed control technologies is essential due to a lack of knowledge in the farming community about the level of yield losses from weeds and safe, effective use of herbicides.



T1= Rifit + 1HW, T2= Machete + 1HW, T3= Argold +1HW, T4= Ronstar + 1HW, T5= 2HW, T6= BRRI weeder+ 1HW

Figure 1. Comparative costs of the differing weed control options. 1 US $ = 65 Taka.

ACKNOWLEDGEMENTS

The research was funded both by the Department for International Development (DFID), UK, and the Irrigated Rice Research Consortium, IRRI, Philippines, and the support is gratefully acknowledged. We are also indebted to the personnel of DAE, Comilla and farmers who co-operated with us in successful completion of this research.

LITERATURE CITED

Ahmed G.J.U., M.S. Hassan, A.J. Mridha , M. A. Jabbar, C.R. Riches, E.J.Z. Robinson, Mortimer M. 2001. Weed management in intensified lowland rice in Bangladesh. British Crop Protection Conference - Weeds 2001, 2: 205 – 210.

Ahmed, G.J.U., A.J. Mridha, M.K.A. Bhuiyan, C.R. Riches and M. Mortimer, 2003. Effect of different weed management systems on weed control, plant growth and grain yield of lowland rice. In Proceedings of the nineteenth Asian Pacific Weed Science Society Conference. 17-21, March, Manila, Philippines, 84-92P.

BRRI (Bangladesh Rice Research Institute (1976) Annual report for 1973-74. Joydebpur, Dhaka, Bangladesh.

Hussain A.M.M., M. Hossain and A. Janaiah.2001.Hybrid rice adoption in Bangladesh A socio-economic assessment of farmer's experience. Research Monograph Series no. 18, Social Sciences Division IRRI, Los Banos, Philippines.

Mamun, A.A. 1990.Weeds and their control. A review of weed research in Bangladesh Agricultural and Rural Development in Bangladesh. Japan Intl. Cooperation agency, Dhaka, Bangladesh, JSARD, Pub. No. 19. pp. 45-72.

Smith, Jr.,R. J. and K. Moody. 1979. Weed control practices in rice. In: Integrated plant protection for Agricultural crops and Forest Trees: Proceedings of the Symposium on the 9th International Congress of Plant Protection, 2, T. Kommedahl (ed.) Washington, D.C., USA. pp. 458-462.

Farmers' participation in development of integrated methods of weedy rice control in Thailand

C. Maneechote[1], S. Jamjod[2], B. Rerkasem[2] and K. Rerkasem[3]
[1]Weed Science Group, Plant Protection Research and Development Office, Department of Agriculture, Chatuchak, Bangkok, Thailand 10900
mchanya@asiaaccess.net.th
[2]Agronomy Department, Faculty of Agriculture, Chiang Mai University, Thailand 50200
[3]Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University, Thailand 50200

Abstract: Weedy rice has now become a serious weed in direct-seeded rice cultivation in the Central Plain of Thailand, since the first observation in 2001 season. Yield loss ranged from 10 to 100% depending on the level of weedy rice infestation. Several methods have been developed in close collaboration with farmers in Kanchanaburi province, Thailand. Four expert farmers who have practiced successful weed control were chosen as examples for illustration. Eradication of weedy rice before sowing clean seed together with panicle removal prior to seed set (Farmer 1) could reduce the number of weedy rice panicles at harvesting from 740 to 0.2 panicles m^{-2} in five seasons and rice yield was increased from 638 to 6,562 kg ha^{-1}. Cleaning rice seeds and removal of weedy rice panicles prior to seed set (Farmer 2) could decrease infestation of weedy rice from 60 to 1.1% in four seasons and rice yield was recovered. Eradication with glyphosate herbicide, one fallow with flooding, clean seed and hand pulling of young weedy rice plants (Farmer 3) successfully reduced weedy rice density from 287 to 4 panicles m^{-2} in the following seasons and rice yield was back to normal. Seed cleaning and herbicide spray-topping to reduce seed bank (Farmer 4) did not decrease the density of weedy rice as fast as the others. It could reduce the weedy rice infestation from 55% to 28% in four seasons. The use of clean seed is the most crucial step in integrated control and very cost effective. However, other components of control (e.g., one fallow, eradication prior to sowing, hand pulling, panicle removal etc.) are also needed to obtain successful results.

Key words: Farmers' participation, integrated management, weedy rice.

INTRODUCTION

In 2001, weedy rice (*Oryza sativa* L.) was firstly recognized as a noxious weed in rice fields in Thailand. Recently, it has become widespread throughout the Central Plain of Thailand. The areas of weedy rice infestation have rapidly increased by sharing contaminated seeds and combined harvesters (Paokrueng 2004). Noldin (2000) estimated that only two red rice seeds kg^{-1} planted in a rice field free of red rice could produce 100 kg red rice ha^{-1} within three seasons. Without weed infestation, the rice yield would be 6-7 t ha^{-1}. When infestation of weedy rice was 40-50%, rice yield decreased by more than 50% (Maneechote et al. 2004a).

A popular control method among farmers is topping off panicles with sickles as weedy rice panicles emerge one or two weeks earlier and are taller than cultivated rice. However, this method is expensive and not effective to reduce the seed bank. Since some of weedy rice plants have begun to mimic crop rice in its appearance (Jamjod et al. 2003), another problem came after a few seasons because of impurity of rice seeds. When cultivated rice is not uniform, farmers need to spend more time to distinguish weedy rice before cutting.

As irrigation system and personal preferences vary among farmers, several methods need to be developed in collaboration with them. This study aimed to develop possible methods for weedy rice control, which are practical for farmers.

MATERIALS AND METHODS

The experiments were conducted in Kanchanaburi, where rice is wet-seeded with high yielding varieties (HYV's) twice a year, in wet and dry seasons. Four expert farmers were selected to test different methods to control weedy rice, which has heavily infested their fields. Foundation seeds from Pathum Thani Rice Research Center, Department of Agriculture (DOA) were used. Possible weed control methods to control weedy rice are applied as follows.

Farmer 1. Mr Sumruey Semthup is a tenant with good irrigation. His field had been infested with weedy rice for three years prior to the experiment. The density of weedy rice at maturity was 740 ± 12 panicle m^{-2}. In February 2002, pre-planting herbicide, glyphosate, was applied to kill the emerged weedy rice and other weeds prior to sowing clean rice seeds. Removal of weedy rice panicles prior to seed set was also practiced. The experiment was repeated for five consecutive seasons from July 2002 to December 2004.

Farmer 2. Mrs Malai Rungrueng is also a tenant with poor irrigation. Unlike Mr. Sumruey, she could not spend time on pre-planting eradication due to water constraint. So she tried to remove the weedy rice panicles manually to reduce seed contamination in the next season. Normally, farmers sell most of the paddy rice they produce each season and keep some as seed for the next crop. In 2002, the farmer's seeds from infested field and foundation seed from DOA were sown in two separate fields and intensive panicle removal of the weedy rice was applied. Using her own seed, Malai noticed that rice plants became varied in height, seed size and ripening period. She found that the crop from clean seeds made removal of weedy rice panicles easier and gained more rice yield, but the crop from her own seeds were uneven, which made removal of weedy rice panicle difficult and time consuming. In February 2003, clean rice seeds were sown and weedy rice panicles were intensively cut prior to seed set. The experiment was repeated for five consecutive seasons during July 2002-December 2004.

Farmer 3. Mr Prasert Jaemwong is a landlord with good irrigated field. In July 2002, one month after harvest, volunteer weedy rice plants were sprayed with glyphosate. The land was ploughed two weeks later and left to fallow with 20-30 cm flood for one season. In the next season, crop rice was sown and only 5% of weedy rice infestation appeared in the field which was all removed by hand to prevent seed set. In the following four seasons, clean seeds were sown and weedy rice plants were removed by hand.

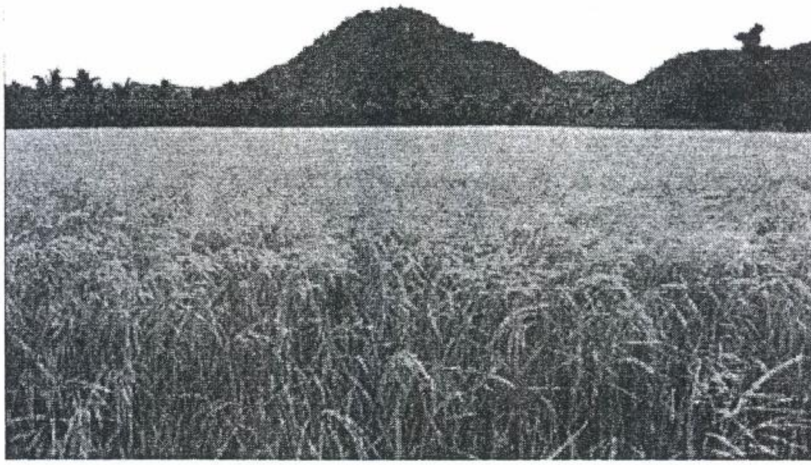
Farmer 4. Mr Boonyong Putta is a tenant with poor irrigation. He was unable to wait until the weedy rice emerged to be eradicated before sowing clean seeds. Normally, he cuts the weedy rice panicles at flowering to reduce seed bank accumulation. He wanted to replace hand removal of panicles with herbicide for economic reasons. Medd et al. (1992) reported that some ACCase-inhibiting herbicides such as fenoxaprop-p-ethyl, flamprop-methyl and tralkoxydim could be used during stem elongation and booting stage of wild oat to reduce seed production. In 2002, effectiveness of spray topping herbicides at 50% anthesis of weedy rice was evaluated in his field and quizalofop-p-tefuryl at 48 g ai ha^{-1} gave seed sterility to weedy rice but there were some injuries on the crop rice (Maneechote et al. 2004b). From February 2003 to December 2004, clean rice seeds and spray-topping with quizalofop at 48 g ai ha^{-1} were practiced for four consecutive seasons.

At harvest every season, four 1x1 m^2 samples were taken and the number of weedy rice and crop rice panicles was determined. The infestation was assessed as percentage of panicles of weedy rice.

RESULTS AND DISCUSSION

Farmer 1: Mr. Sumruey Semthup was successful in controlling weedy rice by using clean seed after eradication of weedy rice seedlings that emerged and removal of panicles at flowering. Weedy rice plants were reduced from 740 to 0.2 panicles m^{-2} by the 4^{th} crop while the rice yield increased 10 times from 638 to 6,562 kg ha^{-1} (Picture 1 and Table 1). Eradication of the emerged weedy rice plants that emerged before planting could reduce the seed bank of weedy rice and panicle removal could prevent new seeds accumulated in the soil. It took at least five crops to bring weedy rice infestation down to a manageable level and rice yield recovered.

In 2001, rice field was severely infested by weedy rice



In 2004, density of weedy rice was reduced by 99%

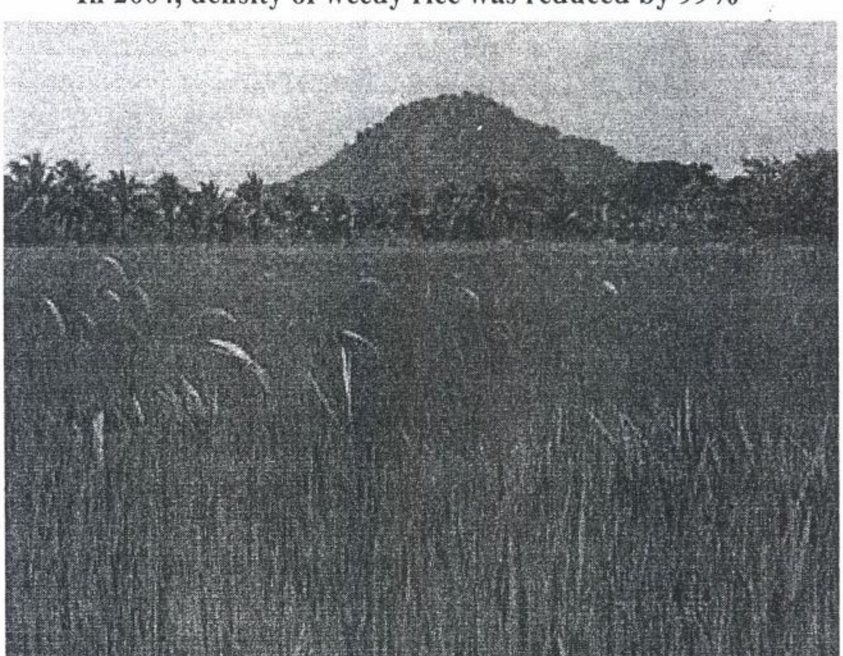


Figure 1. Comparison of weedy rice density in a farmer's field (Mr. Sumruey Semthup) before (upper) and after (lower) integrated management.

Table 1. Effects of integrated management on number and infestation (%) of weedy rice and rice yield. Farmer 1: Sumruey Semthup.

Season	Year	Infestation of weedy rice		Rice yield	Farmer's management
		Panicles no. m^{-2}	%	(kg ha^{-1})	
Wet	2001	740 ±12	79.4 ± 8	638 ± 75	None
Dry	2002	136 ± 21	31.3 ± 3	4,080 ± 228	Eradication of weedy rice before sowing clean rice seeds and panicle removal (one time) at flowering
Dry	2003	65 ± 14	14.2 ± 4	5,306 ± 144	Eradication of weedy rice before sowing clean rice seeds and panicle removal (two times) at flowering
Wet	2004	0.2 ± 0	0.14 ± 0	6,562 ± 331	Eradication of weedy rice before sowing clean rice seeds and panicle removal (three times) at flowering

Each data point is the mean of four replicates ± standard error

Farmer 2: Mrs Malai Rungrueng tried to remove the wild rice panicles manually to reduce seed contamination in the next season. When clean rice seeds were grown, weedy rice was easily removed. She spent less time for cutting the weedy rice panicles than using the farmer's seed. In 2001, infestation of weedy rice in the field sown with her own seeds (Field 1, Table 2) at harvesting was 36.1%; rice yield was 1975 kg ha^{-1}. The density of weedy rice in the field using clean seeds (Field 2) was lower than Field 1 but rice yield was higher. After five seasons, only 1% weedy rice infestation (4 panicles m^{-2}) were found at harvest and rice yield was recovered to 6287 kg ha^{-1} (Table 2).

Table 2. Effects of integrated management on number and infestation (%) of weedy rice and rice yield. Farmer 2: Malai Rungrueng.

Season	Year	Infestation of weedy rice		Rice yield	Farmer's management
		Panicle no. m^{-2}	%	(kg ha^{-1})	
Dry	2002				
	Field 1	199 ± 5	36.1 ± 2	1,975 ± 356	Seeds from last season+ panicle removal (three times) at flowering
	Field 2	86 ± 16	15.8 ± 2	3,856 ± 347	Clean rice seeds + panicle removal (two times) at flowering
Wet	2003	6 ± 3	1.2 ± 1	5,768 ± 241	Clean rice seeds + panicle removal (two times) at flowering
Dry	2004	4 ± 1	1.1 ± 0	6,287 ± 256	Clean rice seeds + panicle removal (two times) at flowering

Each data point is the mean of four replicates ± standard error

Farmer 3: Mr Prasert Jaemwong eradicated weedy rice from his field by one fallow and flooding. Then he took good care of the field by sowing clean seeds and removed the remaining weedy rice plants. From an infestation of 287 weedy rice panicles m^2 in dry season 2001, application of glyphosate and one fallow with flooding together with the use of clean rice seed reduced weedy rice panicles to 24 panicles m^2; rice yield was 4650 kg ha^{-1} (Table 3). About 5% of weedy rice infestations were found in dry season 2003 and less than 1% in dry season 2004. Although the number of weedy rice became very small, long term eradication is needed.

Farmer 4: Mr. Boonyong Putta did not control weedy rice at the early stage of infestation. In 2001, weedy rice infestation was 12% and yield was 4570 kg ha^{-1} (Table 4). One year later, the infestation of weedy rice increased to 55% resulting in the reduction of rice yield by 80%. Spray topping with quizalofop herbicide and the use of clean seed reduced the infestation of weedy rice from 55.5% to 28% within four seasons and this method was less effective, than the other three methods (Table 1-3). Quizalofop did not give a 100% seed sterility; some weedy rice seeds set and accumulated in the soil. In addition, as the crop rice and weedy rice are grown together in the field, the herbicide may cause phytotoxicity on the rice plants at low weedy rice density. At weedy rice density lower than 30% infestation, spray topping with herbicide is less effective and may cause injury on crop plants, therefore, hand removal is more appropriate (Table 2).

Table 3. Effects of integrated management on number and infestation (%) of weedy rice and rice yield. Farmer 3: Prasert Jaemwong.

Season	Year	Infestation of weedy rice		Rice yield	Farmer's management
		Panicles no. m^{-2}	%	(kg ha^{-1})	
Dry	2001	287 ± 24	nd	nd	Glyphosate application after harvest this crop.
Dry	2002	24 ± 2	4.4 ± 1	4,650 ± 362	One fallow with flooding to eliminate the seed bank. Clean seeds and hand pulling were practiced in the following seasons.
Wet	2003	18 ± 11	5.4 ± 4	5,606 ± 325	Clean seeds + hand pulling
Wet	2004	4 ± 1	0.9 ± 0.3	5,300 ± 843	Clean seeds + hand pulling

Each data point is the mean of four replicates ± standard error; nd = not determine

Table 4. Effects of integrated management on number and density of weedy rice and rice yield. (Farmer 4: Boonyong Putta

Season	Year	Infestation of weedy rice		Rice yield	Farmer's management
		Panicles no. m^{-2}	%	(kg ha^{-1})	
Dry	2001	76 ± 14	12 ± 3	4,570 ± 120	None
Dry	2002	428 ± 105	55 ± 9	990 ± 394	None
Dry	2003	235 ± 97	40 ± 8	2,137 ± 462	Clean seeds + spray topping with herbicide to reduce seed set
Wet	2004	102 ± 115	28 ± 18	3,656 ± 169	Clean seeds + spray topping with herbicide to reduce seed set

Each data point is the mean of four replicates ± standard error

One fallow with intensive eradication is the most effective method to control weedy rice. However, it can be practiced when the farmers own their land. In case of tenants, there would be no reason to pay a rent but obtain no yield. The use of clean seeds is the most crucial step in integrated control and very cost effective. However, other components of control (e.g., one fallow, eradication prior to sowing, hand pulling, panicle removal etc.) are also needed to obtain successful results. Prevention is most important way to maintain good yield. Once weedy rice has invaded in the rice field, long term strategies are required to bring back the yield.

ACKNOWLEDGEMENTS

This work was financially supported by the McKnight Foundation. The authors would like to thank Mr. Samruey Samtup, Mrs Malai Ruengrueng, Mr Prasert Jaemwong, Mr. Boonyong Putta and other farmers in Kanchanaburi for their kind cooperation.

LITERATURE CITED

Jamjod S., C. Maneechote and B. Rerkasem. 2003. Diversity dynamics in rice: I Agronomic characters of invasive wild rice populations. CMUPN*lab* working papers V, pp 16-27, Chiang Mai University, Chiang Mai, Thailand.

Maneechote C., S. Jamjod and B. Rerkasem. 2004a. Invasion of weedy rice in the fields in Thailand. IRRN, 29 (2): 20-22.

Maneechote C., S. Jamjod and B. Rerkasem. 2004b. Controlling invasive wild rice with ACCase-inhibiting herbicides. 4th International Crop Science Congress, 26 September–1 October 2004. Brisbane, Australia (http.\\www.cropscience.org.au)

Medd R.W., M.G McMillan and A.S. Cook. 1992. Spray-topping of wild oats (*Avena* spp.) in wheat with selective herbicides. Plant Protection Quaterly, 5: 142-144.

Noldin J.A. 2000. Red rice status and management in the Americas. pp. 21-24. *In* Proceedings of Wild and Weedy Rice in Rice Ecosystems in Asia-A Review, B.B. Baki, D.V. Chin and M. Mortimer, Eds., IRRI

Paokrueng, A. 2004. Estimation of farmers' profit loss from weedy rice invasion in Kanchanaburi province. MS thesis. Faculty of Economics, Chiang Mai University, Thailand. 100p

Direct seeding of rice and the shift in herbicide use in the Philippines

M.C. Casimero[1], G. C. Cataquiz[1], J.C. Beltran[1], S. P. Marsh[2] and R. S. Llewellyn[2]
[1]Philippine Rice Research Institute, Science City of Munoz, 3119, Nueva Ecija, Philippines
mcasimero@philrice.gov.ph
[2]School of Agricultural Resource Economics, University of Western Australia, Crawley, WA 6009

Abstract: More farmers are shifting to direct seeding because of a number of social and economic factors such as reduced availability of labor for transplanting, increased labor costs, reduced water availability and more available herbicides for use in direct seeded rice. Concomitant with the shift towards direct seeding is a more complex weed problem resulting in an increased dependence of farmers on herbicides to control weeds. Forty two percent of the rice area in the Philippines is now estimated to be direct-seeded. This paper presents some data on results of a loop survey conducted in 2002 by the Philippine government, participatory appraisals in two regions and baseline surveys in Nueva Ecija and Iloilo provinces. Results indicate weed community shifts in rice fields, increased herbicide usage in direct-seeded rice compared to transplanted rice, and increasing use of herbicide from groups with higher risk of resistance development. Few farmers are informed about herbicide resistance. The implications of these observations are discussed in relation to future weed management practices in direct seeded rice.

Key words: Direct seeded rice, herbicide usage, herbicide resistance, weed community shifts

INTRODUCTION

In recent years, farmers in the Philippines as well as the rest of Asia have been shifting to direct seeding. Factors such as shortage in labor supply, increasing availability of selective herbicides for rice, decreasing water availability and the need to intensify rice production led to the increase in the hectarage of direct seeded rice. In the Philippines, a sizable increase in the percentage of farmers adopting direct seeding had been observed. In 1995, the proportion of farmers using direct seeding was 25% and increased to 48% in 1995 (Cruz et al 1996) but Pandey and Velasco (2002) reported that the total percentage of rice area established through direct seeding had declined to 42%. Iloilo (>90%) and Nueva Ecija (about 60%) provinces lead in the highest number of farmers adopting direct seeding in the Philippines (Marsh et al 2005).

The weeds associated with rice are dependent on the prevailing agro-ecosystem, crop establishment and the concomitant cultural management practices of farmers. Unlike transplanted rice that has a height advantage over weeds, direct seeded rice is threatened by a more complex weed problem. The culture requires shallow flooding, which results in more exposed soil areas and aerobic condition. Because weeds and rice emerge together, competition is more intense than in transplanted rice. The range of herbicides that can be used safely is limited owing to the sensitivity of seedlings to herbicides. Yield losses in direct seeded rice caused by uncontrolled weeds ranges from 40-96% (Ampong-Nyarko and De Datta 1991).

Depending on the method of crop establishment, available moisture in the field, and their financial capacity, farmers employ varying practices that can directly or indirectly control weeds. Cultural management practices such as land preparation and water management can significantly contribute to the reduction of weed problem and reduce weed control costs when done properly (Casimero and Juliano 2004). Farmers must fully exploit the positive benefits of these agro-ecologically friendly weed management strategies to reduce the negative impact of too much reliance on herbicide usage. With the increasing complexity and intensity of the weed problem associated with direct seeded rice however, herbicide has become the frontline defense of farmers to avert significant yield reductions.

This paper discusses the results of surveys conducted in the Philippines in 2002 and 2004 and how these results impact on the future weed management practices of farmers especially shifts in herbicide usage. Information gathered from a participatory appraisal conducted in Iloilo and Nueva Ecija provinces are also included.

MATERIALS AND METHODS

The loop survey was conducted in 2002 by the Philippine Rice Research Institute (PhilRice) in collaboration with the Bureau of Agricultural Statistics (BAS) in the top ten rice growing provinces in four regions namely, Northeastern Luzon (Region 2), Central Luzon (Region 3), Southern Luzon (Region 5) and the Visayas (Region 6). Structured questionnaires were used to determine the rice production practices as well as associated costs on rice production. Sampling size was determined following a stratified sampling procedure. The total number of farmer respondents from the four regions was 690. The data were gathered by accredited enumerators, and analysed using MS Access software.

The Participatory Resource Appraisal involved a focus group discussion with farmers adopting wet direct seeding who were potential cooperators for the Australian Centre for International Agricultural Research (ACIAR) and PhilRice project on herbicide use strategies and management options for Filipino and Australian cropping. Issues pertaining to direct seeded rice management practices particularly on weed control methods were discussed to establish baseline information on their current practices.

The latest survey was conducted in October and December 2004 in Iloilo and Nueva Ecija provinces, respectively, as part of the baseline information gathering activity of the abovementioned project of PhilRice and ACIAR. Farmer respondents were randomly chosen from the top ten municipalities in the two provinces having the largest areas planted to direct seeded rice. A structured questionnaire was used to obtain the needed information on direct seeding and weed management practices of farmers.

RESULTS AND DISCUSSION

Weeds Associated with Direct Seeded Rice and Weed Community Shifts

It is a common observation that weed pressure is more intense in direct seeded than in transplanted rice. The major ones include the grasses such as *Echinochloa crusgalli*, *Leptochloa chinensis* and weedy rice (*Oryza* species). The commonly associated broadleaf weeds include *Sphenoclea zeylanica, Monochoria vaginalis*, and *Ludwigia octovalvis* and in some fields, *Ipomoea aquatica*. The sedges are dominated by *Cyperus iria, Fimbristylis miliacea*, and *Cyperus difformis*. In both provinces of Iloilo and Nueva Ecija, farmers perceived that the same weed species still grow with direct seeded rice. Recently, however, some shifts in the weed communities had started to emerge. In Iloilo province, farmers reported that *L. chinensis* used to be a secondary weed growing along field bunds but has recently become a major weed in wet direct seeded rice (Casimero and Kawana 2000; Ooi and Casimero 2005). This observation was corroborated by farmers that participated in the PRA and other farmer respondents in the baseline survey. Sixty eight percent of farmers reported that *L. chinensis* is commonly observed in the paddies compared to 49% in 2000 (Table 1). A similar trend is seen in Nueva Ecija province, though the frequency of farmers reporting is lower. *C. rotundus* population in Nueva Ecija seemed to be increasing while it was reported to be decreasing in Iloilo. In Nueva Ecija, farmers have problems with *S. zeylanica* while in Iloilo, they have *F. miliacea*. These changes in weed populations are attributed by farmers to factors such as climatic change (flooding and/or limited water supply), disseminating agents such as birds, animals and water, and repeated usage of herbicides. Farmers also have a notion that chemical companies are intentionally spreading the weeds.

Table 1. Top five weeds reported (% of farmers) to be associated with direct seeded rice by farmers in Iloilo and Nueva Ecija provinces, Philippines.

Weed Species	Iloilo		Nueva Ecija	
	Now	Five years ago	Now	Five years ago
1. Echinochloa spp.	88	80	77	72
2. Leptochloa chinensis	68	49	37	33
3. Ischaemum rugosum	56	61	57	53
4. Fimbristylis miliacea	55	51	-	-
5. Cyperus rotundus	22	27	22	20
6. Sphenoclea zeylanica	-	-	22	21

Changes in Weed Control Methods and Herbicide Usage

With the shift towards direct seeded rice, there has been a concomitant change in the weed control methods of farmers. With the decreasing availability of water, farmers revealed during the participatory appraisal that they are forced to shorten the land preparation time resulting in more weeds growing in the field. However, when there is enough water supply, farmers are able to prepare the land well, use water management and apply herbicides to control the weeds. A decreasing percentage of farmers adopting handweeding as a supplemental weed control method was observed from the loop survey result in 2002 (Figure 1).

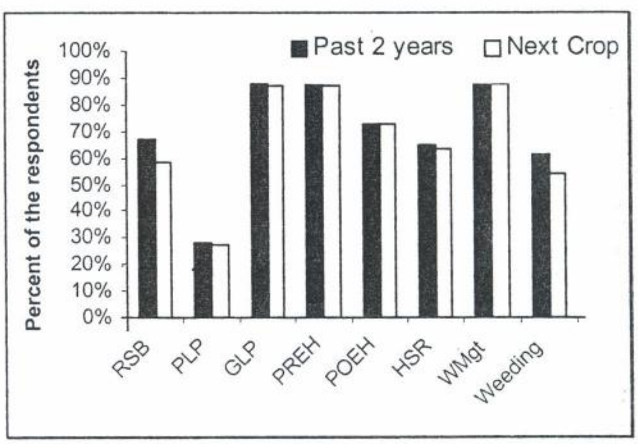


Figure 1. Weed management practices of farmers adopting direct seeding in the Philippines. RSB- rice straw burning; PLP – poor land preparation; GLP- good land preparation; PREH- pre-emergence herbicide, POEH- post-emergence herbicide; HSR- high seeding rate; WMgt- water management; Weeding.

Herbicide usage is higher in direct seeded than in transplanted rice across the six regions in 2001 (Figure 2). On the average, about 80% of farmers who adopt direct seeding spray herbicide. A lower percentage of farmers (50%) who transplanted rice apply herbicides. In the same survey, results showed that butachlor and pretilachlor (single ingredient) made up more than 40% of herbicide used (Figure 3). Butachlor combined with propanil or 2,4-D was applied by more than 10%. Byspiribac sodium was used by less than 10% of the farmers. After 4 years, there was a reverse in the type of herbicides applied on direct seeded rice. In Iloilo and Nueva Ecija, butachlor + propanil comprised about 40% of the herbicides used while usage of butachlor or pretilachlor alone decreased to less than 10% (Figure 3). The newer types of herbicides like sulfonylureas (ethoxysulfuron, bensulfuron) (7%), byspiribac sodium (19%), and aryloxyphenoxypropionates (cyhalofop) (20%) increased considerably. These results indicate that farmers now prefer the newer herbicides that require low dosage rates, even though they are more expensive. It is interesting to note that farmers also perceived that the number of farmers using these new types of herbicides and dosage will be increasing in the next four years while the use of the traditional herbicides will remain the same (data not shown). Traditional herbicides like glyphosate and paraquat commonly used in plantations and non-cropped areas, are being used by a few farmers as post-emergence herbicides to control weeds growing during the fallow period.

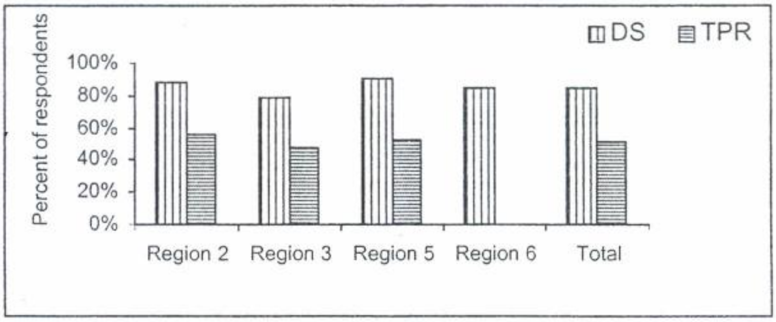


Figure 2. Herbicide usage in transplanted and direct seeded rice in six regions in the Philippines.

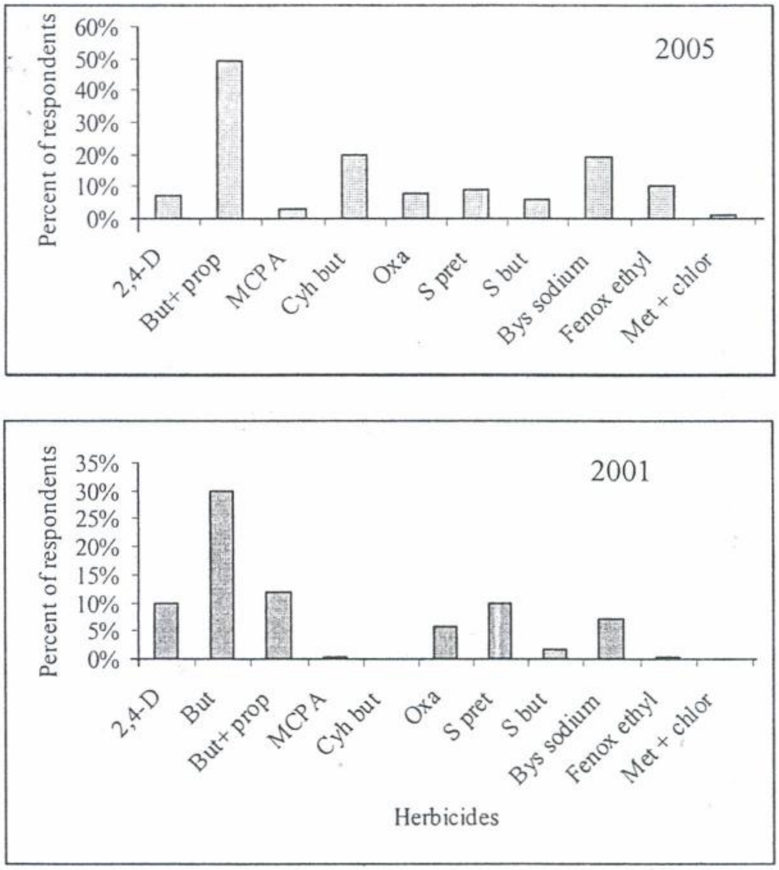


Figure 3. Herbicide usage of farmers in 2001 and in 2005 in Nueva Ecija and Iloilo provinces adopting direct seeding in the Philippines.

Complexity of the Weed Problem

Farmers are faced with more complex weed problems as a result of the shift toward direct seeded rice (Figure 4). Of the 200 farmers surveyed in 2005, only 4% in Iloilo and 8% in Nueva Ecija , did not apply herbicide. More than 90% of farmers depend on herbicides as the first line of defense against weeds. With this high dependence on herbicides, there is an associated health risk to farmers and higher probability of development of herbicide resistance. Farmers perceive that there will be an increase in the use of higher dosage of herbicides, with an interesting trend towards the use of new types of herbicides such as sulfonylureas, pyrimydinyloxybenzoics and aryloxyphenoxypropionates, that are considered highly susceptible to developing herbicide resistance. The latest survey data showed that very few Philippine farmers know about herbicide resistance. These information may lead one to think of possible herbicide resistance development in the country in a few more years if efforts to mitigate it are not seriously considered.

The second direction is towards application of integrated weed management. Integrated weed management is an evolution of the best mix of strategies that farmers adopt according to their field situations. These strategies, direct or indirect, are designed to be cost effective, environmentally sound and socially acceptable (Ooi and Casimero 2004). IWM makes use of cultural, biological, and mechanical methods to effectively control weeds. In areas where water is readily available, IWM is an attractive approach to manage weeds to avert the negative effects of too much reliance on herbicides. For this to happen, the government must improve the irrigation systems and educate farmers on the science of weeds and the benefits of IWM.

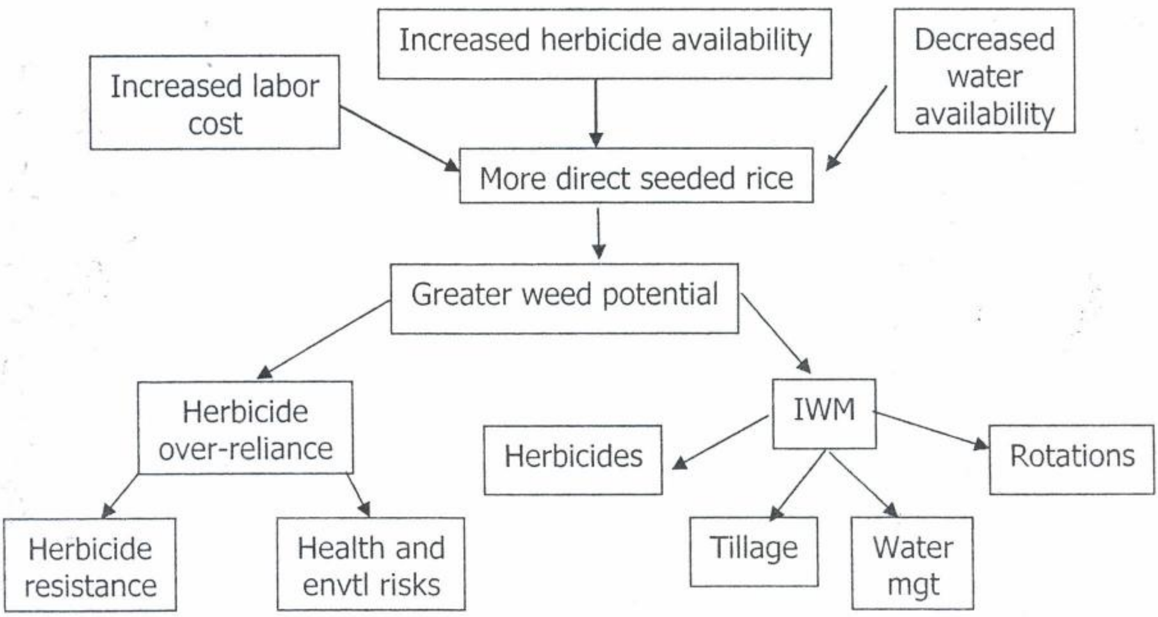


Figure 3. Schematic diagram showing the weed situation currently being faced by farmers adopting direct seeding in the Philippines. (Adapted from ACIAR Project document).

The Future of Weed Management

Many weed scientists espouse integrated weed management as the right approach for farmers to manage weeds. IWM provides effective control of weeds both in the short and long term. However, convincing farmers to adopt IWM faces an uphill battle when they are not involved in the development of the strategy. Integrated Pest Management (IPM) was successful as an approach to insect pest management as farmers were involved in its development (Kenmore 1996; Ooi et al. 2004). This empowerment on farmers on IPM can be used to further elevate the use of participatory approach to learning as vehicle in bringing the science of weeds to farmers. The first Farmer Field

School on weed ecology in the Philippines showed that the participatory approach is an effective way of educating farmers about integrated weed management (Ooi and Casimero 2005). Hençe, more efforts need to be exerted to educate farmers on weed ecology and IWM to avert the potential negative impact of too much reliance on herbicides for weed control in direct seeded rice.

ACKNOWLEDGMENT

The authors wish to acknowledge the PhilRice and DA-BAS for doing the initial the surveys from which some of the data were taken. Our sincerest thanks to the Australian Centre for International Agricultural Research for collaborating with PhilRice to do an adaptation research project on integrated weed management with Filipino farmers.

LITERATURE CITED

Ampong-Nyarko, K·and S.K. De Datta. 1991. A Handbook for Weed Control in Rice. IRRI, Los Banos, Laguna, Philippines

Casimero, MC and Juliano, LM. 2004. Agro-ecological approaches to managing weeds in wet direct-seeded rice in the Philippines. Proceedings of the 14th Australian Weeds Conference. Pp. 121-124.

Casimero MC and Kawana, Y. 2000. Control of grass weeds in wet-direct seeded rice. JICA PhilRice Collaborative Project Report. 25 pp.

Cruz, R.T, Serrano, S.R., Casimero, M.C., Casayuran, P.R., and Obien, S.R. 1996. Direct seeding technology in the Philippines. In Kirchof G and So, H.B. (eds). Management and Clay Soils for Rainfed Lowland Rice-based Cropping Systems. Australian Centre for International Agricultural Research, Canberra, Australia. Pp. 228-236.

Kenmore, PE. 1996. Integrated pest management in rice. In: Biotechnology and Integrated Pest Management, GJ Persley (ed.). CAB International, Pp. 214-232.

Marsh, S.P., Llewellyn, R.S., Casimero, M.C. and Cataquiz, G.C. 2005. Direct seeding of rice and herbicide use in the Philippines: Implications for weed management. Contributed paper presented at the 49th Australian Agricultural and Resource Economics Society Conference, Novotel Pacific Bay Reosrt, Coffs Harbour, NSW, 8-11 February 2005. 30 pp.

Pandey, S. and Velasco, L. 2002. Economics of direct seeding in Asia: Patterns of adoption and research priorities. In Pandey, S, M. Mortimer, L. Wade, T.P. Tuong, K. Lopez and B. Hardy (eds.) Direct Seeding Research Strategies and Opportunities, International Research Insititute, Los banos, Philippines. PP. 3-14.

Ooi, P.A.C. and Casimero, M.C. 2004. Facilitating weed management skills by resource poor farmers. Proceedings of the 35th Pest Management Council of the Philippines Conference, Pp.35-50.

Ooi, P.A.C. and Casimero, M.C. 2005. Enhancing weed management skills by resource poor farmers. Contributed paper presented during the 20th Asian Pacific Weed Science Society Conference., Rex Hotel, Ho Chi Minh City, Vietnam. 7-11 November 2005. 8 pp.

Ooi, PAC, Walter-Echols, G. Dai WD., Morales-Abubakar A.L., Lim, G.S, Pachagounder G., Soomro G.H, Galvan, C, Mancini, F., Petersen R. and Kamp , K. 2004. Environmental Education for Poor Farmers FAO-EU IPM Programme for Cotton in Asia. FAO Regional Office for Asia and Pasific. Bangkok. 62 pp.

Tuber production, population dynamics, and management of purple nutsedge (*Cyperus rotundus* L.) in a rice-onion rotation system

Md. N. Islam[1], A.M. Baltazar[2], J.S. Manuel[2], E.C. Martin[3], J.M. Ramos[3], S.K. De Datta[4], and A.N.M. Rezaul Karim[1]
[1]Bangladesh Agricultural Research Institute, Gazipur, Bangladesh
[2]University of the Philippines Los Banos, Laguna, Philippines
am_baltazar@yahoo.com
[3]Philippine Rice Research Institute, Munoz, Nueva Ecija, Philippines
[4]Virginia Polytechnic Institute and State University, Blacksburg, VA, USA

Abstract. A 2-year field study was conducted during 2003 through 2004 at the IPM CRSP Asia site in the Philippines to determine tuber production and population dynamics of purple nutsedge (*Cyperus rotundus* L.) through two rotations of rice (*Oryza sativa* L.) and onion (*Allium cepa* L.) grown under various management strategies that reduce either tuber production (handweeding and herbicides) or tuber survival (stale-seedbed technique). From an initial density of 1 tuber m^{-2}, populations peaked at 800 tubers m^{-2} during the first crop, decreased to about 50% during the second crop, then to less than 2% during the third and fourth crops. Tuber half-life was obtained in 4 months while tuber longevity was observed in 18 months after the population peak. Tuber production in purple nutsedge growing with crops was 95% lower than when the weed was grown in unrestricted conditions, indicating a density dependent population regulation. Decline in tuber populations in stale-seedbed treatments was more sustained and lasted through the fourth crop, reducing weed control costs and increasing net incomes over those of herbicide or handweeding treatments. Data indicate that strategies to reduce tuber survival are more cost-effective than strategies to reduce tuber production and support the paradigm shift from single season to multi-season long-range population management approaches to control of purple nutsedge to reduce its tuber populations in the soil as well as increase farmers' net incomes.

Key words: Population dynamics, stale-seedbed technique, tillage.

INTRODUCTION

A single purple nutsedge (*Cyperus rotundus* L.) plant growing in unrestricted conditions can produce 4 to 8 M tubers ha^{-1} in a cropping season (Rao 1968). In heavily infested fields, this can result in tuber populations as high as 2000 tubers m^{-2}, 85% of which are in the top 15 cm of the soil (Siriwardana and Nishimoto 1987), ready to sprout and grow into new plants when conditions are favorable. This range of tuber densities is common in rice-onion rotation farms in the Philippines due to build-up of tuber populations. Grown in the same piece of land, tubers in onion are carried-over into flooded rice in an annual rotation pattern. Thus, in a span of 30 years, from being a minor weed in flooded rice in the 1970s, purple nutsedge is now one of the top three most dominant weeds in both onion and flooded rice. Yield losses of up to 90% in onion and up to 50% in rice have been reported (Baltazar et al. 2000). For adequate season-long control, farmers spend about \$200 ha^{-1}, 20% of their production costs, in handweeding and herbicides, increasing their production costs. With an export crop like onion valued at US \$15M in the late 90s, increased production costs means losing out in the global market to countries with lower production costs.

Because dormant tubers can not be killed by herbicides and tuber dormancy ensures survival and build-up of tuber populations in the soil, successful management of this weed is done through two approaches: 1) by reducing tuber production of the weed through herbicides or handweeding; 2) or by reducing survival of tuber populations in the soil using cultural practices. The second approach is suitable in small, highly diversified tropical farms, where control of weeds in crops grown annually in rotation requires a long range population management scheme which takes into account the weeds' population dynamics and carry-over effects across crops. In the long term, this approach requires less inputs and results in higher net benefits than single season approaches using direct weed control inputs of herbicides and handweeding.

This study was conducted to: 1) determine tuber production of purple nutsedge growing alone or in competition with rice and onion; 2) quantify population dynamics and fate of purple nutsedge tubers through four rice-onion crops; and 3) determine cost-effectiveness of management strategies that reduce tuber survival or tuber production.

MATERIALS AND METHODS

Site description and general procedures

All experiments were conducted at the greenhouse and field facilities of the Philippine Rice Research Central Experiment Station in Munoz, Nueva Ecija, Philippines, lat 15-16°N, long 121°E, 50 to 100 m above sea level. Average monthly day and night temperatures ranged between 20 to 32°C, annual mean average of 28°C. Soil is Maligaya clay loam, classification Inceptisols (Eutropepts with Dystropepts).

Tuber production, greenhouse

The greenhouse studies were conducted from September 2003 to February 2004. One tuber weighing about 1.5 g was planted at 3 cm depth at the center of a 100 cm x 100 cm x 30 cm metal tray filled with clay loam soil (Maligaya clay loam). Trays were placed under direct sunlight and plants were watered as needed. Starting at 14 days after planting, height, number of leaves, shoots and tubers were recorded every 2 weeks. At 126 days after planting, plants were separated into shoots, basal bulbs, tubers, rhizomes, and roots and fresh weights of each plant part were recorded.

Field evaluation of management strategies

The area had an annual cropping pattern of rice-vegetable-fallow for 3 years preceding the study. Onion was grown from January to April 2003 and 2004; rice was grown from June to September 2003 and 2004, with a 1 to 2 month fallow period between crops. Before land preparation of the first crop (onion 2003), initial tuber counts were determined from two 0.5 x 0.5 m x 0.3 m in each plot. The tuber populations were low (less than 5 tubers per plot), thus we seeded 1 tuber per m^2 in all plots (total of 20 tubers per plot). Plots were laid out and marked to maintain the same treatments across crops.

Onion. The field was plowed twice and harrowed twice with a hand tractor, then leveled by an animal-drawn implement. Thirty-five day old onion seedlings var. Yellow Granex were transplanted into 4 x 5 m plots at 10 cm x 10 cm spacing. The plots were fertilized with 120-90-60 kg ha^{-1} N, P, K in three splits; first as basal at transplanting, then sidedressed at 30 and 45 DAT. Plots were irrigated 1 day after transplanting and then watered to field capacity at weekly intervals. All other weeds were removed except for purple nutsedge. Captan (20 g 16 L^{-1}) was sprayed when needed to prevent anthracnose, a newly emerging disease of onion in the area. All other recommended practices for onion production were followed.

Rice. The field was irrigated then plowed twice and harrowed twice with a mechanized hand tractor, then leveled using a wooden plank. Water in the field was maintained at 10 cm level. Thirty-day old rice seedlings var. IR-64 were transplanted into 4 by 5 m plots at 15 x 25 cm spacing. The plants were applied with 160-90-40 kg ha^{-1} N, P, K in three splits; one-third as basal at transplanting and the remaining two-thirds top-dressed at 30 and 50 DAT. All other recommended cultural practices for rice production were followed.

Treatments

The following treatments were maintained in the same plots across crops: 1) mechanical stale-seedbed (two harrowings at 2-week interval); 2) preplant or preemergence herbicide (glyphosate for onion and pretilachlor for rice; 3) postemergence herbicide (for onion, glyphosate with a shielded nozzle; for rice, cyhalofop followed by 2,4-D); 4) handweeding (3 times for onion and 2 times for rice); 5) preplant glyphosate followed by one handweeding; 6) weed-free control; 7) farmers' practice (for onion, oxadiazon + oxyfluorfen fb 2 handweedings; for rice butachlor fb 3 handweedings); 8) unweeded control. Mechanical stale-seedbed was applied 2 wk after the last harrowing to allow tubers to sprout and grow. At treatment time, crop and/or weed seedlings were about 6 to 8 cm with two to four leaves. All herbicide treatments were applied with a hydraulic knapsack sprayer in 200 L ha^{-1}.

Data gathered and statistical analysis

The following data were recorded: 1) tuber counts prior to land preparation and after harvest in each crop; 2) shoot counts (non-destructive) at 20 and 40 days after treatment (DAT); 3) time spent in handweeding each plot at 20 and 40 DAT; 4) rice and onion yields; and 5) cost of weed control inputs. Tubers in intact chains were counted in 0.5 x 0.5 x 0.2 m at two points along the diagonal of each plot then returned as intact chains to the same points in the plots from where they were taken. Shoots were counted from 1 x 1 m at the same points where the tuber counts were made. Crop yields were taken from 2 x 5 m^2 at the center of each plot. Costs of all weed control inputs were recorded and partial budget analysis was done to estimate net benefits from the weed control treatments. The treatments were laid out in a Randomized Complete Block Design (RCBD) with four replications. Plot size was 4 m x 5 m. Data were subjected to Analysis of Variance (ANOVA) using General Linear Models Procedure (Statistical Analysis Systems). Treatment means were compared using LSD (0.05).

RESULTS AND DISCUSSION

Tuber and Shoot Production, Greenhouse

Shoot production was slow for the first 100 days after planting (0.5 shoot day^{-1}) and peaked at 1shoot day^{-1} at 112 to 126 days after planting (Figure 1a). At 126 days after planting (18 weeks) the plant produced a maximum of 374 shoots. Each shoot produced about six to eight leaves, peaking at eight leaves per shoot at 42 days after planting.

The number of tubers produced also increased slowly from 0.2 day^{-1} within the first 56 to 84 days of planting to 1 day^{-1} from 84 to 112 days after planting and peaked at 4 day^{-1} at 112 days after planting (Figure 1b). At 98 days after planting, the plant produced 95 tubers, which is similar to the one tuber/day observed in earlier studies (Rao 1968; Smith and Fick 1937). At 126 days (18 weeks) after planting, a single plant produced 549 tubers, which is comparable to the 622 tubers produced by yellow nutsedge (*Cyperus esculentus* L.) in 17 weeks in Georgia, USA (Hauser 1968).

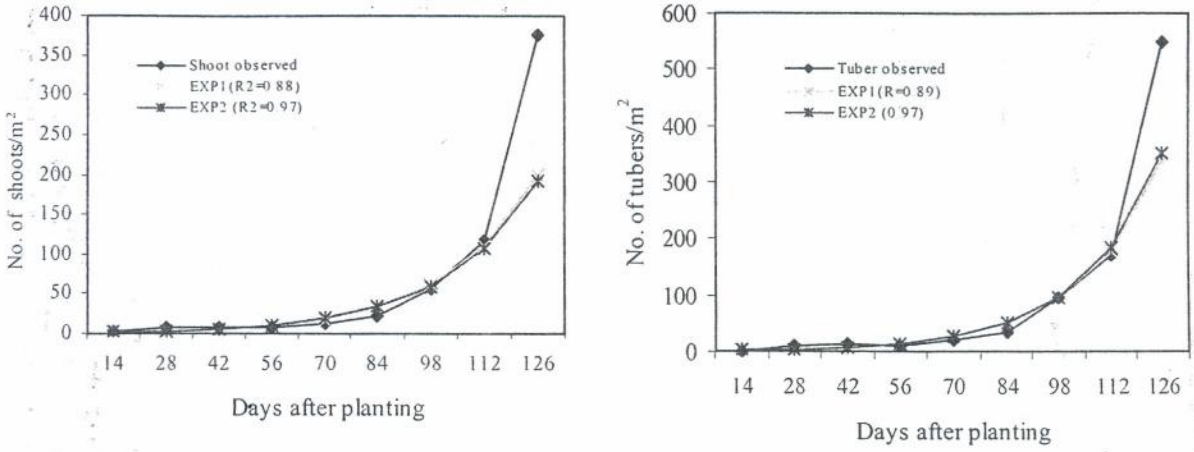


Figure 1. Shoot (1a) and tuber (1b) production from a single tuber of purple nutsedge grown in metal trays from September 2004 to January 2005 at the greenhouse facilities of the Philippine Rice Research Institute Central Experiment Station, Munoz, Nueva Ecija.

Slow production of shoots and tubers for the first 100 days could have been due to longer daylengths during the wet season from September to December, which coincided with the first 100 days of growth. Short photoperiods of 6 to 10 hours of daylight have been reported to increase tuber populations (Berger and Day, 1969). Shorter day lengths from December to January could have contributed to increased tuber production from 112 to 126 days after planting. Because the onion growing season in northern Philippines starts from November to March which coincides with short day lengths (shortest days are in December), increased tuber production within this period translates to very high tuber populations during the onion cropping season.

Tuber and Shoot Population Dynamics, Field

From an initial density of 1 tuber m^{-2}, tuber populations increased to about 300 per 0.5 m^2 at harvest of the first crop (onion) and peaked at about 700 to 900 tubers per 0.5 m^2 at the end of the fallow period before the next crop (rice) (Figure 2). After peaking, tuber populations decreased by 50 to 70% after 4 months, and declined further by 80 to 95 % of peak populations within 7 to 13 months. At harvest of the 4th crop, which was 16 months after the peak population, there was only about 2 to 3 % tubers left, except in the farmers' practice plots where there was about 6% tubers left (Table 1). Our half-life of 4 months for purple nutsedge tuber populations is shorter than the 5 to 7 months half-life obtained for yellow nutsedge (Stoller and Wax 1973) and the 16 months half-life predicted for purple nutsedge (Neeser et al 1997). We also observed 99% tuber mortality in 16 months, indicating shorter persistence of purple nutsedge in the tropics, compared to 99% mortality in 42 months observed for purple and yellow nutsedge in the U.S. (Neeser et al. 1997). Longer persistence of these weeds in temperate than in tropical conditions could be due to warm temperatures and faster rate of tuber desiccation in the tropics.

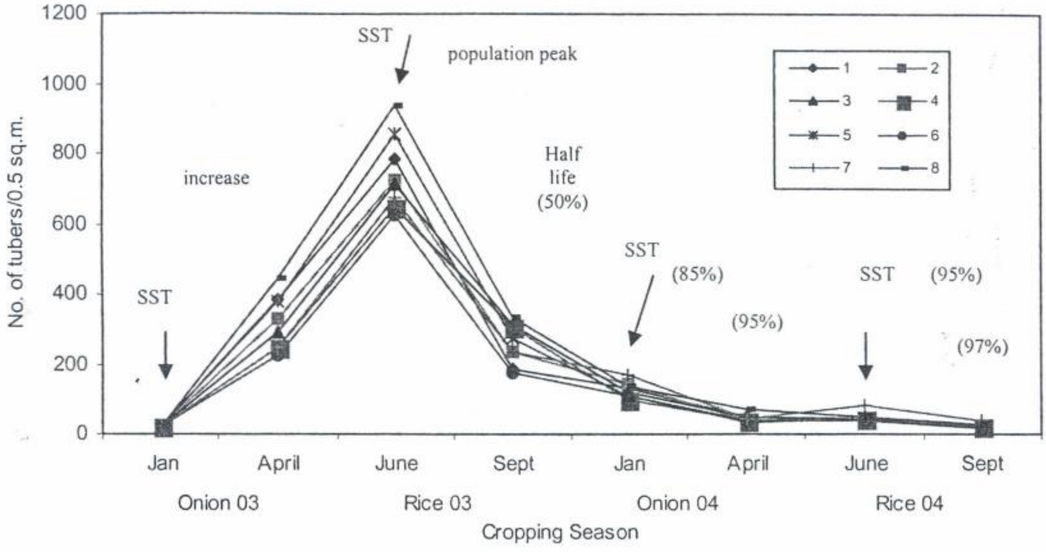


Figure 2: Tuber population dynamics across four crops in a rice-onion cropping system treated with various weed control practices at the PhilRice Central Experiment Station from January 2003 to September 2004; Legend: 1 – stale-seedbed technique; 2 – preplant herbicide; 3 – postplant herbicide; 4 – handweeding 2 or 3 times; 5 – preplant herbicide + 1 handweeding; 6 – farmers' practice; 7 – unweeded control; 8 – weed-free control. Numbers in parenthesis indicate percent decline in population after the population peak.

Table 1. Tuber populations across two rice and two onion crops treated with various weed control practices during the 2003 and 2004 wet and dry seasons at the PhilRice Central Experiment Station, Munoz, Nueva Ecija, Philippines.

Treatment	Onion 03		Rice 03		Onion 04		Rice 04	
	Jan.	April[1]	June[1]	Sept.	Jan.	April	June	Sept.
Stale-seedbed	20	382 ab	782 ab	186 b (76)*	130 (83)	48 ab (94)	38 c (95)	20 cd (98)
Preplant herbicide	20	328 abc	721 ab	237 ab (67)	142 (80)	40 b (94)	38 c (95)	20 cd (97)
Postplant herbicid	20	288 bc	712 ab	310 a (56)	123 (83)	48 ab (93)	46 b (94)	22 bc (97)
Handweeding 3x	20	249 bc	648 b	306 a (53)	99 (85)	40 b (94)	42 bc (94)	20 cd (97)
Preplant herb+Hw	20	379 ab	854 ab	274 ab (68)	111 (87)	32 b (96)	42 bc (95)	20 cd (98)
Weed-free control	20	226 c	626 b	174 b (72)	112 (82)	38 b (94)	40 bc (94)	15 d (98)
Farmer practice	20	249 bc	674 b	233 ab (65)	169 (75)	44 b (93)	82 a (87)	38 a (94)
Unweeded control	20	445 a	935 a	335 a (64)	138 (85)	70 a (93)	50 b (95)	28 b (97)
LSD (0.05)		134	255	108		22	12	

[1]Tuber populations increased from harvest of onion crop until end of fallow period before rice crop; *numbers in parenthesis indicate percent decrease after tuber populations peaked at end of fallow period.

Shoot populations also decreased rapidly at the end of the second crop (Table 2). From more than 200 shoots m^{-2} at the start of the first crop, shoot populations declined by 50 to 80% within 5 to 14 months, during the second and third crops. Within 17 months, at the start of the 4th crop, shoots declined by 97 to 99% with only about 1 to 2 % of the population remaining in all plots except in farmers' practice and unweeded plots where 5% to 8% of tubers were left (Table 2).

During the first crop, tuber and shoot populations in the farmers' practice were lower than those in the stale-seedbed treatments, indicating the immediate effect of herbicides and handweeding compared to the stale-seedbed treatment (Tables 1 and 2). But the rate of decline in the stale-seedbed treatments was faster than in farmers' practice plots and with time, the effect stale-seedbed treatments became apparent. Tuber populations in the stale seedbed plots were lower than those in the farmer's practice through the second and third crops. During the fourth crop, farmers' practice plots had higher tuber populations than in stale seedbed or in unweeded plots. Tuber and shoot populations in preplant and postplant herbicide treatments were higher than those of the stale-seedbed plots and similar to those of the farmers' practice plots.

Table 2. Shoot populations and crop yields from two onion and two rice crops treated with various weed management practices from January 2003 to September 2004 in a rice-onion rotation system at the PhilRice Central Experiment Station.

Treatment	Onion 03		Rice 03		Onion 04		Rice 04	
	Shoot (no m^{-2})*	Yield (t ha^{-1})	Shoot (no m^{-2})*	Yield (t ha^{-1})	Shoot (no m^{-2})*	Yield (t ha^{-1})	Shoot (no m^{-2})*	Yield (t ha^{-1})
Stale-seedbed	252 b	17.4 bc	42 bc (83)	5.1 a	70 abc (72)	33.5 a	2 b (99)	5.7 ab
Preplant herbicide	450 a	13.7 c	74 b (84)	3.7 c	52 cd (88)	15.6 c	4 b (99)	5.2 d
Postplant herbicide	392 a	14.6 c	30 bc (92)	3.8 bc	54 cd (86)	24.6 b	2 b (99)	5.4 cd
Handweeding 3x	104 cd	21.8 b	56 bc (46)	4.7 ab	48 cd (54)	33.8 a	2 b (98)	5.7 ab
Preplant herb+ Hw	222 bc	12.1 cd	46 bc (79)	4.4 abc	36 d (84)	20.3 bc	2 b (99)	5.3 cd
Weed-free control	24 d	21.9 b	4 c (83)	4.8 a	40 d (+)	32.5 a	2 b (92)	5.9 a
Farmer practice	42 d	30.9 a	78 b (+)	4.5 abc	82 a (+)	31.0 a	2 b (95)	5.5 bc
Unweeded control	438 a	6.6 d	176 a (60)	2.5 d	78 ab (82)	0 d	12 a (97)	4.6 e
LSD (0.05)	126	6.8	70	0.9	26	6.3	6	

*taken 40 DAT; numbers in parenthesis indicate percent decline after initial densities during first crop.

Increase in tuber populations from low initial densities until a population peak was reached, followed by a steady decline through the second to the fourth crops, suggest that a density-dependent process regulate population dynamics of purple nutsedge. Similar density-dependent processes were observed in yellow nutsedge grown in tobacco-grass-ley rotation system in Africa (Lapham et al, 1985). Density-dependent population dynamics would also explain the much lower number of tubers produced in the field when the weed was grown with other purple nutsedge plants. In our field study, a single tuber produced an average of 11 tubers and 7 shoots during the rice crop, 14 tubers and 22 shoots during the onion crop and 34 tubers and 39 shoots during the fallow period (Table 3). These were 90 to 95% lower than the 547 tubers and 347 shoots produced when purple nutsedge was grown alone. Much lower rates of increase in tuber populations were also observed when purple nutsedge was grown with crops like beans, sweet potato, maize, bell pepper, and tomato as a result of crop interference (Neeser et al 1998).

Crop yields, Weed Control Costs, and Net Incomes

Except for onion 2003 cropping season, rice and onion yields were highest in the stale-seedbed treatments (Table 2). Yields from farmers' practice, handweeding two to three times and weed-free plots were comparable and were higher than yields from herbicide-treated plots. Lowest yields were obtained from unweeded control plots. Greater competitive ability of rice than onion against purple nutsedge is reflected in the greater yield reductions in unweeded plots during the onion crop than in the rice crop. In fact, no yields were obtained in unweeded plots in the second onion crop.

Table 3. Tuber and shoots produced from a single tuber during the rice and onion crops and fallow period between rice and onion at the PhilRice CES, January 2003 to September 2004.

Treatment	Number of tubers and shoots produced by a single tuber					
	Onion		Rice		Fallow	
	Tuber	Shoot	Tuber	Shoot	Tuber	Shoot
Stale-seedbed technique	17	18	8	4	36	31
Preplant herbicide	16	40	11	9	34	61
Postplant herbicide	14	34	15	7	34	38
Handweeding 2-3 times	10	26	13	13	27	45
Preplant herbicide + HW	15	23	11	5	34	38
Farmers' practice*	12	6	11	6	32	39
Unweeded control	22	28	17	10	47	30
Weed-free control	9	4	7	4	26	30
Average	14	22	11	7	34	39

Total weed control costs in both crops was reduced by 68% in the stale-seedbed plots and by 46 to 69% in the preplant and postplant herbicide applications (Table 4). This was due to reduction in handweeding in the stale-seedbed treatments by 66 % in both rice and onion crops. Preplant and postplant herbicide applications also reduced the amount of handweeding by 56 to 86% over those of farmers' practice or weed-free plots.

Highest net incomes were obtained from plots treated with farmers' practice and those treated with stale-seedbeds (Table 4). In spite of the high handweeding costs, high net incomes were also obtained from the handweeded plots. Lowest net incomes were obtained from the herbicide-treated plots presumably due to lower yields resulting from inadequate weed control.

Although we have shown that one purple nutsedge plant produced 547 tubers in 126 days when grown alone, its tuber production is reduced by about 95% when grown with crops and other weeds.

Table 4. Time spent in handweeding, total weed control costs and net incomes from two onion and two rice crops from January 2003 to September 2004 in a rice-onion cropping system at the PhilRice Cental Experiment Station, Munoz, Nueva Ecija, Philippines.

Treatment	Handweeding time (mday ha^{-1})[1]		Weed control cost (US \$ ha^{-1})[2]	Net income (US \$ ha^{-1})[2]
	Onion	Rice		
Stale-seedbed	104 (66)*	8 (65)*	494 (68)*	5816
Preplant herbicide	104 (66)	5 (78)	553 (63)	3024
Postplant herbicide	41 (86)	5 (78)	471 (69)	4299
Handweeding 2 to 3x	293 (4)	36 (-)	1243 (10)	5489
Preplant herbicide + Hw	135 (56)	20 (13)	764 (46)	3340
Farmers' practice	306	23	1390	5850
Weed-free control	364	60	1606	5035
Unweeded control				496

*Numbers in parentheses indicate percent reduction over those of farmers' practice.
[1]Total of two years (2003 and 2004);
[2]Total costs and net incomes from two onion and two rice crops; 1 US\$ = Php 50 (2004 exchange rate)

Our peak populations of about 1500 tubers in a rice-onion rotation system from initial density of 1 tuber m^{-2} is comparable to peak populations of 1000 tubers m^{-2} from an initial density of 1.5 tubers m^{-2} observed by Lapham (1987) in purple nutsedge growing with tobacco-grass-ley cropping system in Afica.

In our studies, purple nutsedge tuber and shoot populations growing in a rice-onion farm, peaked in 3 to 5 months during the first crop, declined rapidly during the second crop, followed by a slow but steady decline in the third and fourth crops treated with mechanical, (handweeding), cultural (stale-seedbed technique) or chemical (herbicides) control methods. The rate of tuber population decline in stale-seedbed treatment was faster and was sustained through four crops with less weed control costs than those of the other treatments involving herbicides or handweeding. Our study, conducted in a field with high tuber densities of more than 50 tubers m^{-2} indicate that reducing tuber survival through cultural approaches such as the stale seedbed technique is more cost-effective than reducing production rate of new tubers and shoots through herbicides and handweeding, which agree with results of other studies (Jordan et al. 1995; Neeser et al. 1998). Our study also demonstrated the effectiveness of stale-seedbed treatments in reducing purple nutsedge populations in multi-crop rotation systems in contrast to earlier studies showing its effectiveness in single crop or fallow systems (Johnson and Mullinix 1995). Data from our study could be used in developing mechanistic models of purple nutsedge population dynamics as basis in formulating cost-effective long-term management strategies. It also supports the paradigm shift from single season approaches to multi-season population management approaches aimed at long-range management strategies to reduce the weed seedbank in the soil and increase economic benefits for the farmer (Jones and Medd 2000).

ACKNOWLEDGEMENTS

This research is part of Ph.D. dissertation of senior author and was conducted through the Integrated Pest Management Collaborative Research Support Program (IPM CRSP) funded by the USAID Global Bureau Grant No. LAG 4196-G-00-3053-00, with Virginia Tech as lead institution, and University of the Philippines Los Banos, Philippine Rice Research Institute, International Rice Research Institute and Bangladesh Agricultural Research Institute as host country collaborating institutions.

LITERATURE CITED

Baltazar, A.M., E.C. Martin, M.C. Casimero, F.V. Bariuan, S.R. Obien, and S.K. De Datta. 2000. Reducing herbicide use with agronomic practices in onion (*Allium cepa*) grown after rice (*Oryza sativa*). The Philipp. Agric. Scientist 83 (1): 34-44.

Berger, G.B. and B.E. Day. 1969. Dormancy, growth inhibition and tuberization of nutsedge (*Cyperus rotundus* L.) as affected by photoperiod. Proceedings 1st Asian-Pacific Weed Control Interchange. Honolulu, HI. June 12-22, 1967. p. 123.

Hauser, E.W. 1968. Yellow nutsedge – problems, research trends, and outlook. Proceedings Northeast Weed control Conference 22:37-48.

Johnson, W.C. III and B.G. Mullinix Jr. 1995. Weed management in peanut using stale seedbed techniques. Weed Sci. 43:293-297.

Jones, R.E. and R.W. Medd. 2000. Economic thresholds and the case for longer term approaches to population management of weeds. Weed Tech. 14:337-350.

Jordan, N., D.A. Mortensen, D.M. Prenzlow, and K.C. Cox. 1995. Simulation analysis of crop rotation effects on weed seedbanks. Amer. J. Bot. 82:390-398.

Lapham, J. 1985. Unrestricted growth, tuber formation and spread of *Cyperus esculentus* L. in Zimbabwe. Weed Res. 25:232-329.

Lapham, J. 1987. Population dynamics and competitive effects of *Cyperus esculentus*-prediction of cost-effective control measures. British Crop Protection Conference-Weeds. p.1043-1050.

Neeser, C., R. Aguero, and C.J. Swanton. 1997. Survival and dormancy of purple nutsedge (*Cyperus rotundus*) tubers. Weed Sci. 45:784-790.

Neeser, C., R. Aguero, and C.J. Swanton. 1998. A mechanistic model of purple nutsedge (*Cyperus rotundus*) population dynamics. Weed Sci. 46: 673-681.

Rao, J. 1968. Studies on the development of tubers in nutgrass and their starch content at different depths of soil. Madras Agric. Journal 55:19-23.

Siriwardana, G. and R.K. Nishimoto. 1987. Propagules of purple nutsedge (*Cyperus rotundus*) in soil. Weed Technol. 1:217-220.

Smith, E. and G. Fick. 1937. Nutgrass eradication studies. I. Relations of the life history of nutgrass (*Cyperus rotundus* L.) to possible methods of control. Journal of the American Society of Agronomy 29:1007-1013.

Stoller, E.W. and L.M. Wax. 1973. Yellow nutsedge shoot emergence and tuber longevity. Weed Sci. 21:76-81.

Weed management scenario in direct seeding rice in Indo-Gangetic plains-issues and opportunities

A.N. Tewari[1], Y. Singh[2] and A.M. Mortimer[3]
[1] Professor & Principal Investigator (Weed Science)
Chandra Shekhar University of Agriculture and Technology, Kanpur-208002 India
ant_kanpur@rediffmail.com
[2]GB Pant University of Agriculture and Technology, Pantnagar, India
ysingh_42@rediffmail.com
[3]School of Biological Sciences, Liver pool, UK
ammortimer@liverpool.ac.uk

Abstract: Direct seeding (broadcasting/line sowing rice seeds onto a dry/wet seed bed) has been an age old practice throughout the rice growing belt of the Gangetic plains of India. From 1960's, increased canal and tube well irrigation facilities and the advent of high yielding fertilizer responsive dwarf rice led farmers to practice transplanting young seedlings onto puddled soils. The transplanting system ensured optimum plant population, reduced weed competition and prevented water percolation losses enhancing productivity. Contrastingly, direct seeded rice suffered from intense weed competition, inadequate plant stand and poor water retention, resulting in low productivity. In recent years, migration of agricultural labor to urban areas, depletion of ground water, uncertain canal water supply, inadequate power supply and erratic rainfall have compelled rice growers to return to direct seeding. Research and on-farm demonstrations have established that comparable yields of direct seeded and transplanted rice can be obtained through adoption of improved weed management practices with limited irrigation (one pre-sowing irrigation). The system provides 7-10 days early maturity which is more appropriate for multiple cropping programme. In rainfed direct seeded rice, it has been shown that intercropping of short duration pulse crops will improve rice crop productivity and is beneficial for weed management.

Farmers' experience and literature reveal the need to develop location specific weed management technologies for direct seeding rice under different diverse environments. Weedy rice-an emerging problem is serious threat to direct seeded rice. This paper reviews the present scenario of weed management in direct seeding rice and emerging issues in the Gangetic plains of India for promoting rice productivity under resource constraints of present day agriculture.

Key words: Direct seeded rice, intercropping, weed management, weedy rice.

INTRODUCTION

The Indo-Gangetic plains (IGP) are a very fertile agro-ecosystem in India. These have plentiful supply of natural resources that include deep productive soils, good quality surface and ground water and climatic features that permit multiple rice-based cropping systems. In IGP, the mean rainfall ranges from 964 mm (West Uttar Pradesh) to 1425 mm (Gangetic west Bengal) mostly occurring during June to September (75.6% in Gangetic West Bengal to 87% in west Uttar Pradesh). Rice area under irrigation ranges form 27% in West Bengal to 99.8% in Punjab. There is good scope of utilizing this rainfall for direct seeding with supplemental irrigations particularly before onset of monsoon and after withdrawal of monsoon to harvest optimum yield.

Need of direct seeding in IGP

Due to rapid migration of agricultural labor from rural to urban areas, water shortage owing to depletion of ground water, power shortage, unassured canal water supply, erratic rainfall etc., transplanting is often delayed, resulting in poor yield. In transplanting, the production cost is usually high with low benefit-cost ratio compared to direct seeding. Direct seeding offers such advantages as faster and easier sowing, reduced labour and less drudgery, earlier crop maturity by 7-10 days, more efficient water use and higher tolerance of water deficit, less methane emission and often higher profit in areas with assured water supply.

Prospects of direct seeding in IGP

The success of direct seeding rice solely depends upon timely crop establishment, i.e., before the onset of monsoon to encounter weed invasion. This could be possible if the sowing of rice crop is accomplished around the first fortnight of June by giving pre-sowing irrigation followed by one or two irrigations before onset of monsoon. Results of on-station trial as well as on-farm trials revealed encouraging response of direct seeding rice in providing the comparable grain yield of direct seeded rice with transplanted rice (Singh et al. 1997; Dhiman et al. 1998).

ISSUES AND OPPORTUNITIES

Weed problems and yield losses

Generally, direct-seeded rice suffers more from weed competition than transplanted rice. Direct-seeding under unpuddled conditions encourages more weed growth than wet seeding which is done after pudding and leveling the land. The major weeds associated in direct seeded rice are detailed below:

Associated weed flora with moist or dry seeding: In direct seeded rice culture, rice plants compete with weeds from the time they emerge. Weeds pose more serious problems in the production of dry seeded rice than in other rice culture. Among the associated weeds, *Echinochloa colona* and *Cyperus rotundus* are the major weeds. The other weeds are *Dactyloctenium aegyptium*, *Digitaria sanguinalis*, *Eleusine indica*, *Phyllanthus niruri*, *Trianthema monogyna*, *Digera arvensis* and *Cyperus iria*.

Associated weed flora with puddled rice: In this rice culture, the problem is not as severe as in direct seeded dry rice. The weeds like *Echinochloa colona* and *Fimbristylis littoralis* predominate. *Cyperus iria* and *Cyperus difformis* also occur. Grasses are more difficult to control in wet-seeded rice as they emerge at the same time as, or even earlier than rice thus there is greater competition for similar growth requirements.

Studies carried out at Central Rice Research Institute, Cuttack revealed that in the absence of weed control, yield losses due to weeds was 46% under direct seeding on dry soil and 20% in puddled rice (De Datta 1981). Grain yield of direct seeded rainfed rice has been found to increase by 40.3% in absence of weed competition and removal of grassy and broadleaved weeds, separately from mixed population of all types of weeds recorded 26.5% and 33.9% increase in the grain yield, respectively, over removal of none. However, removal of sedges failed to increase grain yield significantly (Tewari and Singh 1989). Moorthy and Manna (1984) reported 24.3% loss in yield due to sedges under puddled seeded conditions. They further reported that in such a typical agro-ecosystem of rice culture, 97-100% of the weeds were sedges. The grain yield increased by 32.0%, 24.0% and 19.1% due to removal of two out of three types of weeds namely, sedges + grassy, sedges + broadleaved and grassy + broadleaved weeds, respectively. De Datta (1979) reported that allowing sedges and broadleaved weeds throughout reduced the grain yield in direct seeded rice by 24%, whereas grassy weeds and combination of all the three types caused 86 and 100% yield reductions, respectively. In view of extremely severe weed competition during early stage, the yield loss in upland rice can be 100 percent (Manna et al. 1971).

It has been experimentally proven that economical yield could be harvested if the weeding operation is accomplished during critical competitive period. In a field experiment conducted at Kanpur (India) and other locations, the critical period of weed competition has been identified as 2-

4 weeks after sowing under direct seeded (dry) and 2-5 weeks after sowing in direct seeded puddled rice (Tewari and Singh 1991).

Weed management

Weed management was identified as the third most important area of research in rice in terms of generating economic surplus in a study made by the National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi. The earliest practice of weed control was mechanical weeding supplemented with good seedbed preparation, crop rotation, water management etc. A traditional practice known as *beushening* or *biasi* in broadcast sown rice is practiced in eastern states of India-Orissa, Chhattisgarh, Bihar, Jharkhand and to a lesser extent in Assam, West Bengal and U.P. in shallow lowland situation. This operation involves shallows cross ploughing in the fields 30-40 days after monsoon rains are received and there is water depth in the field, around 10 cm. This operation is followed by leveling with a plank.

Considerable work on the use of herbicides in upland rice has been done in India and abroad. The promising pre-emergence herbicides for weed control in upland rice are butachlor, thiobencarb, anilophos, oxadiazon and pendimethalin. In the rainy season, these herbicides provide weed-free situation up to 30-35 days after sowing rice crop and thereafter weeds start germinating and therefore, supplementary hand weeding is required. Pre-emergence application of butachlor at rates of 1.5-2.0 kg ha^{-1} was reported to control majority of weed flora in upland situation. (Bhargavi and Reddy 1990). Basically, it controls grasses but some sedges and broad leaf weeds are also controlled. Deshmukh and Trivedi (1987) noted better performance in terms of weed control and grain yield with pre-emergence application of oxadiazon (0.75 kg ha^{-1}) supplemented with one hand weeding at 30 days after sowing. Pendimethalin (1.5kg ha^{-1}) alone or in combination with one hand weeding gave promising result (Bhagat et al. 1991). Better performance of anilophos (0.4-0.5 kg ha^{-1}) was reported by Chandrakar et al. (1993). Butachlor (2 kg ha^{-1}) followed by one hand weeding at 25 days after sowing could bring the yield of direct seeded irrigated rice in the same bracket with weed free created manually thrice (Rathi and Tewari 1979).

A new herbicide formulation butanil (a combination of butachlor and propanil) could be used as a post-emergence spray for controlling the weeds in upland situation (Moorthy and Saha 2002). Similarly, fenoxyprop, a new post-emergence herbicide performed well against grasses when sprayed 25 days after sowing at a dose of 70 g ha^{-1} (Singh et al. 2002). Singh (1997) observed that pre-emergence application of anilophos (0.6 kg ha^{-1}) or butachlor (1.5 kg ha^{-1}) coupled with post emergence application of 2, 4-D at 0.5 kg ha^{-1} were effective in controlling weeds. Moorthy (2002) observed that the new herbicide formulation pyrazosulfuron ethyl at 15 g ha^{-1} showed promising effect in controlling weeds in direct-seeded shallow rice.

The results of weed management trials done at 21 and 18 locations during 1998 and 1999, respectively, under the All India Coordinated Rice Improvement Project indicated that in direct sown rice under puddled condition, the combination herbicide anilophos + ethoxysulfuron at both the doses (0.250 + 0.010 kg ha^{-1} and 0.375 + 0.015 kg ha^{-1}) was found promising in controlling broad spectrum of weeds and recorded on par grain yield with two hand weeding. The problem of changing weed flora will be effectively tackled by combination of herbicides which are effective as pre and post emergence herbicides. (Subbaiah et.al.2002). Oxadiazon (0.8 kg ha^{-1}) was found to kill all types of annual grasses, sedges and broadleaved weeds and increased grain yield in puddled rice (19.39%) over untreated (Tewari et al. 1991).

Water Management

Large amounts of water are needed to maintain standing water in a rice crop, and even more if the soil is not puddled. Flooding suppresses growth of terrestrial or semi-aquatic weeds and makes them easier to control by cultural or chemical methods. It also enhances herbicide efficacy.

However, this opportunity of ponding water in direct seeded rice is seldom achieved especially under upland situations. Research has shown a 20-25% savings in water, without yield loss, mainly resulting from less seepage losses and decline in soil permeability from puddling Prihar and Grewal 1985). However, farmers often apply excess water in the crop and the fields do not need to be flooded to achieve high yields. Bhuiyan (1992) reported 40% savings in water without yield loss by replacing shallow water regimes with a saturated soil regime.

Cultivars

Fast growing rice cultivars with rapid growth coupled with abundant leaves which could compete well with weeds, should be sown. The varieties *Kalinga, Vandana,* RR151-3, RR20-158 and RR 151-1 are considered reasonably weed competitive. Results of a recent study carried out at the National Research Centre for Weed Science, Jabalpur (India) indicated that the semi-tall variety *Vandana* showed better competitive abilities against *Cyperus iria* than the short statured varieties *Heera* and *Annada*. It has also done well under single-hand weeded condition (Moorthy 2004).

Allelopathic potential of cultivars that can suppress weeds by releasing certain toxic substances may play a greater role in the future. However, research on these lines is still inadequate and no practical recommendation is available to utilize allelopathic plants for weed management in direct seeded rice. There is need to screen vast rice germplasm collections available in the country for their allelopathic traits and the scope of using them for breeding allelopathic varieties with other desirable characters.

Optimum Crop Stand

Row seeding is specifically advantageous as it maintains optimum stand of the crop and facilitates better utilization of applied nutrients and mechanical weed control. Drilling (sowing in continuous lines) and dibbling (bunch seeding or hill seeding) are the line sowing methods, which have a distinct advantage over broadcast method of sowing. Bhan (1968) found that narrow spacing (15cm) was superior to wide spacing (30 and 45 cm) in minimizing weed competition and increasing productive tillers and yield in upland rice. A spacing of 20 cm between rows and 10 cm between hills is considered sufficient for establishing optimum crop stand. Line sowing can be achieved by using seed drills or sowing behind the plough. It is necessary to use optimum seed rate for establishing optimum crop stand. Moorthy and Mittra (1991) recorded similar reduction in weed biomass with increasing seed rates from 50-100 kg ha^{-1}.

Nitrogen Application

Time and method of nitrogen application is very important in direct seeding rice especially when weed infestations are severe. With dry-seeded rice, the basal application of fertilizer should be delayed until weeds are removed. In upland rice, basal application of the entire N fertilizer encourages higher weed growth. The recommended N (40-60 kg ha^{-1}) has to be applied in 3 half splits at 20 days after sowing and the two equal splits each at maximum tillering and panicle initiation stage (Moorthy and Mittra 1990). However, a small quantity of N at sowing in the furrows helps in increasing the initial vigor of the crop plants, which in turn helps in tolerating early weed competition.

Intercropping

Intercropping of rice with pulses and oil seeds in upland rainfed condition is prevalent practice in rice growing areas. Intercropping of upland rice with certain weed suppressing crops like cowpea and greengram was found advantageous (Hussain and Gogoi 1996). Growing of sole crop of direct seeded dry rice proved uneconomical in many cases and intercropping of pigeon pea, black gram and ground nut with direct seeded dry rice proved advantageous as it enhanced rice equivalent yield over its sole cropping. Butachlor (1.5 kg ha^{-1},) followed by inter-culture at 40 days after sowing for pure rice and in intercropping with pulses has been found effective and economical (Kar 2002).

Emerging Issue of Weedy Rice

In India, weedy rice has been a problem associated with direct seeded broadcast rice under dry conditions. The problem is not so intense in wet seeded/transplanted culture. Weedy rice has been found to cause significant yield reduction in domestic rices in eastern India. Following strategies have been suggested to overcome the problem of weedy rice.

1. Farmers in eastern India prefer to grow purple leaf varieties of rice in areas of wild rice/weedy rice problem. This facilitates easier weeding of weedy rice, which are greenish. The purple leaf varieties included P-502, R-575, L-12 and C.P. 1 (Gupta 1998). *Kalashree*-a variety with purple base developed at Central Rice Research Institute, Cuttack (India) and another one *Shymala* developed at Indira Ghandhi Agricultural University, Raipur (India) had been recommended for wild rice-infested areas.
2. Seed bank of weedy rice may be exhausted by employing deep tillage operations done repeatedly before sowing/transplanting rice. Richharia (1964) recommended direct sowing of pre-germinated rice seeds on puddled fields, deep ploughing to burry wild rice seeds, transplanting rice seedlings in lines for easy identification and manual removal and changing crop rotation to reduce weedy rice infestation. He also suggested to keep ducks for grazing the seed and seedlings of wild rice.
3. Rouging off -types and weedy rice types during tillering, booting and flowering stages of rice is the only method of controlling weedy rice.
4. Removal of the dropped weedy rice seeds from the ground may help in preventing further dissemination. Farmers must be vigilant towards combine harvesters and other farm implements to avoid weedy seeds dissemination.

Future Thrust

Following areas of research need to be intensified:

1. Location-specific low cost weed management technologies involving herbicides and implements must be developed for direct seeding raised under different ecologies.
2. Since there is good scope of wet seeded rice, selection of competitive cultivars with rapid growth, abundant leaves and leaf area and bushy growth habit is most important for competing weeds.
3. Since direct seeding of sole rice especially under rainfed situation is often found uneconomic, intercropping of short duration pulses and oil seeds with direct seeded dry rice under additive series has good scope to utilize natural resources for realizing greater profit.
4. Information on weedy rice infested area, magnitude of infestations, estimation of losses, determining economic threshold level are required especially under direct seeded rice.
5. Long term field studies may be initiated on a permanent site in cropping systems involving direct seeding rice to monitor the changes in weedy rice infestations influenced by tillage and agronomical practices.
6. Rotation of crops will certainly play significant role in checking the infestation of weedy rice in cultivated rice. Profitable crop rotations may be developed.

In general, it is suggested to enhance awareness among farmers in relation to the emerging problem of weedy rice and its effective management. Regulations pertaining to weedy rice seed contamination in rice may be enforced.

LITERATURE CITED

Bhagat K.L., Dahama A.K. and Singh H., 1991. Performance of herbicides in direct-seeded upland rice. Annals of Agricultural Research, 12 (4): 422-424.

Bhan V.M. 1968. Riso, 17: 149-154.

Bhargavi K. and Reddy T.V. 1990. Effect of time and method of application of herbicides on weed control in semi-dry rice. *Indian Journal of Agricultural Science,* 60 (2): 147-150.

Bhuiyan S.I. 1992. Water management in relation to crop production: Case study in rice. Outlook on Agriculture, 21:293-299.

Chandrakar B.L., Tripathi R.S., Tuteja S.A.S. and Taunk. 1993. Effect of application timings and formulation of anilophos in broadcast seeded semi-dry rice. Proceeding of International Symposium of Indian Society of Weed Science on Integrated Weed Management for Sustainable Agriculture, Hisar: 13-15.

De Datta S.K. 1979. Weed problems and methods of control in tropical rice. in symposium on weed control in tropical crops P. 9-44. Pub. Weed Sciences Society Philippines, INC, and Philippines Council for Agriculture and Resources Research.

De Datta S.K. 1981. Principles and practices of rice production. John Wiley and sons. New York, 460-507.

Deshmukh M.R. and Trivedi K.K. 1987. Response of upland rice to weed control methods. International Rice Research Newsletter, 12 (4): 47-48.

Dhiman, S.D., Sharma H.C., Nandlal D.P., M.H. and Singh D. 1998. Effect of irrigation methods, crop establishment and fertilizer management on soil properties and productivity in rice (*Oryza sativa*) – wheat (*Triticum aestivum*) sequence. Indian Journal of Agronomy, 43 (2): 208-212.

Gupta O.P. 1998. Weed management practices in field crops and vegetables. In: Modern weed management, Agro Botanica publishers: Bikanar, India: 301-342.

Hatta S. 1967. Water consumption in paddy field and water saving rice culture in the tropical zone. Japan Tropical Agriculture, 11:106-112.

Hussain J. and Gogoi A.K. 1996. Non-chemical weed management in upland direct seeded rice. Indian Journal of Weed Science, 28 (1&2): 89-90.

Kar Gouranga 2002. Upland rice ecosystem in India. Indian Farming Vol.52 (7) Oct. 2002. pp 13 – 17.

Manna G.B., Rao M.V. and Dubey A.N. 1971. Oryza, 8:256-268.

Moorthy B.T.S. 2002. Evaluation of pyrazosulfuron ethyl alone and in combination with molinate for controlling weeds in rainfed direct-seeded lowland rice. Indian Journal of Weed Science, 34 (3&4): 285-286.

Moorthy B.T.S. 2004. Integrated weed management in rice under different ecologies, NRCWS Technical Bulletin No3, p4, National Research Centre for Weed Science, Jabalpur (India).

Moorthy B.T.S. and Manna G.B. 1984. Herbicides for weed control in puddled seeded rice. Indian Journal of Weed Science, 16 (3): 148-155.

Moorthy B.T.S. and Mitra B.N. 1990. Uptake of nutrients by upland rice and associated weeds as influenced by nitrogen application schedules and weed management practices. Crop Research, 3 (2): 144-150.

Moorthy B.T.S. and Mitra B.N. 1991. Influence of seeding densities and weed management practices on the performance of upland rice. Thailand Journal of Agricultural Sciences, 24: 19-27.

Moorthy B.T.S. and Saha Sanjoy 2002. Evaluation of pre and post emergence herbicides for their effects on weeds and upland direct seeded rice. Indian Journal of Weed Science, 34 (3&4): 197-200.

Rathi K.S. and Tewari A.N.1979. Weed management in upland direct seeded paddy under irrigated condition. Indian Journal of Agricultural Research, 13 (2):111-112

Richharia R.H. 1964. Wild rice menace and possible methods of it control CRRI publication (India).

Singh K.M., Pal S.K., Verma U.N., Thakur R. and Singh M.K. 1997. Effect of time and methods of planting on performance of rice (*Oryiza sativa*), cultivars under medium land of Bihar plateau. Indian Journal of Agronomy, 42 (3): 443-445.

Singh P.K., Anil Dixit and Parey S.K. 2002. Transfer of Technology, Weed News, 2 (4):2.

Singh U.P. 1997. Studies on weed management and crop establishment in rainfed medium deep water logged rice ecosystem. Indian Journal of Weed Science, 29 (1&2) 80-81.

Subbaiah S.V., Kumar R.M. and Mishra B. 2002. Modern agronomic techniques to increase rice production. Indian farming, 52 (9). P 7-12.

Tewari A.N. and Singh R.D. 1991. Crop-weed competition in upland direct seeded rainfed rice. Indian Journal of Weed Science, 23 (1& 2): 51-52.

Tewari A.N., Chandra S. and Singh V. 1991. Chemical weed control in direct seed puddled rice under irrigated condition. Indian Journal of Weed Science, 23 (3 & 4): 85-86.

Tewari A.N.; and Singh K.K. 1989. Effect of removal of types of weed flora in upland direct seeded rainfed rice. Indian Journal of Weed Science, 21 (3 & 4) : 72-74.

Weed management for sustainable rice (*Oryza sativa* L.) production in West Bengal – A study on environmental perspective

S. Mitra and D. K. Khan
Department of Environmental Science, University of Kalyani, Kalyani, 741235, Nadia, West Bengal, India
drdkkhan@vsnl.net

Abstract: Field experiments were carried out during *rabi* (2003) and *kharif* (2004) seasons in selected plots located in the Zonal Adaptive Research Station (Farms), Krishnagar, Nadia, West Bengal. The experiment was designed to find out the feasibility of effective weed management practices in the light of crop yield, vis-à-vis, cost benefit aspect and probable environmental degradation. Selected plots were treated with a) mulching by straw, b) glyphosate 2 kg a i ha^{-1} and c) green manuring. One plot remained unweeded. In order to achieve better results each plot is further subdivided for application of i) pretilachlor 400 ml ha^{-1} (3 DAT), ii) one hand weeding (21 DAT), iii) pretilachlor 400 ml ha^{-1} (3 DAT) with one hand weeding (21 DAT). One unweeded plot remained as control plot. The experimental results showed that the number, types and dry weight of weeds varied greatly with time and treatment. Normally unweeded plot contains the largest number and types of weeds. Occurrences of microflora (bacteria) showed great variation in number in different plots. Observational data on microflora revealed initial retardation of growth just after application of glyphosate and pretilachlor but it regained its growth slowly and reached its peak after 70 days. In green manured plot prolific presence of nitrogen fixing bacteria and phosphate solubilising bacteria was observed. Actinomycetes showed little variation in each experimental plot. Unweeded plot revealed the highest number of total bacteria. The largest concentration of fungus was observed in mulched plots. Such concentration thinned out with changes in microclimatic condition. Data on yield of crops revealed maximum achievement in green-manured plot. However, plots treated with glyphosate and mulching showed similar results. Significant differences in yield were observed in unweeded plot. Laboratory analysis of water samples collected from different rhizosphere layer revealed arsenic (As) maintained a constant level except in one location where glyphosate and pretilachlor are both applied as a measure of weed control and management. The experimental results suggest that better weed management could not be achieved by following only one method of weed control.

Key words: Crop yield, environmental degradation, glyphosate, microflora, mulching, pretilachlor.

INTRODUCTION

Rural economy in our country is primarily agriculture-based where rice (*Oryza sativa L*) is one of the most important staple food crops. The production of rice in India is rather low compared to other countries. Of the various reasons put forward to explain the low productivity of rice in India weed menace is considered one of the most important. Estimates revealed that the yield loss varies between 18 to 50 % depending upon the seasons and landforms (Balasubramanian and Duraiswamy 1996). Weeds are also considered a major constraint for increased rice production (Labrada 1996). To overcome the constraints of rice production, farmers are adopting newer methods. High yielding varieties require application of herbicides to control weeds. Farmers are using herbicides for controlling weeds for quick results but indiscriminate use of herbicides has brought an adverse effect on the environment.

Thus a study was undertaken in the alluvial zone of Lower Ganga Delta to explore the feasibility of weed management practice that will conserve our environment without degrading the rice production in the aspect of weed character and influence, microfloral population, groundwater pollution and phytotoxic extent.

MATERIALS AND METHODS

Crop: Rice; Variety: IET-4094, Design: Split plot; Replication: 3, Plot size: 4 m × 3 m, Experimental time: Boro season of 2003 and Aman season of 2004, Soil type: Loamy soil, Climate: Sub Humid Tropic, Rainfall: 104.05 cm (average annual), Height: 15 m above sea level. The study was conducted with the help of some treatment combinations like, Main plot: 4, [Mulching by straw (M_1), Treatment by glyphosate 2 kg a.i. ha^{-1} (M_2), Green manuring by dhaincha (M_3), Unweeded plot (M_4)]. Sub plot: 4 [pretilachlor treatment 0.75 kg a.i. ha^{-1} at 3 days after transplanting (DAT) (T_1), one hand weeding at 21 DAT (T_2), one hand weeding at 21 DAT + pretilachlor 0.75 kg a.i. ha^{-1} at 3 DAT (T_3) and unweeded control (T_4)]

Sampling: Samples for weed number and dry weight analysis were collected at 20, 40, 60 and 80 DAT. Microflora were analysed from the samples collected at 4 DAT (next day of pretilachlor application), 20 DAT, 40 DAT, 60 DAT and 80 DAT. Visual rating of phytotoxicity were observed at 10 DAT, 25 DAT and 40 DAT. Groundwater from rhizosphere zone was collected at 15 DAT, 30 DAT, 60 DAT and 75 DAT for analyzing arsenic (As) content. After harvesting, the grain and straw yield of the crop along with other yield parameters like number of effective panicles $hill^{-1}$, number of filled grains $panicle^{-1}$, thousand grain weight etc. were recorded.

RESULTS AND DISCUSSIONS

The experimental results showed that the number, types and dry weight of weeds varied greatly with time and treatment. Normally unweeded plot contain the largest number of weeds, while their occurrence was not as abundant in other plots under observation (Table 1-3). The M_3 treatment showed lowest dry weight in the later stages of observation particularly in Aman season (Table 4-6). Occurrences of bacteria were variable in number in different plots. Observational data on microflora revealed initial retardation of growth just after application of glyphosate and pretilachlor but it regained its growth slowly and reached the peak about 40-60 days after application of herbicide (Table 7).

Table 1. Effect of different weed management practices on n umber of weeds m^{-2} of paddy field at 20 DAT (Boro 2003).

	Grass					Sedge					Broad leave				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	0.33	0.33	1.33	1.33	0.83	0.66	0.33	0.66	1.32	0.75	1	0.66	0.33	0.66	0.66
T_2	3	3.66	3.66	11	5.33	3	2.33	6	14	6.83	2	4	5.33	11.33	5.66
T_3	0	1	1.33	2.66	1.25	1	1	2	3.33	1.83	0.33	0.33	0	3.66	1.08
T_4	5.33	2.66	5.33	12	6.33	8.66	4	9.33	11	8.25	2	10.66	4.33	14	7.75
Mean	2.16	1.92	2.92	6.75		3.83	1.92	4.5	7.42		1.33	3.92	2.5	7.42	
	A	B		B×A	A×B	A	B		B×A	A×B	A	B		B×A	A×B
SEM(±)	0.51	0.89		1.79	1.63	0.52	0.72		1.46	1.37	0.99	0.98		1.97	1.98
C.D(0.05)	1.76	2.62		5.23	2.10	1.78	2.12		4.27	4.10	3.45	2.89		5.77	6.05

Table 2. Effect of different weed management practices on number of weeds m^{-2} of paddy field at 40 DAT (Boro 2003).

	Grass					Sedge					Broad leave				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	2.33	1.33	3.66	3.33	2.67	11	5.33	4.33	6.33	6.75	2	2.66	5.33	1.66	2.92
T_2	5.66	4.33	3	3.33	4.08	13	9.66	9.0	9.66	10.33	4.66	6.66	8.0	10.0	7.33
T_3	1.66	3.33	2.33	2.33	2.42	1.33	4.66	3.33	4.0	3.33	2	4.33	2.0	8.0	4.08
T_4	10	7.33	9.66	6.66	8.42	14.33	19.66	18.66	21.66	18.58	4.66	14.66	11.33	21.33	13.0
Mean	4.92	4.08	4.67	3.92		9.92	9.83	8.83	10.42		3.33	7.08	6.67	10.25	

	A	B	B×A	A×B	A	B	B×A	A×B	A	B	B×A	A×B
SEM(±)	0.77	0.42	1.53	0.76	0.77	1.13	2.26	2.11	0.83	1.08	2.16	2.05
C.D(0.05)	2.68	1.23	4.48	2.27	2.71	3.30	6.61	6.31	2.89	3.16	6.32	6.16

Table 3. Effect of different weed management practices on number of weeds m^{-2} of paddy field at 60 DAT (Boro 2003).

	Grass					Sedge					Broad leave				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	2.66	3.33	2.33	1.66	2.5	9.66	6.66	7.33	10.33	8.5	2	2.33	5.33	2.66	3.08
T_2	4.33	6.33	3.66	3.66	4.41	10.66	12.0	12.0	14.66	12.33	6	8.66	7.33	10.0	8.0
T_3	1	2.33	1.66	1.66	1.66	4.0	6.66	3.33	8.33	5.58	2	3.33	2.33	4.33	3.0
T_4	9.66	6.33	9.66	10.66	9.08	15.33	20.0	15.66	23.33	18.58	5	20.66	13.0	19.0	14.42
Mean	4.42	4.58	4.33	4.33		9.92	11.33	9.58	14.17		3.75	8.75	7.0	9.0	

	A	B	B×A	A×B	A	B	B×A	A×B	A	B	B×A	A×B
SEM(±)	0.56	0.60	1.20	1.20	0.58	0.80	1.62	1.52	1.20	0.80	3.82	1.87
C.D(0.05)	1.93	1.76	3.52	3.59	2.03	2.36	4.72	4.56	4.18	2.40	11.17	5.87

In green-manured plots, high opulation of nitrogen fixing bacteria and phosphate solubilising bacteria was observed (Table 8 & 9). Unweeded plot had the highest number of total bacteria (Table 7), while largest concentration of fungus was observed in mulched plot (Table 11) and also at T_3 sub-plot at 40 DAT (Table 11) which thinned out with the change of micro-climate Actinomycetes showed no symmetric variation in each experimental plot except in the unweeded plot, which gave the highest result at 60 DAT (Table 10). The proliferation of micro-organisms particularly the aerobic non-symbiotic N_2-fixing bacteria and P-solubilising bacteria, up to a certain period can be attributed to the utilization of these micro-organisms of the herbicides and their degraded products as their source of energy, carbon and other nutrients for growth and development.

Visual rating of the phytotoxic effect showed that the pretilachlor had the highest level of phytotoxicity over glyphosate at 20 DAT, which recovered slowly with time. The effect was less on green manure treated plot and the recovery was also fastest in that plot (Table 12). Laboratory analysis of water samples collected from different plots at rhizosphere zone revealed that arsenic (As) was maintained at a constant level except at the location where both glyphostate and pretilachlor were applied (M_2T_1 & M_2T_3). The result reached near the maximum permissible limit or maximum acceptable concentration (MAC) for India, i.e., 0.05 mg L^{-1} water.

Table 4. Effect of different weed management practices on weed dry matter weight (g m^{-2}) at 20 DAT (Aman 2004).

	Grass					Sedge					Broad leave				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	0.37	0.29	0.31	0.65	0.40	0.64	1.21	1.08	1.11	1.01	0.54	0.46	0.21	0.89	0.53
T_2	1.89	2.01	1.73	4.02	2.41	4.36	2.02	2.37	7.38	4.03	2.52	2.74	1.98	5.28	3.13
T_3	0.33	0.45	0.36	1.74	0.72	0.81	1.44	1.42	2.78	1.61	0.43	0.54	0.19	2.14	0.82
T_4	1.97	2.03	2.04	4.85	2.72	3.41	4.01	2.93	7.27	4.40	4.96	3.99	3.24	6.97	4.79
Mean	1.14	1.19	1.11	2.82		2.30	2.17	1.95	4.63		2.11	1.93	1.40	3.82	

	A	B	B×A	A×B	A	B	B×A	A×B	A	B	B×A	A×B
SEM(±)	0.32	0.41	0.82	0.50	0.43	0.42	0.84	0.67	0.36	0.29	0.59	0.55
C.D(0.05)	1.10	1.21	2.41	1.49	1.5	1.23	2.46	1.98	1.25	0.87	1.74	1.73

Table 5. Effect of different weed management practices on weed dry matter weight (g m^{-2}) at 40 DAT (Aman 2004).

	Grass					Sedge					Broad leave				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	0.85	0.32	0.59	2.43	1.04	5.66	0.41	1.31	8.15	3.88	1.26	0.65	1.58	6.64	2.54
T_2	0.20	0.47	1.06	1.22	0.74	5.09	2.70	3.50	11.98	5.82	1.20	2.98	2.60	5.22	3.0
T_3	0	0.78	0.33	1.42	0.63	5.66	1.38	2.19	9.06	4.57	2.70	0.61	1.1	5.66	2.52
T_4	4.76	5.57	3.94	15.44	7.43	46.50	27.48	32.09	87.17	48.31	23.97	13.51	8.52	12.52	14.63
Mean	1.45	1.78	1.48	5.12		15.73	7.99	9.77	29.09		7.28	4.44	3.45	7.51	

	A	B	B×A	A×B	A	B	B×A	A×B	A	B	B×A	A×B
SEM(±)	0.38	0.60	1.20	1.18	2.85	3.54	7.09	6.78	0.94	1.37	2.74	2.94
C.D(0.05)	1.34	1.78	3.55	3.61	9.89	10.38	20.76	20.45	3.28	4.04	8.04	9.11

Table 6. Effect of different weed management practices on weed dry matter weight (g m^{-2}) at 60 DAT (Aman 2004).

	Grass					Sedge					Broad leave				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	2.34	1.08	1.23	2.03	1.67	9.13	1.88	2.75	7.63	5.35	1.89	0.91	4.96	3.39	2.78
T_2	1.24	2.89	1.36	3.97	2.37	8.94	12.35	6.12	15.46	10.72	3.18	5.45	1.37	7.70	4.42
T_3	1.03	1.16	1.42	2.37	1.49	13.46	2.57	1.47	16.92	8.60	2.54	1.97	1.0	7.10	3.15
T_4	7.37	4.77	3.89	14.97	7.75	66.92	63.49	39.17	56.72	56.57	25.49	17.77	7.06	24.35	18.67
Mean	2.99	2.48	1.97	5.84		24.6	20.07	12.38	24.18		8.27	6.52	3.60	10.63	

	A	B	B×A	A×B	A	B	B×A	A×B	A	B	B×A	A×B
SEM(±)	0.61	0.57	1.14	1.16	2.15	1.97	3.95	4.77	1.66	1.25	2.51	2.74
C.D(0.05)	2.14	1.67	3.35	3.58	7.44	5.79	11.55	15.17	5.74	3.68	7.37	8.55

Table 7. Effect of different weed management practices on number of total bacteria per 10^{-6} g of soil at different dates (Boro 2003).

	4 DAT					20 DAT					40 DAT					60 DAT				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	7.66	3.33	9.33	13.66	8.5	16.66	24.33	20.33	24.33	21.42	32	63.66	39.66	41.66	44.25	15.66	16.0	20.0	22.0	18.42
T_2	13.66	10.00	16.33	15.33	13.83	12	16.33	10.00	13.66	13.0	19.33	40.0	38.33	30.33	32.0	18.66	21.0	15.33	16.33	17.83
T_3	8.00	3.00	10.33	15.00	9.08	15.66	25.33	24.0	25.66	22.66	47.33	80.33	65.66	70.33	65.92	12.0	18.33	28.33	16.33	18.75
T_4	15.66	9.66	14.66	16.66	14.16	21.33	22.00	25.33	32.00	25.16	87.66	65.33	56.33	62.00	67.83	18.00	43.0	33.33	38.0	33.08
Mean	11.25	6.8	12.66	15.16		16.42	22.00	19.92	23.92		46.58	62.33	50.00	51.08		16.08	24.58	24.25	23.16	
	A	B	B×A	A×B		A	B	B×A	A×B		A	B	B×A	A×B						
SEM(±)	0.84	0.90	1.81	1.78		1.51	1.11	2.23	2.45		3.81	3.69	7.39	7.45		1.28	2.46	4.92	4.45	
C.D(0.05)	2.95	2.64	5.29	5.38		5.25	3.26	6.52	7.66		13.21	10.79	21.58	22.81		4.43	7.19	14.38	13.19	

The green manure treated plots obtained highest yield, however, pretilachlor followed with one hand weeding showed significantly higher grain yield and economic profitability. The unweeded plot showed significantly lower grain yield (Table 13). The experimental results obtained from this study indicate a similar trend during Rabi and Kharif seasons wit some degree of variation.

Satisfactory weed control can be achieved by following a combination of at least two methods. Pretilachlor applied at 0.75 kg a.i ha^{-1} at 3 DAT + one hand weeding at 21 DAT. However, green manuring may be a better option for weed control for rice cultivation taking both the aspect of environment and economic viability.

Table 8. Effect of different weed management practices on no. of N-fixing bacteria per10^{-4} g of soil at different dates (Boro 2003).

	4 DAT					20 DAT					40 DAT					60 DAT				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	21.66	17.33	22.66	22.33	21.0	55.0	53.33	129.33	54.66	73.08	45.66	61.33	43.0	41.0	47.75	78.33	89.33	128.33	110.33	101.58
T_2	21.00	20.33	35.33	31.0	26.92	43.66	39.0	102.0	39.33	56.0	29.66	42.00	29.66	27.33	32.16	103.33	107.0	181.33	96.66	122.08
T_3	14.66	12.66	21.33	22.33	17.75	73.66	97.33	168.66	55.0	98.66	59.0	81.66	63.0	65.66	67.33	74.33	96.0	162.66	91.0	106.0
T_4	19.33	22.33	35.66	27.66	26.25	133	90.0	114.66	57.33	106.25	46.0	77.33	50.33	56.66	57.58	97.0	89.0	119.0	96.33	100.33
Mean	19.16	18.16	28.75	25.83		76.33	69.92	136.16	51.58		45.25	65.58	46.5	47.66		88.25	95.33	147.8	98.58	
	A	B	B×A	A×B		A	B	B×A	A×B		A	B	B×A	A×B						
SEM(±)	1.96	1.44	2.87	3.17		6.72	6.89	13.78	13.70		1.98	3.89	7.78	7.03		5.94	5.10	10.20	10.65	
C.D(0.05)	6.78	4.20	8.40	9.92		23.26	20.13	40.24	41.79		6.88	11.37	22.73	20.80		20.50	14.90	29.80	32.92	

Table 9. Effect of different weed management practices on no. of P-solubilising bacteria per 10^{-4} g of soil at different date (Boro 2003).

	4 DAT					20 DAT					40 DAT					60 DAT				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T1	9.00	6.00	13.0	15.66	10.92	18.33	16.33	23.66	18.0	19.08	72.0	98	70.66	69.33	77.5	74.33	51.0	53.0	61.0	59.83
T2	18.00	15.00	21.66	30.0	21.17	6.0	16.33	28.33	12.66	15.83	44.33	62.33	39.0	52.0	49.42	85.33	66.33	67.0	58.46	69.33
T3	11.66	8.00	14.0	15.33	12.25	13.33	34.33	33.0	23.33	26.0	87.33	111.33	74.66	87.33	90.16	73.0	55.0	67.66	48.66	61.08
T4	18.33	14.33	20.66	28.66	20.50	11.66	32.33	27.66	25.33	24.25	59.66	81.0	66.33	65.33	68.08	85.0	80.66	73.0	60.0	74.66
Mean	14.25	10.83	17.33	22.42		12.33	24.83	28.17	19.83		65.83	88.16	62.66	68.5		79.42	63.25	65.16	57.08	
	A	B	B×A	A×B		A	B	B×A	A×B		A	B	B×A	A×B		A	B	B×A	A×B	
SEM(±)	1.80	1.54	3.08	3.22		1.05	1.81	3.61	3.30		2.94	4.20	8.41	7.86		4.76	3.51	7.02	7.73	
C.D(0.05)	6.24	4.50	9.0	9.95		3.66	5.28	10.55	9.83		10.17	12.29	24.57	23.56		16.49	10.27	20.53	24.18	

Table 10. Effect of different weed management practices on no. of actinomycetes per 10^{-5} g of soil at different dates (Boro 2003).

	4 DAT					20 DAT					40 DAT					60 DAT				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mea
T_1	18.33	17.66	25	28.66	22.42	36.33	79.66	43.66	24.0	45.92	66.0	77.0	42.0	38.33	55.83	53.66	56.0	49.0	109.66	67.0
T_2	31.0	21.33	36	38.66	31.75	28.33	68.33	25.66	18.66	35.25	45.33	56.33	24.33	27.0	38.25	51.0	59.33	59.33	116.66	70.3
T_3	18.3	16.0	48	22.0	26.08	59.0	75.66	41.66	48.33	56.16	86.66	101.0	70.33	76.33	83.58	61.33	44.66	51.0	107.0	66.
T_4	31.33	25	39.66	35.0	32.75	92.0	59.33	35.33	52.33	59.75	69.66	85.33	62.33	64.66	70.50	55.33	89.66	60.0	93.33	74.5
Mean	24.75	20.0	37.16	31.08		53.92	70.75	36.58	35.83		66.92	79.92	49.75	51.58		55.33	62.42	54.83	105.42	
	A	B	B×A	A×B		A	B	B×A	A×B		A	B	B×A	A×B						
SEM(±)	2.87	2.55	5.10	5.27		3.39	2.80	5.61	5.92		3.73	3.82	7.63	7.59		5.57	5.40	10.80	10.89	
C.D(0.05)	9.94	7.46	14.92	16.24		11.75	8.19	16.37	18.34		12.93	11.16	22.30	23.17		19.28	15.78	31.54	33.34	

Table 11. Effect of different weed management practices on no. of fungus 10^{-4} g of soil at different dates (Boro 2003).

	4 DAT					20 DAT					40 DAT					60 DAT				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	M
T_1	9.0	9.33	14.0	10.33	10.66	9.0	12.0	12.0	14.0	11.75	67.0	66.0	52.33	55.0	60.08	6.66	14.0	8.66	18.66	1
T_2	15.0	10.33	22.33	18.33	16.50	7.66	12.66	10.66	10.0	10.25	52.0	54.66	42.0	39.66	47.08	9.33	14.66	5.33	17.33	11
T_3	14.0	8.66	14.33	14.66	12.92	12.66	15.0	16.0	21.66	16.33	85.0	98.66	78.0	80.66	85.58	8.66	15.0	7.66	17.0	12
T_4	19.0	11.33	17.33	25.33	18.25	9.66	12.0	18.66	19.66	15.0	74.66	81.66	73.66	64.33	73.58	10.0	19.66	8.0	24.66	15
Mean	14.25	9.91	17.0	17.16		9.75	12.92	14.33	16.33		69.66	65.25	61.50	59.92		8.66	15.83	7.42	19.42	
	A	B	B×A	A×B		A	B	B×A	A×B		A	B	B×A	A×B		A	B	B×A	A	
SEM(±)	0.98	1.89	3.79	3.43		2.49	1.44	2.88	3.53		2.10	4.83	9.65	8.62		1.69	1.16	2.32	5.	
C.D(0.05)	3.43	5.54	11.07	10.16		8.65	4.22	8.43	11.30		7.29	14.10	28.18	25.45		5.88	3.39	6.78	17.	

Table12. Effect of different weed management practices on visual rating of phytotoxicity (Boro 2003).

	20 DAT					40 DAT				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	2	3.33	0.66	2.66	2.16	1.33	1	0	0.66	0.75
T_2	0	0	0	0.33	0.08	0	0	0	0	0
T_3	1.66	4.0	0.66	2.66	2.25	1	1.66	0	0.66	0.83
T_4	0	0	0	0.66	0.16	0	0	0	0.33	0.08
Mean	0.9	1.8	0.33	1.58		0.58	0.66	0	0.42	

	A	B	B×A	A×B	A	B	B×A	A×B
SEM(±)	0.09	0.40	0.80	0.70	0.06	0.09	0.18	0.18
C.D(0.05)	0.32	1.17	2.34	2.06	0.23	0.29	0.58	0.55

Table 13. Comparative study on yield of paddy in t ha^{-1} at different weed management practices.

	Boro 2003					Aman - 2004				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
T_1	4.11	3.96	4.63	3.80	4.13	3.66	3.39	4.17	3.30	3.63
T_2	4.22	4.97	4.97	3.85	4.28	4.02	3.47	4.27	3.30	3.77
T_3	5.16	4.93	6.25	4.06	5.08	4.52	4.11	4.97	3.61	4.30
T_4	3.94	3.60	4.33	3.20	3.76	3.61	3.19	4.02	2.92	3.44
Mean	4.35	4.16	5.03	3.73		3.95	3.54	4.36	3.28	

	A	B	B×A	A×B	A	B	B×A	A×B
SEM(±)	0.08	0.04	0.09	0.12	0.07	0.07	0.14	0.15
C.D(0.05)	0.30	0.15	0.31	0.37	0.245	0.22	0.44	0.45

LITERATURE CITED

Balasubramanian,N. and Duraiswamy,V.K. 1996. Integrated weed management in cereal, millets and pulse crop. *Adv. Weed Mgt. AgroEco. Context* (Summer Institute, 10-19 June 1996.TNAU,Coembatore):160-163.

Labrada,R.1996. Weed control in rice.In Weed Management in rice, FAO Plant Production and Protection Paper-139 (B.A.Auld and K.U.Kim eds.), FAO,UN.Oxford & IBH Publication Co. Pvt.Ltd.:3-5.

Evaluation of efficiency and economics of weed management in rice-based *paira* cropping system

S.S. Mondal, D. Acharya, M. Saha and G. Sounda
Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741252, W.B, India
shyam_mondal2003@yahoo.co.in

Abstract: Field experiments were carried out during *kharif* and *rabi* seasons of 2001-2002 and 2002-03 at farmer's field with a clay loam soil to evaluate the efficiency and economic weed management in rice-linseed *paira* cropping system in rainfed condition of West Bengal. The experiment was conducted in Randomized Block Design with six weed control treatments viz. butachlor at 1 kg a.i. ha^{-1}; butachlor at 1.5 kg a.i. ha^{-1}; hand-weeding at 20 and 40 DAT; weed control with paddy weeder at 30 DAT; butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT; and unweeded control. The major weed species found in the rice field were *Echinochloa crusgalli, Paspalum distichum, Cyperus iria, Cyperus difformis, Fimbristylis littoralis, Eclipta alba, Ludwigia parviflora, Marsilea quadrifolia, Ammania baccifera, Sphenoclea zeylanica,* etc. The results revealed that maximum yield of rice as well as linseed as *utera* crop (4673 kg ha^{-1} and 664 kg ha^{-1}, respectively) was obtained under weed-free check where hand weeding was done twice at 20 and 40 days after sowing (with 68.6% weed control efficiency), followed with butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT treatment (4605 kg ha^{-1} and 619 kg ha^{-1} of rice and linseed) (with 62.6% weed control efficiency), respectively. Similar responses were also observed in yield attributes of the crops and nutrient status of soil. However, highest benefit-cost ratio was found in butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT.

Keywords: Benefit cost ratio, butachlor, hand weeding, Paira cropping, weed control efficiency

INTRODUCTION

Paira crops are sown two weeks after the flowering of rice in muddy/marshy conditions with no tillage and raised on residual soil moisture. So adoption of *paira* cropping in humid areas results in increased cropping intensity and optimum resource utilization. Since the weed problem under *Paira* cropping is somewhat different from that under tilled condition, thorough background knowledge on the weed flora and management of weeds through proper selection of crops is needed for efficient weed control.

MATERIALS AND METHODS

Field experiments were carried out during *kharif* and *rabi* seasons of 2001-2002 and 2002-03 at farmer's field, Burdwan in clay loam soil (neutral pH, 0.070% total N, 7.8 kg available P and 201 kg available K ha^{-1}), to evaluate the efficient and economic weed management in rice-linseed *paira* cropping system in rainfed condition of West Bengal. The experiment was laid out following a Randomized Block Design with six weed control treatments, viz., butachlor at 1 kg a.i. ha^{-1}; butachlor at 1.5 kg a.i. ha^{-1}; hand-weeding at 20 and 40 DAT; weed control with paddy weeder at 30 DAT; butachlor ar 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT; and unweeded control.

RESULTS AND DISCUSSION

Predominant weed flora

The major weed species found in the rice field were *Echinochloa crusgalli, Paspalum distichum, Cyperus iria, Cyperus difformis, Fimbristylis littoralis, Eclipta alba, Ludwigia parviflora, Marsilea quadrifolia, Ammania baccifera, Sphenoclea zeylanica* etc.

Effect of herbicides on weed density, weed dry matter and yield

In rice, at 60 DAT the minimum weed population m^{-2} (6.01) and weed dry weight (65.63 g m^{-2}) were obtained under hand weeding at 20 and 40 DAT (Table 1). The highest weed control efficiency (68.6 %) was recorded in this treatment also. However, the highest benefit-cost ratio of the system (2.31) was obtained under pre-emergence application of butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT treatment on rice (Mondal et al. 2005). Minimum grain yields of rice and seed yield of linseed were recorded in weedy check treatment.

Table 1. Effects of weed control treatments on weed population m^{-2}, total weed dry weight (g m^{-2}), weed control efficiency (%) in rice at 60 DAT, yield component and productivity of rice in rice-linseed *paira* cropping system (pooled data of two years).

Treatment	Weed population (number m^{-2})	Total dry weight (g m^{-2})	WCE (%)	No. of effective tillers m^{-2}	No. of grains panicle^{-1}	1000-seed weight (g)	Grain yield of rice (kg ha^{-1})
Butachlor at 1 kg a.i. ha^{-1}	9.52	11.21	37.6	331.2	70.2	23.4	4272
Butachlor at 1.5 kg a.i. ha^{-1}	7.28	7.42	58.7	347.2	80.6	23.4	4464
Hand-weeding at 20 and 40 DAT	6.01	5.63	68.6	369.7	88.1	24.4	4673
Weed control with paddy weeder at 30 DAT	7.98	9.54	46.8	336.2	75.4	22.6	4356
Butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT	6.83	6.72	62.6	360.4	85.3	24.2	4605
Unweeded control	14.25	17.97	-	310.6	64.5	20.4	3069
CD (at 5%)	0.92	1.69	-	12.3	4.2	NS	128

Thus, the laborious, cumbersome and costly hand weeding method of weed control in rice-based paira cropping system could be replaced by application of butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT.

Effect of weed control treatment on yield attribute and yield of rice

Maximum yield of rice (4673 kg ha^{-1}) was obtained under weed free check where hand weeding was done twice at 20 and 40 days after sowing in rice. This treatment had the highest number of effective tillers m^{-2} (369.7), grain panicle^{-1} (88.1) and highest test weight (24.4 g). Higher grain yield (4605 kg ha^{-1}) also obtained when the weed control was done with Butachlor (1.5 kg a.i ha^{-1}) + one hand weeding at 40 DAT treatment.

Effect of weed control treatment on yield attribute and yield of linseed as (a paira crop)

Maximum seed yield of linseed (664 kg ha^{-1}) was obtained under weed free check where hand weeding was done twice at 20 and 40 days after sowing in rice. This treatment had the highest number of capsules per plant (27.92), seeds per capsule (8.52) and highest test weight (7.30 g). Higher seed yield (619 kg ha^{-1}) was also obtained when the weed control was done with butachlor (1.5 kg a.i. ha^{-1}) + one hand weeding at 40 DAT of rice treatment.

Table 2. Effects of weed control treatments on weed population m^{-2}, total weed dry weight (g m^{-2}), weed control efficiency (%) in linseed, yield component and productivity of linseed in rice-linseed *paira* cropping system (pooled data of two years).

Treatment	No. of capsules plant^{-1}	No. of seeds capsules^{-1}	1000-seed weight (g)	Seed yield of linseed (kg ha^{-1})	Soil moisture content at flowering of linseed (%)	Relative water content at flowering (%)	Benefit-cost ratio of the system
Butachlor at 1 kg a.i. ha^{-1}	18.41	6.87	6.21	536	8.25	69.4	1.65
Butachlor at 1.5 kg a.i. ha^{-1}	22.86	7.45	6.87	576	9.48	75.9	2.02
Hand-weeding at 20 and 40 DAT	27.93	8.52	7.3	664	11.48	84.8	1.95
Weed control with paddy weeder at 30 DAT	21.89	7.01	6.42	543	8.38	71.1	1.78
Butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT	25.1	8.1	7.16	619	10.15	80.6	2.31
Un weeded control	10.98	5.8	5.62	301	7.69	54.2	0.4
CD (at 5%)	1.8	0.37	NS	62	0.72	0.8	-

Effect of weed control treatment on soil moisture content and relative water content at flowering of linseed

Soil moisture content (11.48%) and relative water content (84.8%) at flowering stage of linseed were significantly higher with two hand weeding treatment in rice crop. Presence of higher moisture content in this treatment may be due to higher suppression of weeds, which led to higher percentage of relative water at flowering stage of linseed. Good response was also observed in plots that received butachlor (1.5 kg a.i. ha^{-1}) + one hand weeding at 40 DAT of rice.

Effect of weed control treatment on soil nutrient status and benefit: cost ratio of the system

Nutrient status of soil differed significantly among the treatments. Highest nitrogen (0.0758%), available phosphorus (19.78 kg ha^{-1}) and available potassium (282.4 kg ha^{-1}) were found in plots where rice was hand-weeded twice. However, the highest benefit- cost ratio (2.31) of the system was recorded in plots applied with butachlor (1.5 kg a.i. ha^{-1}) + one hand weeding at 40 DAT of rice, followed by the only butachlor treated plots applied with 1.5 kg a.i. ha^{-1} (2.02).

Table 3. Nutrient uptake by crops in rice-linseed (as *paira*) cropping systems.

Treatment	Soil nutrient status after the two year of rice-linseed *paira* cropping sequence		
	Total N (%)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Butachlor at 1 kg a.i. ha^{-1}	0.0722	16.47	272.1
Butachlor at 1.5 kg a.i. ha^{-1}	0.0738	18.44	272.9
Hand-weeding at 20 and 40 DAT	0.0758	19.78	282.4
Weed control with paddy weeder at 30 DAT	0.073	17.12	269.1
Butachlor at 1.5 kg a.i. ha^{-1} + one hand weeding at 40 DAT	0.0743	18.96	275.3
Unweeded control	0.0712	15.26	265.8
CD (at 5%)	0.0014	0.58	0.8
Initial status of soil	0.0714	16.74	278.2

LITERATURE CITED

Mondal, S.S., Ghosh, A., and Acharya, D. 2005. Eco- safety weed management of Paira cropping system. Abstract published in First International Weed Seminar on Innovative Approaches for Eco-safety Weed Management. 21-24 January, 2005. pp.71.

Sustainable eco-rational weed management strategy for rice based cropping system in inceptisol soils of India

R. K. Ghosh[1*], D. Pal[1], J, Mukherjee[1], S. N. Mukherjee[1] S.A. Ram[2] and A. Bose[3]
[1] Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya,
Mohanpur - 741252, West Bengal, India
rkgbckv@rediffmail.com
[2] Sumitomo Chemical India Pvt. Ltd 145 / 14th Floor, Maker Chamber VI,
220, Nariman Point, Mumbai - 400021
3 Excel Crop Care Limited, 706, Central Plaza, 2/6 Sarat Bose Road
Kolkata- 700020, West Bengal, India

Abstract: Rainfed rice-based cropping system covers nearly one half of the agricultural areas in India. With its burgeoning population, about 3 million tons of food grain per annum needs to be produced in the next 20 years. Weed, being one the major pests of crops causes 18-20% yield losses in lowland situation and 35-45% upland situation in developing countries like India. In *Inceptisol* rotation of rice with winter crops like wheat, maize, potato, oilseeds and vegetables has become a widely adopted production system. Double cropping is believed to help in reducing major associated weed infestations of both rice and winter annual crops. Losses due to weeds in our country are 9.28 mt in cereals, 0.78 mt in pulse, 0.57 mt in oilseeds and 7.2 mt in fiber and other commercial crops. But removal of weeds at farm level is largely restricted to mechanical and manual approach. Sharp increase of labor wages and unavailability's of labor due to industrialization and urbanization in the critical crop weed period are bound to make herbicides more acceptable to farmers. Rice followed by wheat, maize, mustard, potato and vegetables like onion are the dominant crop sequences in *Inceptisols* of India. Safer herbicide combinations with improved rotational and economical management technologies based on rice ecology are available. The benefit cost ratio of controlling weeds is 3-4 times more in chemical than to manual method. Field experiments conducted during 2000-2004 in an Inceptisol soil revealed that pretilachlor at 400 g ha^{-1} as pre emergence, acetachlor at 150 g ha^{-1}, pyrazosulfuron ethyl at 30 g ha^{-1}, imazosulfuron at 30 g ha^{-1} or carfentrazone ethyl at 40g ha^{-1} as early post emergence in rice. Metribuzin at 600 g ha^{-1} in potato at pre emergence, isoproteuron at 750 g ha^{-1} in wheat, atrazine at 2000 g ha^{-1} with surfactant in maize, peddimethalin and at 750 g ha^{-1} and oryzalin at 30 g ha^{-1} in onion as post emergence can replace the traditional two hand weeding. These are environmentally safer, not phytotoxic to crop plants and do not harm the population of beneficial soil micro-flora at the rhizosphere.

Key words: Crop sequences, economical, environment, herbicide.

INTRODUCTION

Nearly half of the agricultural areas in Asia is covered by rain-fed rice based cropping system. India would need an additional 3 mt food grain per annum in the coming 20 years as our burgeoning population is expected to reach 1.5 billion by 2025. It has been estimated that weeds cause 5% loss in agricultural production of most developed countries, 10% in developed countries, and 25% in least developed countries (Bhowmik 1998). In Eastern India rotation of rice with winter crops like wheat, maize, potato, vegetables and rapeseed-mustard has become a widely adopted production system. Double cropping is believed to help in reducing infestation of major associated weed flora of both rice and winter annual crops though losses of weed were 4.2 mt in cereals, 0.78 mt in pulses, 0.57mt in oilseeds and 7.2mt in fiber and other commercial crops (Sahoo and Saraswat 1998). Yield loss caused by weeds in lowland situation accounts for 11-20% in the transplanted rice (Ghosh and Moorty 1998). In India, yield loss due to weeds varies from 12-72% (Bhan 1997).

Weed removal at farm level is largely restricted to mechanical and cultural methods (Yaduraju & Mishra 2002) Sharp increase in wages and unavailability of labor due to industrialization and urbanization are bound to make herbicides more acceptable to farmers. Herbicides due to their effectiveness and easiness in application have become the major weed control measure in most Asian rice production systems (Kit-ung Kim 2004). In India reliance on herbicides for managing weeds in rice based cropping system has been increasing sharply. In view of the above, field studies were conducted on rice followed by rice, wheat, maize, rapeseed-mustard, sesame, potato and onion to evaluate a) the efficacy of herbicides in controlling weeds and b) the effects of herbicides on micro-flora population in the rhizosphere of an *Inceptisol* soil.

MATERIALS AND METHODS

Field experiment were conducted on rice – rice (2002-2003), rice – wheat (2003-04), rice – maize (2002-2003), rice – potato (2002-2003), rice – rapeseed / mustard (2004-2005), rice - onion (2004-2005) in the Viswavidyalaya farm situated at 89^0 E longitude, 23.5^0 N latitude with average altitude of 9.75 m MSL. The soil is sandy clay loam with pH 6.9, organic carbon – 0.067%, total nitrogen 0.062%, available phosphorus 125 kg ha^{-1}, and available potash 125 kg ha^{-1}. Temperature begins to rise from May and reach maximum in July. It starts dropping from middle of October and gradually attains the minimum in January. The mean monthly rainfall is highest in July and lowest in January. The average rainfall is 1700 mm per annum of which around 75% occurs during June to September. The lowest relative humidity is observed in December to January while the maximum is in July to August. The experiments were laid out following the Randomized Complete Block Design (RCBD) with three replications. Plot size was 4 m x 5 m. In each experiment, there were 7 to 10 weed management treatments including the weedy and handweeded checks. Microbial population of the beneficial non-symbiotic (NS) N-fixing and P-solubilizing bacteria were analyzed by serial dilution technique and pour plate method using Jensen's agar medium and Pikovskaia's medium, respectively.

RESULTS AND DISCUSSION

The weed flora observed in the rice field was composed of *Echinochloa* sp. (*Echinochloa crus-galli, colonum, glabrescens), Leersia hexandra, Cyperus iria, Cyperus difformis, Ammania baccifera, Eclipta alba, Blainvillea latifolia, Sphenoclea zeylanica, Marsilea quadrifolia* and *Stellaria media.* In winter crops *Chenopodium album, Gnaphalium luteoalbum, Checorium intybus, Melilotus alba, Solanum nigrum, Physalis minima* and *Portulaca oleracea* were observed besides the grasses *Digitaria sanguinalis* and *Echinochloa colona.* The most important weed found in the flora was purple nut sedge (*Cyperus rotundus*).

It was observed that winter crops following transplanted rice had fewer weeds than when these crops were planted after direct seeded rice. Population of *Cyperus rotundus* was minimal after transplanted rice. The growth of this weed may have been hampered by the presence of stagnant water which prevented rhizome growth and development. More grass weeds were observed in the succeeding crops planted after direct seeded rice but broadleaves were dominant in the winter crops grown after puddled rice.

In transplanted rice, pyrazosulfuron ethyl at 30g ha^{-1}, pretilachlor at 400g ha^{-1}, butachlor at 1250g ha^{-1}, clomazone at 150g ha^{-1}, 2, 4-D ethyl ester at 850g ha^{-1}, acetachlor at 150g ha^{-1}, carfentrazone ethyl at 30g ha^{-1} and imazosulfuron at 30g ha^{-1} were tested in both rice–rice and rice followed by winter crops. Results showed that pyrazosulfuron ethyl (average of four doses) recorded 59.6%, 18.9% and 65.5% higher grain yield, NS N-fixing (37.5%) and P- solubilizing bacteria (98.3%), respectively compared with the weedy check while statistically at par with the plots handweeded twice. Acetachlor had 61% higher grain yield over the weedy check and at par with plots handweeded twice but showed decreased micro-flora population than the hand weeding and weedy checks. In another experiment, higher grain yields were obtained with the application of pyrazosulfuron ethyl (19.4%), 2,4-D ethyl ester (11.3%) and carfentrazone ethyl (14.4%) compared with the weedy check but were at par with the hand weeded check. Carfentrazone ethyl initially reduced the micro-flora population while 2, 4-D ethyl ester showed stimulating effect. Clomazone at its higher dose (>150g ha^{-1}) induced phytotoxicity, mainly bleaching of older leaves, in rice. All other herbicides did not show any phytotoxicity when applied at recommended doses (Tables 2-4).

In rice followed by zero- tilled rapeseed-mustard under four different rice cultures namely, direct seeded (DS) + Ambica paddy weeder at 21 DAS, DS + Biasi at 21 DAS, puddled direct seeded and transplanted, the weed dry weight was highest in DS + Ambica paddy weeder at 21 DAS. Biasi showed minimum broadleaf weed population. The puddled direct seeded and transplanted rice had similar grass weed population. The grain yield of zero-tilled rapeseed-mustard was highest transplanted rice maybe because of less population of nutsedge and grasses (Table 1).

Table 1. Effect of weed management treatments on grain yield and dry weight of weeds in rice-rapeseed crop sequence.

Treatment	Paddy yield (t ha^{-1})	Zero till Rapeseed yield (t ha^{-1})	Dry weight of weeds in paddy at 60 DAS (g m^{-2})		
			Grass	Sedge	Broad leaf
Direct sown rice + Ambica paddy weeder	1.31	0.11	12.5	67.36	17.28
Beushaning rice	1.84	0.15	6.01	22.40	1.58
Puddled direct seeded rice	2.30	0.32	0.89	12.79	1.77
Transplanted rice	3.22	0.38	2.08	15.70	1.17
CD (P=0.05)	0.41	0.09	1.01	6.33	2.01

Table 2. Effect of weed management treatments on grain and straw yield, population of micro flora and weed index of transplanted rainy season rice.

Treatments	Dose (g ha^{-1})	Weed index	Grain yield (tha^{-1})	Straw yield (t ha^{-1})	Aerobic NS- N fixing bacteria (CFU x 10^5 g^{-1})	Actinomyc-etes (CFU x 10^5 g^{-1})
Carfentrazone ethyl	15	11.06	4.42	5.23	35.17	66.23
Carfentrazone ethyl	20	8.04	4.57	5.54	35.77	69.80
Carfentrazone ethyl	25	4.82	4.73	5.61	35.07	68.88
Carfentrazone ethyl	30	4.22	4.76	5.45	35.88	70.17
Carfentrazone ethyl	40	3.42	4.80	5.68	35.93	70.18
2,4-D ethyl ester	850	8.85	4.53	5.52	41.40	77.27
Pyrazosulfuron ethyl	30	2.21	4.86	5.76	37.69	66.26
Hand weeding	20 & 40 DAT		4.97	5.84	35.92	68.29
Weedy check	-	18.10	4.07	5.00	34.22	64.34
CD at 5%			0.63	0.34	1.35	4.53

Table 3. Effect of weed management treatments on grain yield, straw yield, and dry weight of weeds of rainy season paddy rice.

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Dry weight of total weeds ($g\ m^{-2}$) at 75 DAT
Imazosulfuron 20 $g\ ha^{-1}$	4.43	4.68	8.21
Imazosulfuron 30 $g\ ha^{-1}$	4.62	4.80	7.57
Imazosulfuron 40 $g\ ha^{-1}$	4.78	4.86	7.73
Imazosulfuron 20 $g\ ha^{-1}$ + 2,4- DEE 425 $g\ ha^{-1}$	4.47	4.64	7.91
Imazosulfuron 30 $g\ ha^{-1}$ + 2,4- DEE 425 $g\ ha^{-1}$	4.79	4.88	7.33
Imazosulfuron 40 $g\ ha^{-1}$ + 2,4- DEE 425 $g\ ha^{-1}$	4.81	4.95	6.87
Imazosulfuron 20 $g\ ha^{-1}$ + Pretilachlor 550 $g\ ha^{-1}$	4.58	4.70	7.86
Imazosulfuron 30 $g\ ha^{-1}$ + Pretilachlor 550 $g\ ha^{-1}$	4.83	5.04	6.45
Imazosulfuron 40 $g\ ha^{-1}$ + Pretilachlor 550 $g\ ha^{-1}$	4.96	5.11	6.21
Pretilachlor 750 $g\ ha^{-1}$	4.60	4.83	7.8
2,4- DEE 850 $g\ ha^{-1}$	4.42	4.66	8.52
Untreated control	3.58	4.07	16.72
SEm (±)	0.29	0.25	0.48
CD (P=0.05)	0.84	0.73	1.39

Table 4. Effect of weed management treatments on grain and straw yield, population of micro flora and WCE of transplanted winter rice.

Treatments	Dose ($g\ ha^{-1}$)	WCE (%) (at harvest)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	NS N-fixing bacteria (CFU x $10^5\ g^{-1}$)	P-solubilizing microorganism (CFU x $10^5\ g^{1}$)
PSE 10 WP	20	15.75	5.19	7.15	196.33	32.5
PSE 10 WP	25	23.85	5.23	8.05	222.00	48
PSE 10 WP	50	70.17	6.20	8.41	235.83	53.33
PSE 10 WP	100	81.76	7.19	9.11	250.83	59.17
Acetochlor	100	29.44	5.70	8.20	162.33	13.50
Acetochlor	150	37.44	6.02	8.20	148.83	10.33
Acetochlor	200	68.43	6.30	9.07	126.50	7.67
Hand weeding	20 & 40 DAT	57.56	6.11	11.00	164.50	24.33
Control	-	--	3.73	6.93	190.33	29.17
CD at 5%		--	1.26	2.11	6.11	3.23

In potato metribuzin @ 600 $g\ ha^{-1}$, twice HW and pendimethalin @ 560 $g\ ha^{-1}$ recorded 84.3, 86.7 and 67.5% higher tuber yield, respectively over the weedy check proving the efficacy of these herbicides though-initial reduction of the micro-flora population was observed. Metribuzin reduced the NS-N fixing and P- solubilizing bacteria population by 29% compared with the weedy check (Table 5).

Table 5. Effect of weed management treatments on grain and straw yield, population of micro flora and WCE of potato.

Treatments	Dose ($g\ ha^{-1}$)	Weed control efficiency (%) at 90 DAP	Tuber yield ($t\ ha^{-1}$)	Net production value	NS -N fixing bacteria (CFU x $10^5\ g^{-1}$)	P solubilizing microorganism (CFU x $10^5\ g^1$)
Unweeded Control		--	12.35	0.67	208.69	76.40
Hand weeding	15 &30 DAP	83.41	22.91	1.67	215.67	73.87
Metribuzin	375	42.81	17.63	1.26	210.46	66.99
Metribuzin	450	55.01	18.05	1.30	186.35	56.57
Metribuzin	525	58.50	19.21	1.57	169.50	49.50
Metribuzin	600	76.03	22.62	1.84	155.13	42.37
Pendimethalin	560	71.54	20.91	1.55	204.87	43.36
CD at 5%	--	--	0.362	--	8.36	8.43

In maize, surfactants at 220 ml ha^{-1} used along with atrazine at 2 kg ha^{-1} showed 18.1 and 40.7% higher grain yield over atrazine alone and the weedy check, respectively. The NS N-fixing and P-solubilizing bacteria had higher population over the weedy check and hand weeding. The pH was not reduced in herbicide treated plots. The availability of NPK and micronutrients were not affected by the application of herbicides compared with HW and weedy checks (Table 6).

Table 6. Effect of weed management treatments on grain and straw yield, population of micro flora and weed index of maize.

Treatments	Dose	Weed index	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	NS - N fixing bacteria (CFU x $10^5\ g^{-1}$)	P-solubi lizing micro organism (CFU x $10^5\ g^{-1}$)
Unweeded control	---	35.9	3.19	11.20	123.67	89.64
Hand weeding	40 & 60	00.0	4.97	27.23	191.26	106.79
Atrazine	2 kg ha^{-1}	30.76	3.80	15.57	276.25	161.41
Atrazine+ ASPA 80	(2 kg +220ml)ha^{-1}	27.90	4.10	18.63	229.24	133.21
Atrazine+ Actove 80	(2 kg +220ml)ha^{-1}	26.20	4.88	21.10	234.56	144.58
Atrazine+ Agrocer 02	(2 kg +220ml)ha^{-1}	26.76	4.72	19.56	216.52	127.17
Atrazine+ Agrocer 03	(2 kg +220ml)ha^{-1}	30.21	4.25	16.76	233.88	141.29
CD at 5%	-	-	0.10	1.47	0.641	0.58

In wheat, isoproturon applied in combination with 2,4-D showed better performance in reducing the weed flora and increasing wheat yield compared with the other herbicides tested and HW treated plots (Table 7). Oryzalin recorded higher yield (13.07 t ha^{-1}) when applied at 8.75 l ha^{-1} because of its excellent weed control efficacy in comparison to pendimethalin or hand weeding (Table 8).

These findings corroborate the results obtained from experiments conducted by Shaik Mohammad (2001), Subbaiah (2003) and Datta *et. al.* (2005) in rice, Krishnaveni and Issac Sunil (2004) on rice-rice cropping system, Singh and Mishra (2003) in rice–wheat crop sequence, Ghosh *et. al.* (2004) on maize, Patel and Barevadia (2003) on vegetable and its succeeding crop, and Taab and Alizadeh (2004) on lentil.

Conclusively, using safer herbicides replace the more expensive traditional hand weeding method without polluting the environment and harming the population of soil micro-flora in the rhizosphere of *Inceptisol* soils in India.

Table 7. Effect of weed management treatments on grain yield and dry weight of weeds of wheat.

Treatment	Grain yield ($g\ ha^{-1}$)	Dry weight of total weeds ($g\ m^{-1}$)		
		20 DAA	40 DAA	At harvest
Isoproturon+2,4-D @ 500 g + 200g	22.67	9.13	15.33	22.61
Isoproturon +2,4-D @ 600 g + 300g	24.00	8.44	10.33	22.35
Isoproturon +2,4-D @ 700 g + 400g	24.33	8.40	13.67	21.11
Isoproturon +2,4-D @ 800 g + 500g	23.77	6.44	12.00	20.47
Isoproturon +2,4-D @ 900 g + 600g	21.33	6.60	10.67	15.51
Metsulfuron methyl @ 4 g +ADJ	28.67	5.04	8.67	13.11
Sulfosulfuron @ 25g + ADJ	31.67	4.3	9.67	10.25
Fenoxaprop @ 100 g+ ADJ	28.33	4.39	7.67	12.57
2,4-D @ 450g	25.00	3.99	9.33	15.47
Clodinafop @ 60 g	28.33	4.61	8.00	9.45
Isoproturon @1000g	31.67	2.23	6.67	9.48
Untreated control	15.00	19.21	20.67	31.07
SEm (±)	2.42	0.54	0.83	4.04
CD (P=0.05)	7.07	1.57	2.42	11.8

DAA: days after application

Table 8. Effect of weed management treatments on bulb yield and storability of onion.

Treatment	Bulb yield ($t\ ha^{-1}$)	Weight of bulb (g) after second month	Loss in weight (%)
Oryzalin @ 3.75 l ha^{-1}	9.48	700	6.66
Oryzalin @ 5 l ha^{-1}	9.50	755	6.44
Oryzalin @ 6.25 l ha^{-1}	10.27	780	8.77
Oryzalin @ 7.5 l ha^{-1}	11.38	845	7.34
Oryzalin @ 8.75 l ha^{-1}	13.07	970	8.92
Pendimethalin 5 l ha^{-1}	12.38	850	8.60
Oxyfluorfen 0.425 l ha^{-1}	6.90	645	8.64
Control	3.03	560	7.43
Hand weeding	10.13	845	7.34
CD (P=0.05)	3.43	S.d. = 117.92	

ACKNOWLEDGEMENTS

The authors thankfully acknowledge the assistance and help received from M/S Excel Crop Care Ltd., M/S Sumitomo Chemicals India Ltd., M/S Rallis India Ltd, M/S FMC India Ltd. and M/S Indofil Chemicals Company, India.

LITERATURE CITED

Bhan V.M. 1997. Vision Project 2020. National Research Centre for Weed Science. Prospective Plan. 53.

Bhowmik P.C. 1998. Herbicides in relation to food security and environment, a global perspective. Proc. 1st Int. Agro. Cong. Nov 23-27, 1998, New Delhi, India, Pages 244-258.

Ghosh A. and Moorthy B.T.S. 1998. Weed management deserves more attention in rainfed lowland cultivation. Indian Farming, 48 (1): 15-18.

Ghosh R.K., Moitra A., Mukherjee A. and Sarkar, P.K. 2004. Environment pollution study of Atrazine with surfectant in Inceptisol soil in India. Abstract, Weed Science Society Humanits, International Weed Science Conference Durban, South Africa, 19-24 June, 2004, Page 80.

Datta J.K. Roy S. and Gorai A.K. 2005. Evaluation of four herbicides on weed culture in kharif rice and their impact on soil bacterial population. 1st International Weed Science Conference, Page 123.

Kit ung Kim. 2004. Integrated weed management in rice based cropping system. Abstract - Weed Science Society Humanits - 4th International Weed Science Conference Durban, South Africa, 19-24 June, 2004. Page 97.

Purshotam S. and Mishra O.P. 2003. Long term effect of weed management practices in rice – wheat cropping system. Abstract-Binneal Conference of ISWS, March 12-14, 2003 Pantnagar, India. Page 44.

Anandha K.S. and Issac S.C. 2004. IWM practices for a rice-rice cropping system. Abstracts National Symposium on recent advances in rice based farming system 17-19 November, 2004. CRRI, Orissa. Pages 56.

Patel S.M. and Barevadia T.N. 2003. Chemical weed control studies in chilly nursery and their residual effect on succeeding crops Abstract-Binneal Conference of ISWS, March 12-14, 2003. Pantnagar, India. Pages 44.

Subbaiah S.M. 2003. Efficacy of herbicide mixtures on weed conrol in direct seeded rice under puddle condition. Workshop and seminar on IPM. October 14-18, 2003 at DRR, Hydrabad. Pages 1-16.

Sahoo K.M. and Saraswat V.N. 1988. Magnitude of losses in the yields of major crops due to weed competition in India. Pesticide Information. April-June. Pages 2-9.

Shaik Mohammad. 2001. Weed management options in rice culture. First Biennial Conference of ISWS in the new millennium on, "Eco-friendly weed management option for sustainable Agriuculture". May 23-24, 2001, Bangalore, India. Page 76.

Taab A. and Alizadch, H.M. 2004. Economics of weed control in lentil in Iran. Abstract, Weed Science Society Humanits, 4th International Weed Science Conference, Durban, South Africa, 19-24 June, 2004. Page 46.

Yaduraju N.T. and Mishra J.C. 2002. Herbicides Boon or Bane. Keynote address in the opening of WBCISWS, BCKV.

Effects of water and weed management practices on weed growth and yield performance of transplanted hybrid rice

P. Bandyopadhyay, P. Banerjee and S. Chowdhury
Department of Agronomy, Faculty of Agriculture,
Bidhan Chandra Krishi Viswavidyalaya, Nadia – 741252, West Bengal, India
pratit_kly@hotmail.com

Abstract: A field experiment was conducted in silty loam soil at Bidhan Chandra Krishi Viswavidyalaya, Instructional Farm, Mohanpur, Nadia, West Bengal, India, in two consecutive winter seasons of 2002-03 and 2003-04 to study the effect of irrigation and different weed management practices on weed growth and relative performance of transplanted hybrid rice. The experiment was laid out in a split plot design with 4 treatments of irrigation as main plots and 5 weed control treatments as subplots and replicated thrice. The predominant weed flora in the experimental field was composite in nature consisting of *Echinochloa crus-galli, Cynodon dactylon, Leersia hexandra, Cyperus rotundus, Cyperus difformis, Fimbristylis miliacea, Ludwigia parviflora, Monochoria vaginalis, Marsilea quadrifolia.* The hybrid cultivar Pro Agro 6444 was used. Continuous submergence of 5±2 cm depth of water reduced the weed crop competition ,increased the grain yield by 32.7%, and decreased the dry matter production of total weeds at harvest by 6.5% over 3 days after disappearance of ponded water. Continuous submergence of 5±2 cm recorded highest application of water (187.5 cm) over 3 days after disappearance of water (69.25 cm) as revealed by the mean data of two consecutive seasons. Hand weeding twice (25 & 45 DAT) and chemical weed control through herbicides are as equally effective as weed free plots in reducing population and dry matter of weeds, improving grain yield and other yield attributing characters, besides significantly superior over unweeded check treatment. An increase of 12.3 to 21.9% grain yield was recorded due to adoption of weed management practices. None of the herbicidal treatments showed any phytotoxic symptom on rice crop at 1 to 10 days after herbicides application. Highest weed control efficiency (%) and highest weed index (%) were observed under weed-free (81.55%) and unweeded check (24.04%) respectively, over other weed management practices.

Key words: Irrigation management, transplanted hybrid rice, weed management

INTRODUCTION

There is a wrong conviction that, standing water of higher depth all throughout the life period of plant is essential for growing a good crop of rice. It has been observed that standing water is necessary only to a depth of 5 cm and part of the life of plant (Ghosh and Bhattacharjee 1959b; Dastane 1967). Puddling followed by continuous submergence of land, effectively control weeds, in transplanted rice field. In rice fields, varying soil moisture regimes, like continuous submergence to drier situation, are followed. Singh and Singh (1988) recorded least weed growth and maximum crop yield under continuous submergence. The germination and emergence of weed seeds are closely related with the moisture status and depth of water standing on the soil. Thus, a full proof irrigation management is important for controlling weeds in transplanted hybrid rice cultivation during Boro season. Irrigation management not only controls weed growth but also decides the efficiency of applied herbicides to the crop (Moody 1978). Hand weeding, though it is laborious, expensive and time consuming, is still one of the most effective method for controlling weeds in our country. However, the chemical method of weed control is a better alternative and also advantageous over hand weeding particularly under intensive cropping system. The main objective of the present investigation was to find out the effects of different water regimes and irrigation practices on weed growth and yield of transplanted hybrid rice.

MATERIALS AND METHODS

A field study was conducted in two consecutive winter seasons (2002-03 and 2003-04) at Instructional Farm, Mohanpur, Nadia, W. Bengal, India. The soil was silty loam with pH 6.8. Initially, the soil was low in nitrogen, medium in phosphorus and high in potassium content. The experiment was laid out in split plot design with water management practices as main plots and weed management as sub-plots with three replications. Four events of irrigation, viz., 5±2 cm continuous submergence (I_0), 1 day after disappearance of 5 cm ponded water (I_1), 2 days after disappearance of 5 cm ponded water (I_2) and 3 days after disappearance of ponded water (I_3) and four weed management practices, viz., unweeded check (W_0), weed free continuous weeding (W_1) pyrazosulfuron ethyl (25 g ha^{-1}) at 7 days after treatment (DAT) (W_2) , pretilachlor (400 ml ha^{-1}) at 3 DAT (W_3) and hand weeding twice at 25 & 45 DAT (W_4) were included in the treatments. Full doses of P_2O_5 and K_2O were applied as basal. Half of the N was applied during tilling stage and the rest in two equal splits at 10 days after transplanting and just before panicle initiation stage. Population of weeds and dry weights in each plot were recorded from 0.5 x 0.5 m^2 at 30, 60, 90 DAT and harvest. The crop received 166.3 mm and 208.6 mm rainfall during the growth period 2002-03 and 2003-04, respectively. In two consecutive seasons, the crop under continuous submergence (I_0) received 187.5 cm of irrigation water followed by 90.8 cm, 82. 5 cm and 69.5 cm under 1, 2 and 3 days after disappearance of ponded water (i.e, I_1, I_2 and I_3), respectively.

Weed control efficiency (WCE) and Weed index (WI) were computed using the following standard formulae:

$$WCE(\%) = \frac{\text{Weed dry weight in unweeded check plot - Weed dry Weight in treated plot}}{\text{Weed dry weight in unweed check plot}} \times 100$$

$$WI(\%) = \frac{\text{Grain yield of weed free plot – Grain yield of other treatment}}{\text{Grain yield of weed free plot}} \times 100$$

RESULTS AND DISCUSSION

Weed Flora

The predominant weed flora associated with the crop were *Echinochloa crus-galli, Cynodon dactylon, Leersia hexandra, Cyperus rotundus, Cyperus difformis, Fimbristylis miliacea, Ludwigia parviflora, Monochoria vaginalis, Marsilea quadrifolia* etc.

Effect of Irrigation

Under continuous submergence of 5±2 cm ponded water, there was significant reduction in population and dry matter production of weed as compared to other drier treatments at all stages of observation except at harvest on weed population and dry matter production at 60 & 90 DAT, respectively (Table 1). Among the drier treatments, minimum drier (1 day after disappearance of ponded water) significantly reduced the population and dry weight of weeds at all stages of observations over extreme drier treatment (3 days after disappearance of ponded water) except at harvest on weed population, and 60 and 90 DAT on dry matter production, respectively. Due to lack of oxygen under submerged condition, most of the weeds could not germinate and thereby low dry matter production of weeds were observed at different stages of investigation. Bhan (1983) also reported lower emergence of weeds due to continuous submergence.

Yield of hybrid rice was significantly influenced by water management practices (Table 2). Continuous submergence of 5±2 cm produced significantly higher yield than other drier treatments except the minimum drier treatment (1 day after disappearance of water). Among the drier treatments, minimum drier condition (1 day after disappearance of ponded water) responded significantly over maximum drier treatment (3 days after disappearance of ponded water). Continuous submergence produced 16.49% higher grain yield than the maximum drier treatment. Also, the yield attributing characters, viz., number of effective tiller m^{-2}, length of panicle (cm), number of field grains $panicle^{-1}$, and 1000 grain weight were higher under continuous submergence of 5±2 cm of ponded water due to lower weed crop competition. Similar findings were also observed by Prihar and Sandhu (1989).

Effect of weed management practices

Substantial population and dry matter production of weeds were observed under different weed control treatments at all stages of observation compared to the unweeded check (Table 1). Such effects were more pronounced in the weed-free check followed by hand weeding twice (25 & 45 DAT) at all stages of observations. Among the herbicidal treatments, pyrazosulfuron ethyl (W_2) at 25 g ha^{-1} was equally effective and significantly superior over pretilachlor (W_3) for controlling population and dry matter production of weeds at all the stages of observation. Weed control efficiency was also highest (81.55%) in the weed-free check (W_1) followed by hand weeding twice (W_4), pyrazosulfuron ethyl (W_2) and pretilachlor (W_3), respectively.

Table 1. Effect of water and weed management practices on weed population and dry matter weight of weed at 30, 60, 90 DAT and at harvest in transplanted hybrid rice (Pooled of 2 years).

Treatments	Weed population (m^{-2})				Dry matter weight (gm m^{-2})				W. C. E. (%) at Harvest
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest	
Irrigation management practices									
I_1	12.23	18.27	24.80	27.73	5.42	6.17	12.82	14.79	
I_2	13.03	19.23	25.50	28.20	5.55	7.12	12.78	14.96	
I_3	13.20	19.77	26.07	28.70	5.77	7.15	12.89	15.29	
I_4	13.87	20.57	26.37	29.47	5.88	7.40	13.17	15.82	
S. Em(±)	0.34	0.35	0.31	0.41	0.09	0.13	0.16	0.14	
CD(P=0.05)	0.85	0.88	0.38	NS	0.24	NS	NS	0.36	
Weed management practices									
W_0	18.92	38.33	50.04	53.54	12.00	17.95	28.26	33.93	
W_1	6.42	10.79	14.70	16.83	3.01	3.50	6.15	6.26	81.55
W_2	8.75	13.17	19.25	22.50	3.90	4.13	8.89	12.98	61.74
W_3	10.50	23.96	27.75	30.83	4.86	6.76	13.70	15.49	54.35
W_4	9.08	11.21	16.67	18.92	3.52	3.71	7.22	7.41	78.16
S. Em(±)	0.37	0.40	0.40	0.36	0.16	0.15	0.26	0.21	
CD(P=0.05)	0.89	0.98	0.98	0.88	0.38	0.37	0.63	0.52	

Table 2. Effect of water and weed management practices on weed index (WI), grain yield (t ha^{-1}) and different yield attributing characters of transplanted hybrid rice (Pooled of 2 years).

Treatments	No of effective tiller m^{-2}	Length of panicle (cm)	No. of filled $panicle^{-1}$	1000 grain wt.	Grain yield (t ha^{-1})	W. I. (%)
Irrigation management practices						
I_1	324.012	25.002	72.813	22.252	8.97	-
I_2	322.770	24.734	71.721	22.223	8.43	-
I_3	320.860	24.187	70.764	22.098	8.20	-
I_4	321.064	24.070	69.774	22.026	7.79	-
S. Em(±)	0.4629	0.1692	0.2245	0.0123	0.386	-
CD(P=0.05)	1.1650	0.425	0.564	0.0309	0.969	-
Weed management practices						
W_0	282.630	23.594	61.491	21.220	5.72	24.04
W_1	340.704	25.269	79.050	22.723	7.53	-
W_2	331.215	24.388	72.008	22.544	6.81	9.56
W_3	319.600	24.098	68.687	21.626	6.71	10.88
W_4	336.733	25.143	75.104	22.637	7.14	5.17
S. Em(±)	0.4557	0.1651	0.2299	0.0154	0.377	-
CD(P=0.05)	1.0950	0.396	0.578	0.0370	0.907	-

Grain yield and the yield attributing characters of hybrid rice were significantly influenced by the different weed management practices (Table. 2). Higher grain yield and other yield attributing characters were recorded in the weed-free check (W_1) followed by hand weeding twice, which were 24.03 and 19.88 % more than the grain yield of the unweeded check, these were statistically at par. This finding corroborates the findings of Choubey et al. (1998). Among the herbicidal treatments, pyrazosulfuron ethyl (W_2) was found superior over pretilachlor. Increase in grain yield and other yield attributing characters were mainly due to low weed-crop competition in different weed management treatment. The highest weed index (24.04%) was recorded in the unweeded check.

The results indicated that higher grain yield of hybrid rice can be obtained by continuous submergence of 5±2 cm depth of water in combination with hand weeding twice (25 & 45 DAT) followed by chemicals like pyrazosulfuron ethyl at 25 g ha^{-1}.

LITERATURE CITED

Bhan V. M. 1983. Effect of hydrology, soil moisture regime and fertility management of weed population and their control in rice. In Proc. Conf. On Weed Control in Rice. 31 Aug – 4 Sept. 1981, Philippines, pp. 47-56.

Choubey N. K., Tripathi R. S., Ghosh B. C. and Kolhe S. S. 1998. Effect of water and weed management practices on weed growth & performance of transplanted rice Oryza. 35(3): 252-55.

Moody K. 1978. Weed control in integrated rice using non-chemical method. Report of training programme for weed control in rice, held at Maligaya, Philippines.

Prihar S. S. and Sandhu B. S. 1989. Irrigation in field crops, principles and practices, ICHR, New Delhi, pp. 84-94.

Singh R. K. and Singh R. D. 1988. Efficiency of herbicides under different water management practices in transplanted rice. Indian J. Weed Sci. 20 : 15-19.

Competition correlation of rice –weed system using a mass ratio order parameter

J. Y. Shen, P. Zhou, L. K. Cao, and Y. T. Lu
School of Agriculture and Biology, Shanghai Jiaotong University, Shanghai, China
2678Qixin Rd. Shanghai 201101
jyshen88@sjtu.edu.cn or ytlu@sjtu.edu.cn

Abstract: The competition between rice and weed in rice-weed system was investigated using biomass ratio of rice to weed as the order parameter of rice-weed system. The loss of rice yield (Y) and the system order parameter (q as q_1 and q_2 for early and late stages of rice growth, respectively) was correlated as follows: $Y=125.93e^{-1.0373q_1}$ and $Y=94.417e^{-0.7813q_2}$, and that the order parameters at the separation point (q_A) was 1.12. The results served as the basis for a novel theory that the rice-weed ecological system would go through dissipative processes that were responsible for the formation of a self-organized spatially ordered structure, order parameter q was made vast strides high layer orderliness of system (favoring rice or small yield loss) if $q_1 > q_A$ (1.12). This concept was employed in establishing a simple yet better herbicide application strategy which has been successfully demonstrated in three rice fields. It should be promoted for general acceptance to play an important role in preventing weed community malignant succession and/or agricultural ecosystem and environmental deterioration.

Key words: Biomass, herbicide, weed management, yield loss.

INTRODUCTION

Excessive application of chemical herbicides has resulted in: reduced bio-diversity of the countryside (Shen et al. 2004a), lower farming profitability, high concentrations of pesticide residues in the environment (Heap 1997), and health concerns (Shen and Tong 2004), as well as more herbicide resistant weeds (Shen et al. 2004b) thereby presenting more challenges to weed control in rice fields. In response to these pressures, there is a move in China towards more sustainable weed management systems. Knowledge of the effect of weed populations on crop yield is necessary to make any weed management decision.

A comprehensive study on competition between rice and weeds in the rice field and the control critical periods is required to formulate an effective weed management program (Johnson et al. 2004). There is yet no report of studies using biomass ratio of rice to weeds as the system order parameter to predict the competition and development of rice-weed ecosystem. Therefore, the objectives of this research were to study competition correlation between rice and weed, order parameter, as well as application of order parameter on dosage of herbicide and combination of herbicides. The expected results will help to establish an optimal weed management program to reduce herbicide residues, to prevent agricultural ecosystem and environment from deterioration, and to increase farming profit.

MATERIALS AND METHODS

Experiment of competition correlation between rice and weed was conducted in direct-sown rice fields at Zhangze Town, Shanghai, from May to October in 2001. The experimental design was a randomized complete block with four replications. The plot size was 2.5 by 2.5 m. The treatments were seven weed densities of 0, 50, 100, 150, 200, 250, and > 250 plants m^{-2}, and manual weeding was undertaken at weekly intervals to maintain the treatment weed densities. No herbicide application was made during the growth period. Weeds and rice were sampled from four 0.25 m^2 in each plot at 30, 45, 60 days after sowing (DAS). The weeds and rice were separated and weighed, respectively. At harvest, yield components were observed by taking samples from four 0.25 m^2 per plot. Samples were threshed separately, and the grains were dried and weighed. Yield components recorded were: the number of panicles, tiller number per square meter, percent of full grains, number of available spikelets per panicle, and 1000-grain weight.

Experiments of different dosage of herbicide were conducted in direct-sown rice fields at Zhangze Town, Shanghai, from May to October in 2002. The experimental design was a randomized complete block with four replications. Each plot size was 13 by 7m. Two DAS, treatments were applied with pretilachlor EC at 0, 337.5, 450.0, 562.5 ml ai ha^{-1} respectively. The sampling and the measurement and record of yield components were similar as above.

Experiments of different combination of herbicides were conducted in experimental rice fields of Shanghai Pudong New Area Agricultural Technical Extension Center, from May to October in 2002. The experimental design was a randomized complete block with four replications. Each plot size was 10 by 5 m. The treatments were two combinations of herbicide. At 2 DAS, the test field was treated with 450.0 ml ai ha^{-1} of pretilachlor EC, and, at 16 DAS, it was treated again with lonsat WP at 1260.0 g ai ha^{-1} or zark at 197.5 g ai ha^{-1}. Further trials to test optimal combinations of herbicides were carried out in three kinds of soil and weed properties direct-sown rice fields: Zhangze 4th village in western Shanghai (4% organic matters, 22% clay, pH 6.8), Maoshen village of Yuepu Town in central Shanghai (2% organic matters, 16% clay, pH 7.6), and experimental fields of Shanghai Pudong New Area Agricultural Technical Extension Center in eastern Shanghai (2% organic matters, 13% clay, pH 7.8), from May to October in 2003. The trial areas were respectively 1334.0, 1900.0, and 1680.0 m^2, respectively. At 2 DAS, the test field treated with 450.0 ml ai ha^{-1} of Pretilachlor EC, and at 16 DAS, it was treated again with Zark WP 197.50 g ai ha^{-1}, respectively. The sampling and the measurement and record of yield components were similar as above.

RESULTS AND DISCUSSION

Competition correlation between rice and weed

Data on changing values of the order parameter in rice-weed system (Table 1) showed that interaction between rice and weed strengthened continuously in the first 30 DAS; it reached the peak at around 45 DAS and was then kept stable at 60 DAS. When weed was present at a high density (> 250 plants m^{-2}) in rice fields, the intensive competition between weed and rice would result in a large rice yield loss. Total biomass of weed and rice were 998.2 g m^{-2} and 149.7 g m^{-2} ($P<0.01$), respectively, and the rice yield loss was about 82%. Decreasing the weed density from a high level, total biomass of weed and rice yield loss decreased slowly because of compensation effect of individual growth. When the weed density fell to 100 plants m^{-2}, although there was less competition between weeds, the competition between weed and rice remained intensive. As weed density decreased further, although individual weed could grow actively, its ability in causing rice yield loss was much reduced. When weed density dropped to 50 plants m^{-2}, rice was dominant with a low yield loss of 10%. However, further gain in rice biomass or reduction in yield loss would be much less when the weed densities decreased further below 50 plants m^{-2}.

Table 1 Description of six levels weed densities (plants m^{-2}) used to test the change order parameter at three rice growth periods (30, 45, 60 days after sowing, DAS).

Weed density Plants m^{-2}	30 DAS		45 DAS		60 DAS	
	q_1		q		q_2	
50	2.35	a *	2.14	a	2.86	a
100	1.36	b	1.39	b	1.20	b
150	0.99	bc	0.81	c	0.80	b
200	0.70	c	0.54	d	0.70	b
250	0.45	c	0.48	d	0.39	b
>250	0.41	c	0.24	e	0.15	b

*Numbers in the same column followed by different letters are significantly different at $p<0.05$ level.

Order parameter of rice-weed system

The results of these studies have supported a novel assumption that the competition between rice and weed in the rice-weed system would eventually produce two states: the high level orderliness (HLO) in which rice is dominant and that the yield loss is low and the low level orderliness (LLO) in which weed is dominant and that the yield loss is large. We employed the ratio of negentropy (biomass ratio of rice to weed) as the order parameter (q) in different rice growth periods (q_1 and q_2 for early and late stages of rice growth, respectively) to describe the changing trend of rice-weed interactive status. The law of conservation of energy and entropy that, during transformation of light energy to chemical (biological) energy in an ecosystem, all external elements were equivalence to negentropy; therefore, negentropy could be expressed by fresh weight or dry weight of plant per unit area. It is difficult for a rice-weed system to develop naturally into the HLO. Therefore specific control methods such as herbicides, fertilizers, etc., will be needed to be added to the weed and rice subsystems artificially to adjust q accumulation capacity to made at the early stage to weaken the weed population while strengthen the rice population, resulting in a vast strides order parameter for the system to reach the HLO. In this rice-weed system, q_A is the separation point of system that determines whether the rice-weed system will form the HLO condition at early stages of rice growth. When $q_1 <q_A$, the order parameter decreases since the weed has the superiority, and the system was dominated by weed due to the self organizing effect, the system of late rice growth stage will move toward LLO. When $q_1 >q_A$, the order parameter increases as the rice population has the advantage, and after that, the system was dominated by rice due to the self-organization effect with large increase in q until the late growth period, a stable system state with very small loss in the rice yield. Once the HLO was established, presence of some weed population had little effect on the structure and function of rice-weed system.

As shown in Figures 1, the rice yield loss Y was well correlated to the system order parameter (q_1 or q_2), with r_{q1y}=-0.9954, r_{q2y}=-0.9948 ($r_{0.01}$=-0.9170), in the following manner:

$$Y = 125.93\ e^{-1.0373q_1} \quad (1)$$
$$Y = 94.417\ e^{-0.7813q_2} \quad (2)$$

Assuming $q_1 \geq 0.2223$ and $q_2 \geq 0$, to be more realistic for a practical rice field, the late stage order parameter may be related to the early stage order parameter as:

$$q_2 = 1.3277q_1 - 0.3686 \quad (3)$$

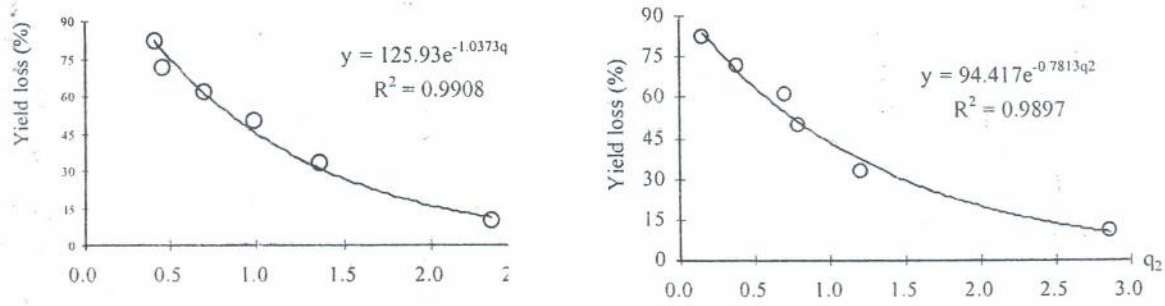


Figure 1. Illustration of relation between order parameter q_1 or q_2 and loss of rice yield used to test by order parameter using a mass ratio at 30and 60 DAS.

Solution of system of the above equation at $q_1 = q_2$, $q_1 = q_A = 1.12$ where q_A was the branch separate point of system.

Application of order parameter

Results of the experiments using different dosages of pretilachlor showed that the order parameter and the weed control effectiveness of the rice-weed system changed with the pretilachlor dose, which acted as the principal control parameter λ (Table 2). Under the natural condition, controlled by weed ($q_1<q_A$), system regressed to LLO. When treated with pretilachlor 337.5 ml ai ha^{-1}, although the weed control effectiveness increased from 53% (30 DAS) to 75% (60 DAS) after transitory coherence effect, the increase in order parameter was relatively small, system stayed in LLO. When the dosage of pretilachlor was raised to 450.0 ml ai ha^{-1}, the order parameter increased substantially 1.63 at 30 DAS to 6.77at 45 DAS ($>q_A$), dissipative processes were responsible for the formation of a self-organized spatially ordered structure, order parameter q made vast strides to 10.26 at 60 DAS. Herbicidal efficiency rose from 87% (30 DAS) to 96% (60 DAS), rice production increased significantly. Another increment in pretilachlor dose (to 562.5 ml ai ha^{-1}), however, produced only 3% ($p>0.05$) increase in weed control effectiveness at its HLO as $q_1>>q_A$, when pretilachlor dose increased by 25%.

In complex rice-weed system (containing many weed species), optimal formulation of herbicide, acting as the principal control parameter λ, is especially important for the proper management of a complex rice-weed system. A new herbicide application plan of pre-emergence treatment with pretilachlor 2 DAS combined with post-emergence with Lonsat WP or Zark WP at the two-leaf stage of rice and further illustrated by the results obtained in rice fields of the three different soil and weed properties areas were employed in the rice fields. The results as shown in Tables 3 and 4 demonstrated the effectiveness of the two-stage herbicide application scheme; the high values of the order parameter attained in each case established a HLO condition respectively at early and late growth stages which resulted in the high weed control effectiveness and significantly increased rice production. This approach would broaden herbicidal spectrum, fully utilize the effect of control parameter to minimize the number of applications, alleviate the pressure upon the local environments by the conventional herbicide application methods due to the excessive amounts of herbicide employed in many applications during the rice growth season.

Table 2. Effects of pretilachlor dosage on the order parameter and weed control efficiency at three rice growth periods.

Date	Treatment ml ai ha^{-1}	Rice biomass $g 0.25m^{-2}$	Weed biomass $g 0.25m^{-2}$	Order parameter q	Control efficiency %
	Control	156.1 a*	1449.3 a	0.11 a	
30 DAS	337.5	287.1 b	686.4 b	0.42 b	52.7 a
(q_1)	450	299.3 b	184.1 c	1.63 c	87.3 b
	562.5	214.4 c	51.1 d	4.19 d	96.3 c
45 DAS	Control	663.6 a	2772.7 a	0.24 a	
	337.5	1618.2 b	1127.3 b	1.44 b	58.9 a
	450	1293.2 c	190.9 c	6.77 c	93.1 b
	562.5	1418.2 d	93.2 d	15.22 d	96.6 b
60 DAS	Control	954.5 a	5140.0 a	0.17 a	
(q_2)	337.5	1597.7 b	1312.5 b	1.22 b	74.5 a
	450	2402.3 c	234.1 c	10.26 c	95.5 b
	562.5	2148.8 d	109.1 d	19.70 d	98.5 b

*Numbers in the same column followed by different letters are significantly different at $p<0.05$ level.

Table 3. Results of two herbicide application programs on the order parameter and weed control efficiency at different rice growth periods.

Date	Type	Control	Lonsat	Zark
30DAS	Rice biomass ($g\ 0.25m^{-2}$)	221.6 a*	490.9 b	487.1 c
	Weed biomass ($g\ 0.25m^{-2}$)	355.7 a	7.2 b	1.1 c
	Order parameter (q_1)	0.62 a	68.14 b	428.66 c
	Control efficiency		98.0 a	99.7 a
60DAS	Rice biomass ($g\ 0.25m^{-2}$)	1961.4 a	3156.1 b	3425.8 c
	Weed biomass ($g\ 0.25m^{-2}$)	2566.9 a	159.5 b	115.9 c
	Order parameter (q_2)	0.76 a	19.79 b	29.56 c
	Control efficiency (%)		93.8 a	95.5 a
Mature period	Yield ($Kg\ ha^{-1}$)	2046 a	8188 b	8094 c

*Numbers in the same column followed by different letters are significantly different at $p<0.05$ level.

Table 4. Pretilachlor + Zark on the order parameter and weed control efficiency in different test fields.

Date	Type	Song-jiang area	Bao-shang area	Pu-dong area
30DAS	Rice biomass ($g\ 0.25m^{-2}$)	360.9 b*	218.1 a	478.3 c
	Weed biomass ($g\ 0.25m^{-2}$)	1.7 a	1.2 a	1.4 a
	Order parameter (q_1)	212.29 b	181.75 a	341.64 c
	Control efficiency	96.7 a	98.1 a	97.3 a
60DAS	Rice biomass ($g\ 0.25m^{-2}$)	2629.5 b	1054.6 a	3515.4 b
	Weed biomass ($g\ 0.25m^{-2}$)	98.2 b	34.4 a	109.9 b
	Order parameter (q_2)	26.78 a	30.67 b	31.99 c
	Control efficiency (%)	95.0 a	95.8 a	95.5 a
Mature period	Yield ($Kg\ ha^{-1}$)	8001 a	9795 c	8292 b

*Numbers in the same column followed by different letters are significantly different at $p<0.05$ level.

In conclusion, the repeatability, convenience, and prediction of order parameter (q) differed in important ways. It offers basic information or instruction on weed management and can be incorporated relatively easily into a farm's weed management strategy. It may be important to overcome blind application of herbicides and to prevent weed population succession and environmental deterioration.

ACKNOWLEDGEMENTS

We thank the Shanghai Science Committee for providing financial support for this project. We also thank all technical staffs who worked on this project.

LITERATURE CITED

Heap I. M. 1997. The occurrence of herbicide resistant weeds worldwide. Pest. Sci. 51: 235-243.

Johnson D. E., Wopereis M. C. S. Mbodj D., Diallo S., Powers S. and Haefele S. M. 2004. Tming of weed management and yield losses due to weeds in irrigated rice in the Sahel. Field Crops Res. 85: 31-42.

Shen J. Y., Z. R. Lu, Y. T. Lu and X. H. Wang. 2004a. Progress on toxicity of nitrogen-fixing cyanobacteria to herbicides. World Pestic. 6:54-61.

Shen J. Y. and Tong G. L. 2004. The green food production and environment. Shanghai Agric. Techno. 1:2-4

Shen J. Y., Lu Z. L. and Lu Y. T. 2004b. Study on weed community succession in rice fields in Shanghai and their factors analysis. Acta Agriculture Shanghai 20:75-81.

The effect of water regime and soil management on methane (CH_4) emission from rice field

Prihasto Setyanto[1], Orbanus Naharia[1], M.Yuli Irianto[2] and Iskandar Zulkarnain[2]
[1]Research Station for Agricultural Environment Preservation,
Jakenan 05 Pati 59182 Central-Java
[2]Syngenta Research and Development Station PO Box 08, Cikampek, West-Java

Abstract: Mitigation of CH_4 emission from rice fields is becoming an important issue. The Agricultural Environment Preservation Research Station in Central Jawa conducted a field study to investigate the effects of water regime and soil tillage on CH_4 emission from paddy fields. Treatments consisted of two factors. The first factor was water regime, e.g., 1) continuously flooded 5 cm, 2) intermittent irrigation and 3) saturated water condition at 0-1 cm water level. The second factor was soil management, e.g., 1) normal tillage, 2) zero tillage+3 lt sulfosate ha^{-1} and 3) zero tillage+3 lt paraquat ha^{-1}. Most of the treatments gave a significant reduction of total CH_4 emission between 34 - 85% during the wet season crop as compared with normal rice cropping practice, while in the dry season the CH_4 reduction ranged between 16 - 92%. No-tillage with non-selective herbicides combined with intermittent/saturated irrigation system significantly reduced methane emissions without significantly affecting rice productivity as compared to normal tillage with continuous flooding (farmers' practice).

Key words: Water management, no- tillage, methane (CH_4) emission, irrigated lowland rice

INTRODUCTION

Irrigated lowland rice systems account for about 80% of the world harvested rice area and 92% of total rice production. Methane (CH_4) is one of the gases released from an anaerobic decomposition of soil organic matter. Flooded rice soil contributes as much as 20% or ~100 Tg CH_4 on an annual basis (Hounghton et al. 1992). The projected increase of rice production during the coming decades (IRRI 1999) is expected to result in further increase in CH_4 fluxes to the atmosphere if prevalent cultivation practices continue (Anastasi *et al.* 1992). Current recommendations to minimize CH_4 emission in rice are based mostly on adapted rice varieties, intermittent irrigation and management of crop residues under full cultivation. No research has been carried out on the effect of no-tillage on CH_4 emission. Further, Indonesian data on the effect of water regime on CH_4 emission still need to be further validated under different soil and climatic conditions. This study reports the results of two experiments on the effect of no-tillage on CH_4 emission from a paddy field under different water regimes.

MATERIALS AND METHODS

Field site description

Two field experiments were conducted during the wet season (November 2002-March 2003), and dry season (April-July 2003), at Jakenan, Central Java (Indonesia). The soil properties were relatively high acidity, low CEC and low organic matter content. The soil was classified as Inceptisol with a silty loam texture.

Experimental layout and soil management

The experiments covered two cropping cycles (wet and dry season) with a short fallow period in between. Rice was grown under irrigated lowland conditions during the two consecutive seasons. Treatments consisted of two factors: water regime (A) and soil management (T). The factor A treatments consisted of three different water regimes e.g. 1) continuously flooded 5 cm (A1), 2) intermittent irrigation (A2) and 3) saturated water condition at 0-1 cm water level (A3). An illustration of the water treatments is shown in Figure 1. Factor B treatments were: 1) normal tillage (T1), 2) zero tillage+3 lha^{-1}sulfosate (TOUCHDOWN SL480) (T2) and 3) zero tillage+3 lha^{-1} paraquat (GRAMOXONE SL200) (T3). The treatments were arranged in 3 x 3 factorial and the experimental design was randomized complete block with three replicates. The experimental plot size was 6 m x 4 m. IR 64 rice cultivar was used in this study and transplanted at 25 days after nursery sowing.

Soil cultivation for T1 treatment was carried out one day before rice transplanting. Herbicides sulfosate (TOUCHDOWN SL480) and paraquat (GRAMOXONE SL200) were sprayed at 9 and 4 days before rice transplanting, respectively. Inorganic fertilizer in the form of urea, SP36 and KCl was applied at the rate of 120 kg N ha^{-1}, 60 kg P ha^{-1} and 90 kg K ha^{-1}, respectively. Water level in the plots was controlled daily.

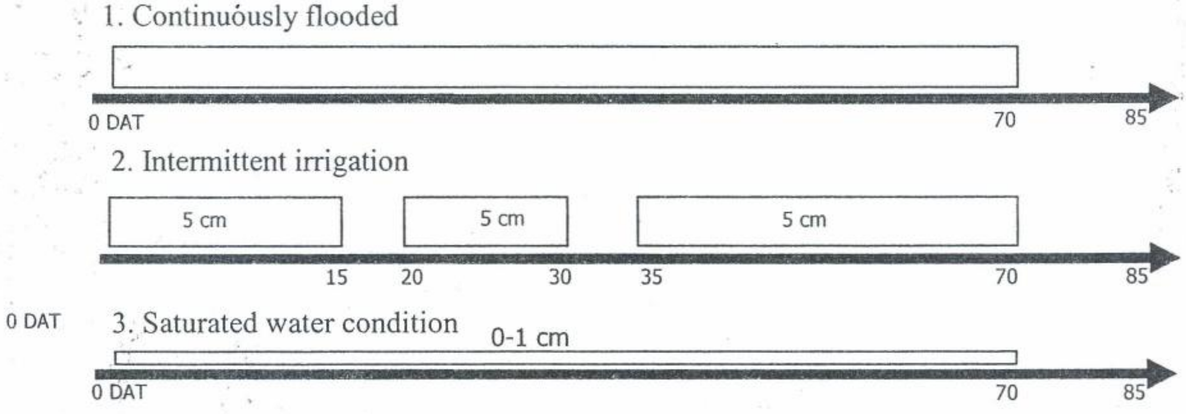


Figure 1. Illustration of the water treatments i.e. 1) continuously flooded 5 cm, 2) intermittent irrigation and 3) saturated water condition at 0-1 cm water level.

Methane flux measurement

Methane fluxes were recorded every four days using the closed chamber method originally described by Schutz *et al.* 1989. Gas samples from each of the plots were collected using a 5 ml plastic syringe at four different intervals i.e. 3, 6, 9 and 12 minutes. Methane gas concentration inside the syringe was analyzed using gas chromatograph Shimadzu GC 8A equipped with flame ionization detector and a 3 m length and 1 mm diameter of porapak N column. The GC performance required for such analyses are; 1) column temperature: 75°C and 2) injector/detector temperature: 90°C. During gas sampling, the temperature increase and the headspace of the chamber were also recorded. This parameter is important for CH_4 flux calculation. Methane flux calculation was derived from the equation described by Lantin et al. (1995).

Data analysis

Data of CH_4 emission and yield parameters from field experiment i.e. rice production, plant height, tiller number and biomass, were analyzed using analysis of variance (ANOVA). The treatment means were compared using Duncan Multiple Range Test (DMRT) and Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Seasonal CH_4 flux

The patterns of CH_4 flux from rice field as affected by water regime in two consecutive seasons are shown in Figures 2 and 3.

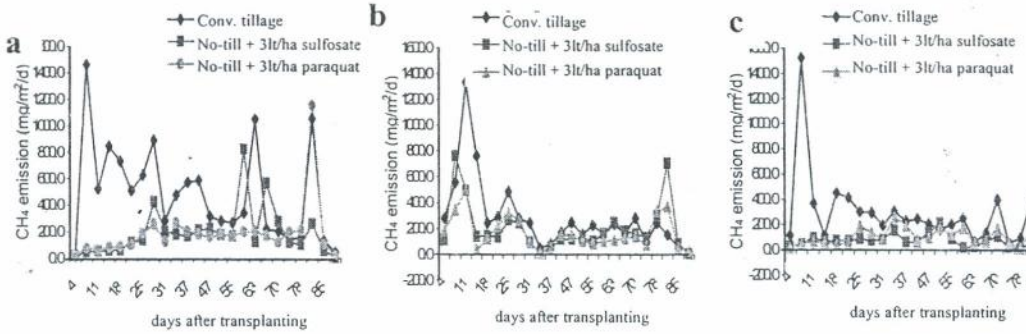


Figure 2. Seasonal CH_4 flux pattern of three different water management practices; a) continously flooded, b) intermittent irrigation and c) saturated water condition, during the wet season 2002/2003 at Jakenan experimental farm, Indonesia.

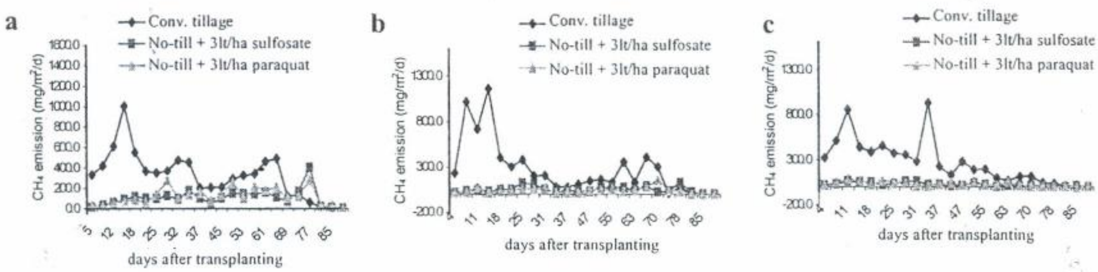


Figure 3. Seasonal CH_4 flux pattern of three different water management practices; a) continously flooded, b) intermittent irrigation and c) saturated water condition, during the dry season 2003 at Jakenan experimental farm, Indonesia.

Methane flux for continuously flooded (A1) started to increase within the first two weeks after flooding with an average 29.7 mg CH_4 m^{-2} h^{-1} in the wet season and 22.8 mg CH_4 m^{-2} h^{-1} in the dry season. After two weeks, the fluxes slightly decreased with an average 16.2 and 13.6 mg CH_4 m^{-2} d^{-1} for the respective season. Other irrigation treatments (A2 and A3) showed the same pattern but with different intensities. For intermittent (A2) the average flux in the first two weeks was the same in both seasons i.e. 26.5 mg CH_4 m^{-2} h^{-1},, while in the latter stage it emitted as much as 7 mg CH_4 m^{-2} h^{-1} and 6.5 mg CH_4 m^{-2} h^{-1} respectively. Saturated irrigation (A3) was showing the lowest flux with the average of 21.4 and 20.6 mg CH_4 m^{-2} h^{-1}, respectively in the first two weeks, then decreased with the average of 9.4 and 11.2 mg CH_4 m^{-2} h^{-1} in the two respective seasons. The average CH_4 emission reduction by implementing A2 and A3 treatment as compared to A1 was 54.7% (23.95%) and 80.1% (11.25%) respectively during the wet season crop, while in the dry season it reduced as much as 55.7% (12.15%) and 79.4% (14.07%). A study conducted by Wang et al. (2000) on different water management also showed similar results. Two or three peaks have been usually observed in most field studies on CH_4 emission e.g. USA (Cicerone et al. 1983), Italy (Schutz et al. 1989) and Japan (Yagi and Minami 1990). The first peak is associated with the decomposition of soil organic matter or plant materials from the previous season. The second and third peaks are associated with the rice plants since they are not observed in unplanted fields (Schultz et al. 1989).

Total seasonal CH_4 emission, grain yield and plant growth parameters

Data in Table 3 show that the water regime significantly influenced CH_4 emission. Continuously flooded water regime (A1) showed the highest seasonal CH_4 emission compared with intermittent irrigation (A2) and saturated 0-1 cm water depth (A3). The pattern was constant in the wet and dry season period. The results of this study were in line with observations of several authors (Husin. 1994; Neue et al. 1995; Setyanto et al. 2000).

Table 3. Total CH_4 emission treated with different water regime as soil tillage.

Treatment	($kg\ CH_4\ ha^{-1} season^{-1}$)	
	WS 2002/03	DS 2003
A1 = Continuous flooding (5 cm)	303.08 a	255.24 a
A2 = Intermittent (5cm)	132.31 b	55.09 b
A3 = Saturated (0-1cm)	137.56 b	53.11 b
T1 = Normal tillage	253.95 a	160.81 a
T2 = No-tillage + 3l ha^{-1} sulfosate	189.07 b	105.98 b
T3 = No-tillage + 3l ha^{-1} paraquat	129.92 b	96.65 b
A1T1 = Continuous flooding+Normal tillage	422.66 a	285.27 a
A1T2 = Continous flooding+No-till 3l ha^{-1} sulfosate	158.33 c	241.05 ab
A1T3 = Continuous flooding+No-till 3l ha^{-1} paraquat	180.85 c	239.41 b
A2T1 = Intermittent+Normal tillage	246.47 b	91.90 c
A2T2 = Intermittent+No-till 3l ha^{-1} sulfosate	177.05 c	43.74 cd
A2T3 = Intermittent+No-till 3l ha^{-1} paraquat	143.71 cd	23.69 d
A3T1 = Saturated+Normal tillage	240.10 bc	105.26 c
A3T2 = Saturated+No-till 3l ha^{-1} sulfosate	61.54 d	33.18 d
A3T3 = Saturated+No-till 3l ha^{-1} paraquat	88.12 d	26.83 d

Number in the same column followed by common letter for treatment A and T are not significantly different ($P<0.05$) by LSD, and interaction by DMRT.

Treatment A1T1 showed the highest seasonal CH_4 emission compared with the other treatments. In the same A1 treatment with different T treatments, i.e., T2 and T3, total CH_4 emission was suppressed. The same pattern was also recorded with A2 and A3 treatments. Those treatments increased methane emission if combined with T1, and decreased it when combined with T2 and T3 treatments. These situations were recorded in both wet and dry season experiments. Very few treatments were showing significant differences on rice grain yield indicating that the treatments did not significantly effect rice productivity (Table 4).

Table 4. Yield (kg ha^{-1}; mc 14%) at different water regime and soil tillage.

Treatment	Soil Tillage							
	T1		T2		T3		Average	
Water regime	WS 2002/03	DS 2003	WS 2002/03	DS 2003	WS 2002/03	DS 2003	WS 2002/03	DS 2003
A1	5167.3	5144.0	5123.6	4656.7	4723.0	5274.30	5004.7 a	5025.0 a
A2	4814.3	4543.0	4725.7	4435.7	4535.3	4323.00	4701.7 b	4535.9 b
A3	4597.7	4321.7	4665.3	4243.7	4571.0	4372.00	4611.3 b	4312.4 b
Average	4859.8	4670.6	4838.2	4445.3	4619.8	4754.40		

Number in the same column followed by common letter for treatment A and T are not significantly different ($P<0.05$) by LSD.

The results of the two field studies show that no-tillage following the aplication of non-selective herbicides such as paraquat (GRAMOXONE SL200) or sulfosate (TOUCHDOWN SL480) can significantly reduce methane emissions from Indonesian rice paddy fields. The reduction is higher during the dry than the wet season. Methane emissions are further reduced when no-tillage is combined with intermittent or saturated irrigation. In the two experiments no tillage did not affect rice productivity significantly as compared to normal tillage with continuous flooding (current farmer's practice). Reduction of methane emission is one further potential benefit of no-tillage rice in the tropics. This combined with short term economical benefits for farmers such as lower water consumption, lower cultivation costs and increased planting index could lead to reconsider opportunities for no-till rice in tropical Asia.

LITERATURE CITED

Anastasi C., Dowding M. and Simpson V.J. 1992. Future CH_4 emission from rice production. J. Geophys. Res., 97: 7521-7525.

Bronson K.F., Neue H.U., Singh U. and Abao Jr. E. 1997. Automated chamber measurements of methane and nitrous oxide flux in a flooded rice soil: I. Residue, Nitrogen and water management. Soi. Soc. Am. J., 61:981-987.

Cicerone R.J. and Oremland R.S. 1983. Biogeochemical aspects on atmospheric methane. Global Biogeochem .Cycles, 2: 299-327.

Hounghton J.T., Calandar BA. And Varney S.K. 1992. Climate change 1992. The supplementary report to the IPCC scientific assessment. Cambridge University Press. Cambridge.

Husin Y.A. 1994. Methane flux from Indonesian wetland rice: the effects of water management and rice variety. PhD Thesis, Bogor Agricultural University.

IRRI- World rice statistics 1993/94. Manila, Philippines, p 42.

Lantin R.S., Aduna J.B. and Javellana A.M.J. 1995. Methane measurements in rice fields. Instruction manual and methodologies, maintenance and troubleshooting guide. A joint undertaking by: IRRI, US-EPA and UNDP.

Neue H.U., Wassmann R. and Lantin R.S. 1995. Mitigation options for methane emission from rice fields. Climate Change and Rice, Springer-Verlag, Berlin. pp 136-144.

Schutz HA., Holzapfel-Pschorn, Conrad R., Rennenberg H. and Seiler W. 1989. A 3-year continuous record on the influence of daytime, season, and fertilizer treatment on methane emission rates from Italian rice paddy. J. Geophys. Res., 16: 405-416.

Setyanto et al. in the text Setyanto, P. Makarim, AK. Fagi, AM. Wassmann, R. and LV, Buendia. 2000 Crop management affecting methane emissions from irrigated and rainfed rice in Central Java (Indonesia). Kluwer Academic Publishers. Nutr Cycl in Agroecosyst, 58: 85-93.

Wang Z.Y., Xu Y.C. Li Z., Guo Y.X., Wassmann R,. Neue H.U. Lantin R.S. Buendia L.V., Ding Y.P. and Wang Z.Z. 2000. A four-year record of methane emissions from irrigated rice fields in the Beijing region of China. Nutr. Cycl. Agroecosyst, 58: 55-65.

Yagi K. and Minami K. 1990. Effect of organic matter application on methane emission from some Japanese paddy fields. Soil. Sci. Plant Nutr., 36: 599-610.

Determination of agronomic and economic IWM practices in field crops

R.E. Blackshaw, E.G. Smith
Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada T1J 4B1
blackshaw@agr.gc.ca

Abstract: Few studies have determined the potential benefits of simultaneous use of several desirable crop production practices on weed management, and even fewer studies have examined the economics of these practices. A four-year field experiment was conducted under zero-till conditions at three sites in Canada to determine the combined effects of seed date (April or May), seed rate (1X or 1.5X), fertilizer timing (fall- or spring-applied), and in-crop herbicide dose (0.5X or 1X) on weed management and crop yield. These treatments were applied to two cycles of a wheat-canola rotation at two sites and to two cycles of a barley-field pea rotation at one site. Treatment combinations of early seeding, higher crop seed rates, and spring-applied fertilizer resulted in improved weed management, with potential to reduce in-crop herbicide doses, while maintaining good crop yields with high quality. Weed seed bank numbers at the conclusion of the four-year studies were not greater with the 0.5X than with the 1X herbicide dose when applied within a competitive cropping system. Economic analyses indicated that spring compared with fall-applied fertilizer and a reduction in herbicide dose to 0.5X consistently resulted in greater profits to the farmer. April compared with May seeding gave greater economic returns in wheat, canola, and field pea but not barley. Increasing crop seed rate reduced profits in field pea but resulted in similar profits in the other three crops while providing the long term benefit of reducing the weed seed bank.

Key words: Economics, herbicide dose, integrated weed management, weed seed bank, yield.

INTRODUCTION

Wheat (*Triticum aestivum*), canola (*Brassica napus*), barley (*Hordeum vulgare*), and field pea (*Pisum sativum*) are among the most economically important crops of the Canadian prairies (Statistics Canada 2003). Herbicides typically account for 20 to 30% of input costs in these crops (Derksen et al. 2002). Farmers are very cognizant of weed control costs and thus are becoming increasingly interested in weed management programs that would reduce weed populations over time and reduce their dependence on herbicides.

Integrated weed management systems have potential to reduce herbicide use (and associated costs) and to provide more robust and long-term management of weeds (Buhler 1999). Numerous agronomic factors such as crop rotation, crop cultivar, seed date, seed rate, row spacing and fertilizer management have been studied for their potential to manage weeds (Gill et al. 1997; Liebman et al. 2001). However, these agronomic practices are not effective with all weeds or feasible with all crops, and many research studies have only looked at one or two of these practices in isolation. There is a need to determine the potential advantages of simultaneous use of several beneficial crop production practices combined with timely herbicide use to develop more comprehensive weed control programs.

A field experiment was conducted to determine the combined effects of seed date, seed rate, fertilizer timing and in-crop herbicide dose on weed growth and crop yield within a wheat-canola-wheat-canola rotation at two locations and within a barley-field pea-barley-field pea rotation at one location.

MATERIALS AND METHODS

The factorial set of treatments consisted of 1) seed date (April or May), 2) seed rate (1X or 1.5X), 3) fertilizer timing (fall- or spring-applied), and 4) in-crop herbicide dose (0.5X or 1X). Treatments were applied to the same plots for four consecutive years within a wheat-canola-wheat-canola rotation (Lethbridge, AB and Scott, SK) and within a barley-field pea-barley-field pea rotation (Lacombe, AB) in zero-tillage production systems. Both crop phases of the rotation were grown each year.

April seeding usually occurred during the last week of April and May seeding occurred during the third or fourth week of May. The recommended seed rates of wheat, canola, barley and field pea were 80, 6, 110, and 225 kg ha^{-1}, respectively. Fertilizer was banded 10 cm deep in October or mid-row banded during the spring seeding operation. At Lethbridge, N and P doses were 75 and 15 kg ha^{-1}, respectively. At Scott, N, P and S doses were applied 70, 15 and 10 kg ha^{-1}, respectively. At Lacombe, N and P were applied at 30 and 15 kg ha^{-1} in barley, and field pea was inoculated with a recommended granular *Rhizobium* innoculant at 6 kg ha^{-1} to meet its N requirements. Phosphorus was applied as a fertilizer blend in field pea giving a dose of 6 and 15 kg ha^{-1} of N and P, respectively. Recommended doses of in-crop herbicides were clodinafop at 70 g ai ha^{-1} plus thifensulfuron:tribenuron at 10:5 g ai ha^{-1} in wheat, glyphosate at 450 g ae ha^{-1} in glyphosate-resistant canola, tralkoxydim at 200 g ai ha^{-1} plus fluroxypyr:clopyralid:MCPA at 140:100:550 g ai ha^{-1} in barley and imazamoz:imazethapyr at 15:15 g ai ha^{-1} in field pea.

Glyphosate at 450 g ha^{-1} was applied to all plots within a respective seed date 3 to 5 days before planting to control existing vegetation. Glyphosate was tank mixed with 2,4-D ester at 450 g ae ha^{-1} if volunteer glyphosate-resistant canola was present. Weed seed was broadcast on the soil surface at approximately 50 seeds m^{-2} per species immediately before crop planting only in the first year to ensure adequate weed populations. Weed species included wild oat (*Avena fatua*), green foxtail (*Setaria viridis*), redroot pigweed (*Amaranthus retroflexus*), common lambsquarters (*Chenopodium album*), redstem filaree (*Erodium cicutarium*), and wild mustard (*Sinapis arvensis*) at Lethbridge; wild oat, redroot pigweed, common lambsquarters, wild buckwheat (*Polygonum convolvulus*), shepherd's-purse (*Capsella bursa-pastoris),* and wild mustard at Scott; and wild oat, false cleavers (*Galium spurium*), common hempnettle (*Galeopsis tetrahit*), and redstem filaree at Lacombe.

Weed shoot biomass was determined in mid- to late-August by cutting plants at ground level in three 0.5 m^2 quadrats per plot and oven-drying at 35 C for 2 weeks. Crop yield was determined by harvesting the center portions of each plot. Threshed samples were dried at 35 C for 2 weeks and then cleaned of weed seed and chaff to calculate clean grain yield. Crop yield was not determined at Scott in 2002 due to extreme drought. The weed seed bank was determined at the conclusion of the 4-year experiments using three cycles of the greenhouse emergence method (Blackshaw et al. 2000).

Data were statistically analysed separately for each location and crop using the MIXED procedure in SAS (Statistical Analysis Systems 1999) with seed date, seed rate, fertilizer timing, herbicide dose and all of their interactions in the model. Treatments means were compared using P-values or Fischer's protected LSD test at the 5% level (Steel and Torrie 1980).

The profitability of the treatments was measured by contribution margin. The contribution margin is the economic return above all variable costs, including seed, innoculant, fertilizer, herbicide, machinery fuel and repairs, insurance, marketing, and interest. It is the economic returns available to cover fixed costs of machinery investment, labor, land, and overhead, which will be the same across all treatments.

RESULTS AND DISCUSSION

Weed Biomass

Above ground weed biomass taken shortly before crop harvest was greater with April than with May seeding in 17 of 23 site-years (data not shown). Observations indicated that there fewer weeds often emerged when preseed glyphosate was applied prior to April compared with May seeding, and thus greater weed numbers were sometimes present in-crop with April seeding. Increasing crop seed rate to 1.5X of recommended reduced weed biomass in 16 of 23 site-years. Spring compared with fall-applied fertilizer reduced weed biomass in 10 of 23 site-years.

Somewhat surprisingly, weed biomass was often similar at the 0.5X and the 1X in-crop herbicide dose (data not shown). Crop seed rate and herbicide dose interacted ($P < 0.05$) to affect weed biomass. Weed biomass was sometimes greater with the 0.5X compared with the 1X in-crop herbicide dose at the 1X but not at the 1.5X seed rate.

Weed Seed Bank

The weed seed bank at the conclusion of the four-year experiment was 35 to 51% greater with April than with May seeding depending on the experiment site (data not shown), indicating that delayed seeding is a desirable practice if weed management (and not crop yield) is the primary goal. An increase in crop seed rate to 1.5X resulted in a 25 to 44% decrease in the weed seed bank. Spring compared with fall-applied fertilizer reduced the weed seed bank by 21 to 24%. The weed seed bank was similar with 0.5X and 1X herbicide doses at 2 of 3 sites when higher crop seed rates and spring-applied fertilizer were utilized.

Crop Yield and Quality

April compared with May seeding resulted in greater crop yields in 10 of 22 site-years (data not shown). Increasing crop seed rate to 1.5X gave greater crop yields in 11 of 22 site-years; yield was never reduced by higher seed rates. Spring compared with fall-applied fertilizer increased crop yield in 7 of 22 site-years and never decreased yield. Crop yields were often similar with 0.5X and 1X herbicide doses, especially if higher seed rates were used.

Wheat protein content was similar with most treatments but canola oil content was greater with April than with May seeding in 4 of 7 site-years (data not shown). Spring compared with fall-applied fertilizer gave higher canola oil levels in 2 of 3 years at Scott.

Economic Assessment

April compared with May seeding resulted in greater economic return for wheat, canola, and field pea but the opposite result occurred for barley (Table 1). Increasing seed rate to 1.5X of recommended resulted in similar economic return in wheat, canola, and barley while reducing weed biomass and the weed seed bank. In contrast, a 1.5X seed rate of field pea resulted in lower economic return due to the high seed costs in this crop.

Table 1. Contribution margin (\$ ha^{-1}) for the seed date and seed rate treatments.

	Wheat[a]	Canola	Barley	Field pea
Seed date				
April	167 a	140 a	113 b	134 a
May	139 b	54 b	156 a	118 b
Seed rate				
1X	197 a	155 a	129 a	141 a
1.5X	199 a	138 a	140 a	110 b

[a]Means followed by the same letter within a treatment and crop are not significantly different (P=0.05).

Spring compared with fall-applied fertilizer gave greater economic returns in both wheat-canola and barley-field pea rotations (Table 2). A reduction in herbicide dose to 0.5X of recommended resulted in greater economic return in wheat-canola and barley-field pea rotations.

Table 2. Contribution margin ($ ha^{-1}) for the fertilizer timing and herbicide dose treatments.

	Wheat-canola rotation[a]	Barley-field pea rotation
Fertilizer timing		
Fall	202 b	114 b
Spring	243 a	146 a
Herbicide dose		
0.5X	151 a	156 a
1X	98 b	105 b

[a]Means followed by the same letter within a treatment and crop rotation are not significantly different (P=0.05).

In conclusion, study findings indicate that several crop production practices are desirable in both agronomic and economic terms. Additionally, greater benefits may be realized by combining several beneficial cropping practices and by implementing these practices over several years. Competitive cropping systems allow more potential to reduce herbicide dose which may further increase economic returns to the farmer.

LITERATURE CITED

Blackshaw R.E., Semach G. and O'Donovan J.T. 2000. Utilization of wheat seed rate to manage redstem filaree (*Erodium cicutarium*) in a zero-tillage cropping system. Weed Technology, 14: 389-396.

Buhler D.D. 1999. Expanding the Context of Weed Management. Haworth Press, Binghamton, NY. 289 p.

Derksen D.A., Anderson R.L., Blackshaw R.E. and Maxwell B. 2002. Weed dynamics and management strategies for cropping systems in the northern Great Plains. Agronomy Journal, 94: 174-185.

Gill K.S., Arshad M.A. and Moyer J.R. 1997. Cultural control of weeds. *In* D. Pimental, ed. Techniques for Reducing Pesticide Use. Wiley, New York. pp. 237-275.

Liebman, M., Mohler, C.L. and Staver, C.P. 2001. Ecological Management of Agricultural Weeds. Cambridge University Press, Cambridge, UK. 532 p.

SAS. 1999. SAS/STAT User's Guide, Version 8. Statistical Analysis Systems Institute, Cary, NC. 3884 p.

Statistics Canada. 2003. Statistical Handbook 2003. Canada Grains Council, Ottawa, Canada.

Steel, R.G.D. and Torrie, J.H. 1980. Principles and Procedures of Statistics, 2nd ed. McGraw-Hill, New York. 633 p.

Weed component and control practices in some of annual upland crops in the North of Vietnam

N. H. Son*, N. V. Tuat and N. T. Tan
National Institute of Plant Protection, Vietnam
hanhson@hn.vnn.vn; tuat@hn.vnn.vn

Abstract: Some upland crops like maize, soybean and vegetables play an important role for farmers in the Northern part of Vietnam since these can bring them additional income in a very small farm. However, weeds are a major constraint in enhancing the production of these crops because there is a shortage of effective alternative control measures to replace conventional manual methods that are no longer suitable in the course of the country's industrialization and civilization. There has been a little survey systematic of weeds involved and their control techniques. This paper will review some results of research on the weed component, conducted by the National Institute of Plant Protection, as well as the popularity and efficacy of current control practices. It is hoped that this review will help farmers improve the effect of integrated weed management with the emphasis in new herbicides application.

Key words: Annual upland crops, integrated weed management

INTRODUCTION

Annual agricultural crops such as maize, soybean, ground nut and vegetables have been broadly cultivated or rotated with water rice in the delta and low land regions of North Vietnam. On the contrary, a recent program on restructuring of cropping system was introduced to the uncultivated upland areas in order to expand agricultural land and increase output per acre. Intercropping was also introduced the perennial upland monoculture orchards. However, weeds which had freely occupied the areas for a long time, strongly competed with the growth and production of the introduced crops. So far, there have been very few systematic surveys of weed status and their control in upland cultivated and uncultivated areas. Therefore, an intensive survey of the weed component and their severity and control in annual crop fields and orchards in upland regions of the four provinces in Northern Vietnam was carried out by the Pesticide and Weed Science Division, NIPP from 1996 – 2000. In addition, effectiveness of several herbicides and cultivation techniques were also tested.

MATERIALS AND METHODS

Weed component and severity

Investigations of weed component and severity covered 10 sites representing different crops, soil types and topography in four provinces, i.e, Ha Tay, Ha Bac, Lao Cai and Hoa Binh in North Vietnam. Five survey plots (50 x 50 cm) were randomly selected in selected annual crop fields or intercropping areas in the orchards before the growing season. These plots were kept free from any weed control practice throughout the cropping season. Weed species were recorded. Their abundance were evaluated following 4 levels from '+' to '++++' based on their densities (plants m^{-2}) or fresh weight (g m^{-2}).

Investigating and estimating farmers' weed control methods

A farmer survey was carried out at the study sites to collect data on their weed control practice and experiences. Subsequently the most effective control method was summed up according to their experience.

Effect of cultivation techniques for control of weeds in upland field

Cultivation techniques such as land ploughing, soil covering with plant debris and inter-cropping were experimented in both orchards and annual crops. Efficacies of herbicides were also tested in combination with cultivation techniques.

Application of herbicides to control weeds in upland fields

Several herbicides such as glyphosate, gramoxone, metolachlor, butachlor, sethoxydim, oxadiazon and fluazifop butyl were evaluated phytotoxity and bio-efficacy to select appropriate activities and their application options for each crop, as well as find ways integrating herbicides with manual control methods.

RESULTS AND DISCUSSIONS

Weed component and severities

Sixty-one weed species belonging to 20 botanical families were recorded. Among these, 35 species were recorded in upland rice, 29 species in plum plantation, 26 species in citrus plantation, 19 species in soybean and ground nut fields, and 28 species in maize fields (Table 1). The most popular among the recorded weeds belong to the families *Poaceae* and *Cyperaceae,* which included 23 and 10 collected weed species, respectively. Several species were found abundantly in almost every surveyed site and crop field such as *Sacchacum spontaneum*, *Paspalum conjugatum*, *Panicum repens*, *Eleusine indica*, *Imperata cylindrica*, *Digitaria adscendens, Sporobolus elongatus*, *Cyperus rotundus* and others. Weed species of families *Asteraceae*, Commellinaceae, *Lamiaceae, Amarranthaceae*, *Mimosaceae* were also found at considerable number.

Table 1. Weed component and severities in upland crops fields.

Family	Species	Weed severities in				
		Upland rice	Plum	Citrus	Soybean + ground nut	Maize
Poaceae	*Saccharum spontaneum* L.	++	+	+		
,,	*Saccharum officinarum* L.	++	++			
,,	*Eragrostis amabilis* Wight et Arn	++		+		
,,	*Panicum indicum* Linn.	+				
,,	*Ischaemum ciliare* Retz.		++	+++		
,,	*Paspalum conjugatum* Berg.			++	++	+
,,	*Paspalum orbiculare* G. Førster			+		
,,	*Panicum brevifolium* Linn.	+	+			
,,	*Panicum bisulcatum* Thunb.		+			
,,	*Panicum repens* Linn.	++	++	++	+	+
,,	*Cynodon dactylon* (L.) Pers			+	++	++
,,	*Imperata cylindrica* (L.) Beauv.	+	+++	++		
,,	*Chloris barbata* Sw.			++	+	+
,,	*Eleusine indica* (L.) Gaertn.	++			++	++
,,	*Digitaria adscendens* (H.B.K) Henr	+	+		++	++
,,	*Digitaria violascens* Link.			+		+

,,	*Digitaria timorensis* Presl Miq.	++	+			
,,	*Rottboellia compressa* Linn. f.	+		+		
,,	*Leptochloa chinensis* (L.) Nees				+++	++
,,	*Phragmites karka* (Retz) Trin.		++			
,,	*Echinochloa colonum* (L.)Link			+		+
,,	*Cyrtococcum patens* (Linn)	++	++			
,,	*Sporobolus elongatus* R. Br.	++			++	++
Cyperaceae	*Cyperus rotundus* Linn.	++	+	+++	+	++
,,	*Cyperus tenuispica* Steud	+	+			
,,	*Cyperus castaneus* Willd.	+	++			
,,	*Cyperus bancanus* Miq.	+				
,,	*Cyperus imbricatus* Retz	+	+			
,,	*Cyperus difformis* L.				+	++
,,	*Cyperus serotinus* Rott.	++	+			
,,	*Cyperus iria* L.					+
,,	*Fimbristylis miliaceae* (L.) Vahl	+	+			+
,,	*Fimbristylis diphylla* (L.) Vahl			+	++	++
Juncaceae	*Juncus Prismatocopus* R.Br.	+				
Oxalidaceae	*Oxalis corniculata* L.	+	+	+		+
Asteraceae	*Gynura pinnatifida* DC.					+
,,	*Eclipta alba* (Linn) Hassk				+	++
,,	*Calotis gaudichaudii* Gagnep	+				
,,	*Ageratum conyjoides* L.	++	+++	+++		
,,	*Xanthium atramorium*			+		
,,	*Bidens pilosa* L.	++	+++	+++		
Malvaceae	*Abutilon indicum* (L.) Sweet	+	+	+		
Lamiaceae	*Leucas zeylanica* R.Br	+++	+	+++		
,,	*Leucas aspera* (Willd) Link.	+++	+			
Fabaceae	*Tephrosia purpurea*			+		
Commellinaceae	*Cyanotis axillaris* (L.) Roem &	+	+++	++		
Apiaceae	*Centella asiatica* (L.) Urb.			+		
Polygonaceae	*Polygonum barbatum* L.					+
Solanaceae	*Physalis angulata* L.				+	++
Amaranthaceae	*Amaranthus viridis* L.	+	+	++	+	+
,,	*Amaranthus spinosus* L.				+	+
,,	*Celosia argentea* L.		+			
,,	*Alternathera sessilis* (L.) R. Br. ex	+			+	++
Euphorbiaceae	*Euphorbia thymifolia* L.				++	++
,,	*Euphorbia hirta* L.				+	++
Chenopodiaceae	*Chenopodium album* L.					+
Brassicaceae	Nasturtium indicum *(L.) Hiern*				++	++
Portulacaceae	*Portulaca oleraceae* L.	+		+		+
Mimosaceae	*Mimosa invisa* Mart	+++	++	++		
Moraceae.	*Cudrania cochinchinensis* (Lour.)	++	+			
Elaeocarpaceae	*Elaeocarpus syloestris* Poir.	+	+			

Weed control implemented by local farmers

Weed control techniques varied depending on farmers and crops. In general, weed control in annual crops in these upland regions still mainly depended on manual and/or hand weeding using simple labor tools such as hoes and hooks. Although hand weeding has many disadvantages, i.e., labor consuming, inefficiency to control perennial weeds and injury to crops which may lead to pathogen infection, it was implemented by 86.4 % of the surveyed farmers (Table 2). The number of farmers who used herbicides to control weeds accounted for only 4.2%. However, about 75.8 to 89.2% of the growers sprayed their crops at least once with herbicides in a cropping season. Cultivation techniques also considerably contributed in control of weeds in upland regions.

Table 2. The popular of weed control methods applied by local people.

Control methods	% Farmer Applied			
	Upland rice	Plum	Orange	Other food and food stuff crops
Hoeing	78.20	64.50	0.00	86.40
Cutting	0.00	48.40	57.90	0.00
Herbicide application	21.80	75.80	89.20	4.20
Grow inter row crop	0.00	0.00	60.80	29.40
Minimized tillage	20.20	0.00	0.00	26.40

Integration of herbicides to manual and cultivation techniques in weed control

Manual weeding, however, often brings about disadvantages such as labor shortage, crop injury, negative effects on inter-row crops and low efficacy to control perennial weeds. In this case, the substitution of cultivation techniques is more effective.

Tillage. Tilling carried out before inflorescence of weeds and/or growing season of the inter crops in the orchards proved to be very effective for control of weeds particularly the perennials. Herbicide application after tillage provided higher control effect on weeds and prolonged the effectiveness of applied herbicides (Table 3). The practice has shown that one time tilling including herbicide application every 2 months offered better weed control and was more economical than three herbicide applications or hand weeding. Fertilization at ploughing may favor crops to absorb nutrients for their fast growth to be able to compete with weeds.

Table 3. Long lasting of glyphosate applied with and without tillage to control weeds in citrus.

Herbicides	Bio-efficacy at 30 days after spraying (%)		Long lasting of product (days)	
	With tillage	Without tillage	With tillage	Without tillage
Lyphoxim 8l ha^{-1}	90.80	78.20	90	70
Roundup 5l ha^{-1}	92.60	82.50	100	75
Nufarm-Glyphosate 6l ha^{-1}	93.80	81.70	100	70
Farm 8l ha^{-1}	94.70	84.60	90	80

Soil covering with plant debris. In orchards, covering the soil with plant debris after cutting, followed by herbicide treatment, provided a good manner of killing perennial weed and strongly suppressed the re-growth of grass and broad leaf weeds (Table 4).

Inter row cropping. Growth competition of crops in inter-row cropping fields suppressed growth of weeds compared to monoculture system. Weed prohibition of 40 to 50% was recorded in inter row cropping of maize or cassava in orchard and sweet potato or cabbage in maize field experimented in Thanh Ha-Hoa Binh and Dan Phuong-Ha Tay during 1998– 999.

Selectivity and effectiveness of different herbicides on appropriate crop

In orchard. Herbicides have been introduced in upland regions only recently. However, their use has gradually become indispensable for weed control in orchards. The most active herbicide group in the upland area was glyphosate, which accounted for 34 commercial products. All four tested herbicides showed relatively high potential for killing weeds in orchards. The effect started at 7 days after application and peaked at day 35. On this day of observation, 90.8 to 94.7% of the young weeds were controlled. Though no injury was recorded in citrus and plum, the application of these herbicides should be carefully isolated from the mixed annual crops whose leaves may be burned.

Table 4. Effectiveness of soil cover on weed control.

Treatment	Duration to re-growth of weeds	Fresh weight of weeds at 3 month after treatment ($g\ m^{-1}$)			
		Grasses	Sedges	Broad leaf	Total
Weed cutting & non soil covered	25	821.5	532.6	1856.3	3210.4
Weed cutting + soil covered with its ground	40	678.3	318.5	1050.2	2047.0
Weed cutting - non soil covered–herbicide application	70	219.8	128.7	510.5	859.0
Weed cutting-soil covered–herbicide application	90	159.7	95.9	375.6	631.2

In upland rice field. Efficacies against weeds and safety towards crops of six tested herbicides depended on application technique and time. Sethoxydim proved to be the most effective herbicide, which killed 90% of small weeds less than 3 cm tall in upland rice field, and was safe to rice. Though two other products, namely butachlor and oxadiazon, were also safe to rice these could provide only 65 to 75% weed control. Glyphosate and metolachlor were found effective and safe when applied at 7 and 3 days, respectively, before sowing paddy.

In maize fields. Both metolachlor and fluazifop-butyl used at recommended dosage showed high selectivity for control of weeds though fluazifop butyl had less effect (64.4%) against grasses. When directly used, gramoxone proved advantageous in both low phytotoxity and high efficacy to control varied weed groups. Specially, this product can be used with grown up weeds and their grounds could be maintained as cover to minimize soil erosion.

In soya bean field. Although high efficacies were recorded in all 3 tested herbicides, only oxadiazon caused no phytotoxity to soya bean when applied immediately after sowing or 1 day latter. Oxadiazon has limited effect against sedges, but a wide spectrum of weed groups was found susceptible to metolachlor.

ACKNOWLEDGEMENT

We thank the Ministry of Agriculture and Rural Development (MARD) of Vietnam for sponsoring our research on weeds and their control in upland crops during the period of 1999-2002.

LITERATURE CITED

Hafliger E. and Scholz H. 1980, 1981, 1982. Grass weeds 1, Grass weeds 2, Monocot weed 3, Copyright by CIBA - GEIGY. Ltd, Basel, Switzerland.

Le Kha Ke et al. 1975. Weed occurred in Vietnam, Volume 1, 2, 3, 4, 5, 6, Ha Noi Science and Technique Publishing House.

Moody K. 1989. Weeds reported in rice in South and Southeast Asia. International Rice Research Institute, Los Banos, Philippines.

Noda K. 1986. Major weed in Thailand. National Weed Science Research Institute Project.

Pham H.H. 1993. Weeds flora in Vietnam - Book N^0 III, Volume 2, Montral Publishing house, pp. 810 – 812.

Nguyen T.T., Nguyen H.S. 1996. Weed survey in rice growing areas and weed control practice in upland rice. In Research Finding Collection of National Institute of Plant Protection, Vietnam.

Nguyen T.T., Nguyen H.S. 1998. Weed survey and control practice in some Citrus production areas of the North, Vietnam. In Research Finding Collection of National Institute of Plant Protection, Vietnam.

Zhang D. and Chen R. 1991. Encyclopedia of Chemical Weed Control on Farm Fand. China Import and Export Corporation of State Farms.

Weed management on rice, wheat, soybeans and cotton in China

Ze Pu Zhang
National Feed Quality Supervision and Test Center
Chinese Academy of Agricultural Sciences; Beijing 100081, China
ze_pu_zhang@msn.com

Abstract: Rice, wheat, soybeans and cotton are the main crops in China. These crops account for about 65% of the 114 million ha of the total cultivated areas in the mainland China. There are 580 species of weeds found in crop fields, About 35.8 million ha of cropland are heavily infested by weeds and the average annual reduction of crop yields is 13.4%. Since the early 1980s, along with rural economic development, chemical weed control became more important and attractive to farmers. The area applied with herbicide has been steadily increasing by approximate 2 million ha per year, from less than one million ha in the early 1970s up to more than 60 million ha in recent years. Chemical weed control has changed cultural practices, saved weeding labor and also raised the yields in rice, wheat, soybeans, cotton and other crops. However, the use of herbicides has caused residual phytotoxicity to succeeding crops, weed shift and weed resistance to herbicides. Weed management based upon chemical control by adopting various effective agricultural measures for maintaining favorable ecological conditions is the more effective measure.

Key words: Cotton, rice, soybeans, wheat, weed management

INTRODUCTION

There are 580 species of weeds found in the crop lands of China, about 35.8 million ha of crop fields are severely damaged, and the average reduction of crop yield is estimated at 13.4%. About 17.5 million t of grains, 500 thousand t of soybeans and 255 thousand t of lint cotton were lost by the most harmful weeds annually (Zhang 1991; Zhang 1996).

The rice growing regions are mainly distributed in the southern parts of China. More than 100 weed species infest in the paddy fields. The important species are: alligator alternanthera (*Alternanthera philoxeroides*), amphibious knotweed (*Polygonum amphibium*), barnyardgrass (*Echinochloa crus-galli)*, bur beggarticks (*Bidens tripartita),* chinese sprangletop (*Leptochloa chinensis*), climbing seedbox (*Ludwigia prostrata*), cow's hair-felt spikesedge (*Eleocharis yokoscensis*), difformed galingale *Cyperus difformis*), distinct pondweed (*Potamogeton distinctus*), dwarf arrow-head (*Sagittaria pygmaea*), flat-stalk bulrush (*Scirpus planiculmis*), Indian rotala (*Rotala indica*), knotgrass (*Paspalum distichum*), korsakow monochoria (*Monochoria korsakowii*), late juncellus (*Juncellus serotinus*), oldworld arrow-head (*Sagittaria trifolia*), procumbent false pimpernel (*Lindernia procumbens*), rice galingale (*Cyperus iria*), rush-like bulrush (*Scirpus juncoides*), sheathed monochoria (*Monochoria vaginalis*), water-plantain (*Alisma orientale*), yerbadetajo (*Eclipta prostrata*) etc. (Zhang 1989; Guan et al. 1993; Bernal & Itoh 2001). In general, the number of the major weeds in certain rice fields at the same time is usually less than 3-4 species.

About 15 million ha of paddy fields are heavily infested with weeds and the reduction of rice yield caused by weeds is 10-20%. Average rice yield loss might be about 10 million ᵗ annually. Before 1980's, the rice production was characterized by abundant labor supply. Along with rural economic development, chemical weed control became more important to farming people, annually increasing the area applied with herbicides to more than one million ha per year. The area applied with herbicide in paddy fields enlarged from 300,000 ha in 1960s to about 20 million ha in 2004. Butachlor, quinclorac, bentazon and bensulfuron are popularly used in recent years (Zhang 1994; Zhang 2001).

In the rice growing regions at the lower reaches of Yangtse river, the long term use of butachlor or thiobencarb in transplanted rice has resulted in the elimination of the dominant barnyard grass population and other grass weeds such as chinese sprangletop, knotgrass and the broadleaf weeds as dwarf arrow-head and alligator alternanthera or the sedges such as late juncellus and flat-stalk bulrush have become dominant.

The wheat growing regions are mainly distributed in the plains of North China. In northeastern and northwestern parts of China and the southern parts of China, about 10 million ha of wheat fields are heavily infested with weeds and the annual reduction of wheat yield reached 4 million t in recent.

In the northwestern and northeastern parts of China, spring wheat are infested with wild oat (*Avena fatua*), lambsquarters (*Chenopodium album*), goosefoot (*Chenopodium glaucum*), denseflower elsholtzia (*Elsholtzia densa*), field sowthistle (*Sonchus brachyotus*), lepyrodiclis (*Lepyrodiclis holosteoides*), field bindweed (*Convolvulus arvensis*), common knotweed (*Polygonum aviculare*) and setose thistle (*Cirsium setosum*). In the northwestern parts of China, wild oat is the most dominant weed causing a yield reduction of up to 50–60%. Triallate is applied by soil incorporation before seeding and diclofop-methyl or difenzoquat is used as a postemergence application to control this difficult weed. Currently, metsulfuron-methyl and fenoxaprop-ethyl are used on a large scale (Zhang 1989; Tu 1999).

In the southern parts of China, winter wheat in wheat-rice double cropping areas at the middle and lower reaches of Yangtse river are infested with American sloughgrass (*Beckmannia syzigachne*), aquatic myosoton (*Myosoton aquaticum*), Carolina geranium (*Geranium carolinianum*), chickweed (*Stellaria media*), common cirsium (*Cirsium segetum*), common vetch (*Vicia sativa*), equal alopecurus (*Alopecurus aequalis*) flixweed tansymustard (*Descurainia sophia*Schur), Iran Speedwell (*Veronica persica*), ivy-like calystegia (*Calystegia hederacea*), Japanese alopecurus (*Alopecurus japonicus*), keng stiff-grass (*Sclerochloa kengiana*), lyrate hemistepta (*Hemistepta lyrata*), Pennsylvania bittercress (*Cardamine hirsuta*), shepherdspurse (*Capsella bursa-pastoris*), sun spurge (*Euphorbia helioscopia*), tender catch-weed bedstraw (*Galium aparine* var. *tenerum*), water chickweed (*Malachium aquaticum*) and wild oat (Lou and Li 1994). These weeds are mainly controlled with chlorotoluron, dicamba, isoproturon, metsulfuron-methyl, chlorsulfuron and amidosulfuron (Tang et al. 1990).

In North China, winter wheat in wheat-maize or wheat-cotton double cropping areas are predominant infested with small goosefoot (*Chenopodium serotinum*), Japanese hop (*Humulus scandens*) and other *Chenopodium* spp., 2,4-D-butyl ester is popularly used for controlling these weeds (Tu 1999).

The main soybean growing regions are distributed in the northeastern parts of China and North China. About 2 million ha of soybeans fields are heavily infested with barnyardgrass, small goosefoot, black nightshade, common dayflower (*Commelina communis*), common elsholtzia, crabgrass, goose grass, cymose knotweed (*Fagopyrum dibotrys*), elsholtzia (Elshotzia ciliata), field horsetail (Equisetum arvense), field sowthistle, goosefoot (*Chenopodium aristatum*), goosegrass, green bristlegrass, Japanese hop, smartweed, knotweed (*Polygonum senticosum*), pigweed, lambsquarter, redroot amaranth, Siberian cocklebur (*Xanthium sibiricum*), wild oat, willowleaf knotweed and some perennial weeds. These cause yield reduction of 10-20% in soybeans. More than 500,000 t soybeans were lost by the most harmful weeds annually (Chen et al. 1991; Chen et al. 1994). Since 1978, the big state farms in Heilongjiang province began to import many new kinds of herbicides such as alachlor, linuron, trifluralin, amiben and metribuzin for pre-emergence application, resulting in the retention of the high yields of soybeans. Till now, highly selective herbicides such as bentazon, fomesafen, fluazifop-butyl, sethoxydim and diclofop-methyl are popularly used by post-emergence application for broadleaf or grass weed control (Chen *et al.*

1994). The total area of chemical control in the main soybeans growing regions is estimated at more than one million ha.

There are two main cotton growing regions in the plains of North China and the river basins at the middle and lower reaches of Yangtse river. The important species of weeds are crabgrasses (*Digitaria* spp.), goosegrass, barnyardgrass, green bristlegrass, burmudagrass, knotgrass, and some broadleaf weeds such as pigweed, smartweed, lambsquarter, and purple nutsedge (*Cyperus rotundus*).. About 2 million ha of cotton fields are heavily infested with these weeds and annual yield reduction of cotton is 10-15% resulting in a yield loss of 255,000 t of lint cotton. Trifluralin, butralin, alachlor, acetochlor, chlorotoluron diuron and oxyfluorfen are widely used for grass weed control. Glyphosate and paraquat are used for eliminating perennial weeds by placement spray at the late stage of cotton growth. Dymron applied by soil incorporation before cotton seeding for controlling purple nutgrass gives a satisfactory result. Sethoxydim, fluazifop-butyl, quizalofop-ethyl and haloxyfop are widely used for grass weed control (Zhang et al. 1999).

Chemical weed control has changed cultural practices, saved labor and retained high crop yields, meanwhile, continuous use of the herbicides on crops for a number of years caused residual phytotoxicity on crops, weed shift problem and resistant weed development (Huang *et al.* 1994). In the early 1990s, an integrated system of weed control was adopted by Chinese farmers in some areas. This weed management, based on herbicide application, adopted various effective agricultural measures for maintaining favorable ecological conditions to eliminate weeds from crop fields.

Deep ploughing in winter time

Deep ploughing the crop fields to a depth of 20-30 cm exposes the vegetative organs of perennial weeds to winter cold resulting in the freezing and drying of the underground organs. In paddy fields, one winter ploughing to a depth of 20-30 cm reduced the number of distinct pondweed plants up to 60%. Even if the fields were ploughed to a depth of 15-18 cm, the density of the weed population was reduced significantly (Zhang 1996). In cotton fields, winter deep ploughing to a depth of more than 20 cm, most overwinter tubers of purple nutsedge might be turned up to expose to the open air, when the winter temperature had decreased to -7^{0}C, the tubers would be killed by freezing in winter, and the remaining ones would be dried in drought spring; in cotton growing season, the density of nutsedge plants was reduced at 80-90%, and the density of tubers decreased at more than 70% in comparison with un-deep-ploughed fields (Zhang 1999).

Tillage before seeding or planting

In the growing season, about one month before sowing, first tillage might remove the perennial weeds; second tillage at two weeks before sowing promotes germination of weeds; a last tillage practiced at one to three days before sowing followed by leveling would eliminate weed emergence. More than only one harrowing, shallow cultivation can destroy weed seedlings and sprouts of annual weeds without turning up the weed seeds from deeper soil layer to the soil surface.

Land paddling and leveling in paddy fields

Paddling and leveling the soil after plowing may reduce the broadleaf weed emergence and keep uniform depth of water layer to submerge weed seedlings in transplanted rice fields.

Preventive weed control in rice seedbeds

Barnyard grass is the predominant weed in rice seedbeds. After the weed seedlings being transplanted with rice seedlings into paddy fields, they will compete with rice at the maximum tillering stage causing great reduction of rice yield. Preventive weed control for rice seedbed could be done through seed selection by using high quality rice seeds uncontaminated with weed seeds; high seeding rates used to suppress barnyard grass; .cleaning out weeds on field margins, irrigation water and implements to avoid spreading weed seeds or propagules from field to field; and eliminating barnyard grass in rice seedbeds with herbicides before transplanting rice seedlings into paddy fields (Zhang 1996).

Good water management for weed control

In water-seeding rice seedbeds, before sowing for a few days, irrigate the seedbeds to a water depth of 10-20 cm a water depth at about 10 cm after sowing. Drain the seedbed when the rice seeds are germinating. After most of the rice seedlings have emerged from the seedbeds again to a depth of 10-20 cm. Maintained the water layer until weed seedlings die.

In paddy fields, after rice transplanting, a deep water layer is maintained a depth of 10-20 cm for a considerably long time as possible in order to reduce infestation of annual weeds such as barnyard grass and other grass weeds.

Dense planting

In rice seedbeds, high seeding rates result in a significant reduction of broadleaf weed density; and in paddy fields appropriate plant closing integrated with good water management could enable rice plants to form a dense, uniform and vigorous colony, and shade weeds resulting good competition with weeds.

In wheat fields, high density and good growth vigor of crop plants might strengthen their ability to compete with weed plants (Tang et al. 1990).

Planting big seedling or hybrid rice

Planting big rice seedlings at the 5–6 leaf stage may raise the rice competitive ability with weeds. The leaf area index may increase about three times more than the younger seedlings two weeks after transplanting. Planting hybrid rice with the morphological type of long-stalked and great canopy reduces the plant height, leaf area index, plant dry weight, panicle length, tiller number and spikelets per panicle of barnyard grass significantly in transplanted rice. The competitive ability of hybrid rice with barnyard grass is more powerful than others of short-stalked and small canopy varieties. The yield components of indica rice with long-stalked and great canopy does not decrease markedly under barnyard grass interference of 50 plants sq m. (Xu & Yu 2000)

Cropping system

Double cropping of rice after wheat, oil-seed rape, barley, broad beans or other winter cropping crops is an effective cropping measure for reducing rice damage from perennial weeds.

Rotating rice with a upland crops such as maize, cotton, sweet potatoes, sesame or soybeans in the rice-wheat double cropping regions could break the life cycle of both the water tolerant and upland weeds. After two-year rotation of the paddy fields to upland condition, the infestations of dwarf arrow-head, Chinese sprangletop and barnyard grass in the rice and upland weeds such as common crabgrass and goose grass in the upland crops were reduced significantly, and Japanese alopecurus could be reduced in the succeeding winter wheat fields. (Zhu & Ma 1993)

LITERATURE CITED

Bernal E. and Itoh K. 2001. [World rice and herbicide resistance.]. In: *Herbicide Resistance and World Grains* (ed. by Powles S. B. and Shaner. D.L.). CRC Press, Boca Raton, London, New York, Washington, D.C. 199–200.

Chen T.B., Zhang Z.Y., Wang Y.M. and Cong L. 1991. Research on application of harmony for controlling weeds in soybean fields. J. Weed Sci., 5 (2), 31–32 (in Chinese).

Chen T.B., Yang X.Y., Zhang Z.Y. and Wang Y. 1994. Study on weed control effect of chlorimuron-ethyl in soybean fields. J. Weed Sci., 8 (2), 8–11 (in Chinese).

Guan G.Q., Teng N.W., Dong C.Q., Jin Z.W. and Huang Y.L. 1993. Most used paddy herbicides. In Identification and Control for Paddy Weeds (ed. by Guan G.Q. *et al.*). Liaoning Scientech Press, Shenyang, 213–266 (in Chinese).

Huang B.Q., Lin S.X., Xiao Z.Y. and Luo Y.P. 1994. Studies on resistance mechanism of barnyardgrass to butachlor and benthiocarb. J. Weed Sci., 8 (2), 1–5 (in Chinese with English abstract).

Lou Y.L. and Li Y.H. 1994. Studies on occurrence and population shift of weeds in rice-wheat fields in Lixia He region. J. Weed Sci., 8 (2), 17–22 (in Chinese with English abstract).

Tang H.Y., Wang X.E. and Shen G.H. 1990. Study on the yield loss of wheat and barley caused by the infestation of *Alopecurus japonicus* and *A. aequalis*. J. Weed Sci., 4 (1), 8–12 (in Chinese with English abstract).

Tu H.L. 1999. Research on weed population change in five main crops.]. Proceedings of the 6th Weed Science Conference of China – Sustainable Weed Management Towards the 21st Century in China (Nanning, China, March 29–April 2, 1999. Guangxi Nationality Press, Nanning, 9–15 (in Chinese).

Xu Z.H. and Yu L.Q. 2000. Ecological control of barnyardgrass by different morphological type rice. Chinese J. Rice Sci., 14, 125–128 (in Chinese with English abstract).

Zhang Z.P. 1989. Field weeds and their control in China. In Weed Problems and their Economic Management. Proceedings of the Symposium in the 12th Conference of Asian-Pacific Weed Science Society (Seoul, Korea, August 21-26, 1989. The Asian-Pacific Weed Science Society, Seoul, Korea, Chonnam University Press, Kwangju, Korea. 111–113.

Zhang Z.P. 1991. Field weeds and their control in China. J. Weed Sci., 5 (1), 44–47 (in Chinese).

Zhang Z.P. 1996. Developing chemical weed control and attaching importance to integrated weed management. In Proceedings of the National Symposium of IPM in China (ed. by Zhang Z.L., Piao Y.F. and Wu J.W.). China Agricultural Science and Technology Press, Beijing, 1110–1114 (in Chinese with English abstract).

Zhang Z.P., Hu X.E., Qian Y.X. and Yang X.Y. 1999. Studies on some biological characteristics of purple nutsedge and its control in cotton fields. Proceedings of the 17th Asian-Pacific Weed Science Society Conference (Bangkok, Thailand, Nov. 22 – 27, 2001). The Organization of The 17th Asian-Pacific Weed Science Society Conference, Bangkok, 276–281.

Zhang Z.P. 2001. Agricultural weeding in conjunction with herbicide application in rice. Proceedings of the 18th Asian-Pacific Weed Science Society Conference (Beijing, China, May 28 –June 2, 2001), Standards Press of China, Beijing, 211–214.

Zhu W.D. and Ma X.H. 1993. Effects of paddy-cotton rotation on weeds and weed community in cotton fields. J. Weed Sci., 7 (3), 5–10 (in Chinese with English abstract).

Herbicidal effect on the weed density and grain yield of wheat under zero versus conventional tillage regimes

N. U. Khan, G. Hassan, K. B. Marwat and N.Khan
NWFP Agricultural University Peshawar 25130, Pakistan
nukmarwat@yahoo.com

Abstract: Traditional farming normally involves intensive soil tillage as the main starting operation to eliminate weeds and prepare seedbed. However in the broader term, excessive tillage reduces soil organic matter content and exposes the soil to wind and water erosion leading to lower productivity. In addition exposure to light induces germination of the dormant weed seeds. Consequently traditional agriculture has increasingly relied on applied inputs to maintain or to increase productivity. Cultural as well as chemical weed control is a basic requirement for sustainable production. Different herbicides were evaluated in zero vs. conventional tillage regimes in wheat crop planted in rice-based cropping system during 2002-03 and 2003-04 at the Agricultural Research Institute, Dera Ismail Khan, Pakistan. Herbicides bromoxynil + MCPA (Buctril-M) and carfentrazone-ethyl + isoproturon (Affinity) were applied during the first year, while Buctril-M and 2, 4-Dichlorophenoxyacetic acid (2, 4-D) in combination with fenoxaprop-p-ethyl (Puma Super) and clodinofop-propargyl (Topik) were used during the second year. The experiments were predominantly infested with the broadleaf weeds i.e. *Convolvulus arvensis, Rumex dentatus, Medicago denticulata* and *Melilotus indica.* Weed density revealed significant differences for tillage operations, herbicides and their interaction. On two years average, zero tillage relatively showed lesser weed infestation than conventional tillage and had four times lesser weeds than tilled plots during both seasons. In interaction, herbicides showed significant decrease ($P \leq 0.05$) in weed infestation against weedy check under either tillage regime during both years. In grain yield, there were significant differences for chemical weed control measures and their interaction with tillage regimes, while tillage operations itself were non significant ($P \leq 0.05$). Buctril-M in no tilled plots produced higher and statistically at par yield with Affinity in conventional tillage during first year. During the second year, maximum and at par grain yield was recorded in plots sprayed with Buctril-M + Puma Super in conventional tillage and 2,4-D + Puma Super in zero tillage plots. There was no significant difference in yield of zero- and conventional tillage plots during both seasons. Weedy check had the lowest yield in either year of studies due to highest weed infestation. During the first year and in the end of the crop season, *Conyza stricta* appeared with heavy infestation only in zero tillage plots but not a single plant was observed in conventional tillage plots. It might be due to non-disturbance of deposited water borne seeds from the preceding rice crop, while in conventional tillage the disturbance exposed seeds to predation or buried them into deeper soil layers. Zero tillage with chemical weed control was more economical by eliminating land preparation expenditure and by saving farm machinery, water, energy, labour, enabling earlier planting and reducing weed competition.

Key words: No-till, rice-wheat cropping system, resource conservation technology (RCT), traditional tillage, weed flora, weedicides.

INTRODUCTION

Rice-wheat cropping system occupies 24 million ha of cultivated land in the Asian subtropics. Farmers practice this system on about 13 million ha in south Asia (Pakistan, Northern India, Nepal and Bangladesh) and in which 1.7 million ha are found in Pakistan. China has an additional 10 million ha of rice-wheat area. In Pakistan, the area under rice crop is 2.4 million ha (Khan et al. 2004). In Pakistan, productivity of rice-wheat system is low. One of the major causes of low wheat productivity in rice growing areas is late sowing due to the late harvest of fine rice crop. Sowing of wheat after mid November causes reduction in grain yield by one percent for each successive delay of one day, i.e., 35 kg ha^{-1} per day (Hobbs et al. 1988). Farmers make 3-4 ploughings and 2-3 plankings for land preparation and sowing of wheat crop after the harvest of rice. In addition, one irrigation of 4-acre inches is given before land preparation, which takes 2-5 weeks to become workable for land preparation practices due to preceding moisture. Occasionally late rains in standing paddy crop and excessive moisture in the soil further delay harvesting of rice, which ultimately delays wheat sowing, resulting in low yield. Another factor is that wheat if sown by broadcasting lead to much reduced seedling emergence. The situation is further worsening with continuous increase in the cost of production such as seed, fertilizer, pesticides, farm machinery, fossil fuel, water, energy, labor and wastage of time.

Reduced or no tillage, as part of integrated crop and weed management are collectively described as conservation tillage. It helps to increase productivity while using available water more effectively by promoting increased levels of soil organic matter and thereby increasing water retention. No-till also prevents soil erosion, reduces release of greenhouse gases from the soil, improves air quality and protects wildlife habitat and biodiversity (Anonymous 2004; Khan et al. 2004). Feldman et al. (1988), however, noticed that no-tillage builds up more diverse community of weed flora than minimum and conventional tillage regimes.

Fortunately, zero tillage technology, which is an important component of conservation agriculture, comprehensively meets the needs of the aforementioned problems like timely sowing, reduced cost of production and enhances wheat productivity (Aslam et al. 199, 1999; Khan et al. 2004). In zero tillage technology, seed is placed into untilled soil by opening a narrow slot, trench of sufficient width and depth for seed coverage (Phillips 1980). Zero tillage is a technology of raising crops like wheat successfully just after rice harvest without prior irrigation and land preparation (Khan et al. 2004). With zero-tillage technology almost all rice stubbles remain intact, but in conventional method of sowing wheat, due to ploughing and planking, most of them are destroyed. Zero tillage accelerates the stubbles decay process for stubbles, enhances the microbial activities in the soil and thus increases the fertilizer use efficiency.

Lesser weed infestation to the extent of 52% was observed in rice-based cropping system, which can be effectively controlled through herbicides in combination with closer row spacing in wheat researchers (Mann et al. 2004; Malik et al. 1998; Hobbs and Gupta 2002; Singh et al. 2002; Hassan et al. 2003c; Streit et al. 2003 and Khan et al. 2004) have observed effective weed control with herbicides in no-till wheat with increased yield. Khan et al. (2001), Khan et al. (2002) and Khan et al. (2003) also noticed significant chemical weed control in conventional tillage wheat and obtained increased yield. Saving in cultivation cost due to zero tillage ranged between Rs. 1500.00 to 2500.00 ha^{-1} depending upon soil type, farm size, saving in irrigation water and reduction in diesel use. The yield increased by 15-20% due to earlier planting and increased plant population. It is a big technical shift in rice-wheat cropping system; therefore it was imperative to determine the effect of herbicides in zero/conventional tillage technology on the weed flora and yield of wheat in rice based cropping system.

MATERIALS AND METHODS

Herbicides in combination with zero/ conventional tillage regimes were compared in wheat crop in a rice-based cropping system during 2002-03 and 2003-04 at the Agricultural Research Institute in Dera Ismail Khan, Pakistan. Herbicidal treatments (Table 1) were also compared with weedy check as sub-plots in a split-plot design with three replications. Cultivar Nasir-2K was sown in the end of October 2002 and 2003 in a sub-plot size of 10 x 3 m^2. Fertilizer was applied at 120-90-60 NPK kg ha^{-1}. All P, K and half N were applied before sowing and the remaining half N was applied at 1st irrigation. All the agronomic practices were equally adopted. During 2002-03, the herbicides i.e. bromoxynil + MCPA (Buctril-M) and carfentrazone-ethyl + isoproturon (Affinity) were sprayed after the emergence of weeds in a proper moisture condition. While Buctril-M and 2, 4-Dichlorophenoxyacetic acid (2, 4-D) in combination with fenoxaprop-p-ethyl (Puma Super) and clodinofop-propargyl (Topik) were used as post-em during second year. Data on weed density (m^{-2}) and grain yield (kg ha^{-1}) were recorded and were subsequently subjected by ANOVA and LSD under MSTATC computer programme (Bricker, 1991). The economic analysis for cost / benefit was run by computing the Marginal Rate of Return (MRoR) as suggested by Jan *et al.* (2004).

Table 1. Detail of treatments in zero vs. conventional tillage wheat.

S.No.	Trade Name	Common Name	Dose ha^{-1}
1.	Buctril-M 40 EC	bromoxynil + MCPA	1.50 L
2.	Affinity 50 WDG	Carfentrazone-ethyl + isoproturon	2.00 kg
3.	2, 4-D salt	2, 4-Dichlorophenoxyacetic acid	1.75 kg
4.	Puma super 75 EW	fenoxaprop-p-ethyl	1.25 L
5.	Topik 15 WP	clodinofop-propargyl	0.25 kg
6.	Weedy Check	-	-

RESULTS AND DISCUSSION

Weed Density

The infestation of the weeds *Convolvulus arvensis*, *Rumex dentatus*, *Medicago denticulata* and *Melilotus indica* was observed in both experiments during 2002-03 and 2003-04. In weed density, there were significant differences ($P<0.05$) for tillage operations, herbicides and their interactions (Tables 2 and 5). For two years, zero tillage relatively showed lesser weed infestation than conventional tillage and had four times lesser weeds than the tilled plots. Malik et al. (1998), Hobbs and Gupta (2002), Singh et al. (2002), Streit et al. (2003) Mann et al., 2004, and Khan et al. (2004) observed 30-52% lesser weed flora in no-till plots than conventional tillage. However, Feldman et al. (1988) noticed more diverse weed flora in no-tillage plots than minimum and conventional tillage regimes in wheat. In interaction, herbicides showed significant decrease ($P\leq0.05$) in weed infestation against weedy check under either tillage regime during both years. Both herbicides (Buctril-M and Affinity) showed significant decrease in weed infestation and at par weed control against weedy check regardless of tillage intensity during 2002-03. In 2003-04, the four herbicide mixtures, i.e., two broad leaf (Buctril-M & 2,4-D) and two narrow leaf (Puma super & Topik) also showed significant decrease in weed infestation and at par weed control against weedy check in either tillage regime. Hobbs et al. (1988), Aslam et al. (1991 / 1999), Hobbs and Gupta (2002), Singh et al. (2002) and Mann and Ashraf (2003) and Khan et al. (2004) have also recorded similar findings in zero/ conventional tillage practices for wheat in rice based cropping system.

In the first experiment during 2002-03 at earing of wheat crop, the weed *Conyza stricta* appeared with heavy infestation only in zero tillage plots but absolutely was not observed in tilled plots. The data on *Conyza stricta* population showed significant differences for tillage operations either under herbicides or weedy check (Table 4). On average, in no-till plots the *Conyza* population was 13.44 weeds m^{-2}. In interaction, both the herbicides and weedy check showed statistically at par population of *Conyza stricta* (12.67 to 14.33 weeds m^2) in zero tillage plots, while in conventional tillage plots the herbicides and weedy check manifested zero population of that weed. It is concluded that it might be due to conserving and non-disturbance of weed seed bank of deposited water-borne seeds from the preceding rice crop in zero till plots, while in conventional tillage regime the practices and disturbances exposed seeds to predation or buried them into deeper soil layers before germination. Feldman et al. (1988) also noticed more diverse weed flora in no-tillage plots than minimum and conventional tillage regimes in wheat.

Grain Yield

In case of grain yield (Tables 3 and 6), there were also significant differences for weed control treatments and their interaction with tillage operations, but tillage operations were non-significant ($P<0.05$) from each other during 2002-03 and 2003-04. During 2002-03, plots sprayed with Affinity (3631 kg ha^{-1}) had increased grain yield but were statistically at par with Buctril-M (3518 kg ha^{-1}). In interactions, Affinity with conventional tillage (3681 kg ha^{-1}) surpassed all the weed control measures, but was at par with Buctril-M, which may be due to its broad-spectrum weed control efficiency. Weedy check had shown the lowest and at par grain yield in either tillage regime. During 2003-04, all the herbicides mixtures were statistically at par and had more grain yield than weedy check. However, on average, plots sprayed with Buctril-M + Puma super (3577 kg ha^{-1}) had increased grain yield followed by 2,4-D + Topik (3572 kg ha^{-1}). In interactions, Buctril-M + Puma super with conventional tillage (3840 kg ha^{-1}) and 2,4-D + Puma super with zero tillage (3832 kg ha^{-1}) had maximum and statistically at par grain yield. The above two herbicide mixtures were statistically comparable with 2,4-D + Topik with conventional tillage (3727 kg ha^{-1}). Weedy check had the lowest grain yield and was comparable in either tillage regime. Streit et al. (2003) also observed that post-em weed control was generally better than that of pre-emergence weed control. The results corroborate the findings of Khan *et al.* (2001), Khan et al. (2002), Hassan et al. (2003a, 2003b & 2003c), Khan et al. (2003) and Khan et al. (2004) who also observed good weed control and increased wheat yield with herbicides.

It is concluded from our findings that many variables including tillage, timely sowing, fertilizer and seed placement contribute to productivity. With proper equipment and good crop management techniques, the above results assured that there is a good probability that yield will be equivalent or higher under zero tillage as compared to conventional tillage systems (Tables 3 and 6), saving 100% cost of land preparation. Zero tillage, as a resource conservation technology (RCT) integrated with chemical weed control, was also found more economical by saving time and specially expenditure on labor, land preparation and irrigation and economizing soil water which is limiting crop production factor. According to economic analysis (Tables 7 and 8) for cost / benefit, zero tillage showed more benefit including the herbicide expenditure due to production of equal or higher grain yield and also by 100% saving in land preparation costs. Development and dissemination of such resource conservation technology has been a timely intervention to reduce production costs, improve efficiency of natural resource management practices, benefit the environment, and exploit potential to improve living of the farming community.

Table 2. Herbicides effect on weed density in zero vs. conventional tillage wheat during 2002-2003.

Treatments	Weed Density (# m^2)		Means
	Conventional Tillage	Zero Tillage	
Buctril-M	2.87 c	2.00 c	2.44 b
Affinity	3.67 c	2.33 c	3.00 b
Weedy Check	25.33 a	9.33 b	17.33 a
Means	10.62 a	4.55 b	

Table 3. Herbicides effect on grain yield in zero vs. conventional tillage wheat during 2002-2003.

Treatments	Grain Yield (kg ha^{-1})		Means
	Conventional Tillage	Zero Tillage	
Buctril-M	3563 a	3472 a	3518 a
Affinity	3680 a	3581 a	3631 a
Weedy Check	2963 b	2892 b	2928 b
Means	3402	3315	

Table 4. Herbicides effect on *Conyza stricta* population in zero vs. conventional tillage wheat during 2002-03.

Treatments	*Conyza stricta* (# m^2)		Means
	Conventional Tillage	Zero Tillage	
Buctril-M	0.00 b	12.67 a	6.33
Affinity	0.00 b	13.33 a	6.67
Weedy Check	0.00 b	14.33 a	7.17
Means	0.00 b	13.44 a	

Table 5. Herbicides effect on weed density in zero vs. conventional tillage wheat during 2003-2004.

Treatments	Weed Density (# m^2)		Means
	Conventional Tillage	Zero Tillage	
Buctril M + Puma Super	2.00 c	1.00 c	1.50 b
Buctril M + Topik	2.00 c	1.00 c	1.50 b
2, 4-D + Puma Super	3.50 c	2.50 c	3.00 b
2, 4-D + Topik	3.50 c	2.50 c	3.00 b
Weedy Check	32.00 a	10.00 b	21.00 a
Means	9.00 a	3.40 b	

Table 6. Herbicides effect on grain yield zero vs. conventional tillage wheat during 2003-2004.

Treatments	Grain yield (kg ha^{-1})		Means
	Conventional Tillage	Zero Tillage	
Buctril M + Puma Super	3840 a	3313 d	3577 a
Buctril M + Topik	3537 bc	3450 cd	3493 a
2, 4-D + Puma Super	3465 cd	3832 a	3468 a
2, 4-D + Topik	3727 ab	3417 cd	3572 a
Weedy Check	3072 e	3003 e	3038 b
Means	3528	3403	

Means sharing a letter in common in the same column in all the tables do not significantly differ at $P<0.05$.

Table 7. Marginal Rate of Return (MRoR) in zero vs. conventional tillage wheat during 2002-2003.

Treatments	Grain Yield kg ha^{-1}	Variable Income (Rs.ha^{-1})	Costs that Vary (Rs. ha^{-1})	Savings (Rs. ha^{-1})	Net Benefit (3-4+5)
Buctril-M + Zero Tillage	3472	5090.00	-	+2875.00	7965.00
Affinity + Zero Tillage	3581	6180.00	-	+2100.00	8280.00
Buctril-M + Conventional Tillage.	3563	6000.00	725.00	-	5275.00
Affinity + Conventional Tillage	3680	7170.00	1500.00	-	5670.00
Weedy Check + Zero Tillage	2892	-710.00	-	+3600.00	2890.00
Weedy Check + Conventional Tillage	2963	0	0	-	-

Price of Buctril-M 1500 ml ha^{-1} @ Rs. 290 per pack of 500 ml.
Price of Affinity 2000 g ha^{-1} @ Rs. 600 per pack of 800 g.
Cost of Land Preparation = Rs. 3600 ha^{-1}.
Price of Wheat = Rs 10 kg^{-1}.

Table 8. Marginal rate of return (MRoR) in zero vs. conventional tillage wheat during 2003-2004.

Treatments	Grain Yield kg ha^{-1}	Variable Income ($Rs.ha^{-1}$)	Costs that Vary (Rs. ha^{-1})	Savings (Rs. ha^{-1})	Net Benefit Rs. (3-4+5)
Buctril-M + Puma super + Zero Tillage	3313	2410.00	-	+1650.00	4060.00
Buctril-M + Topik + Zero Tillage	3450	3780.00	-	+1848.00	5628.00
2, 4-D + Puma super + Zero Tillage.	3832	7600.00	-	+1655.00	9255.00
2, 4-D + Topik + Zero Tillage	3417	3450.00	-	+1853.00	5303.00
Buctril-M + Puma super + Conventional Tillage	3840	7680.00	1950.00	-	5730.00
Buctril-M + Topik + Conventional Tillage	3537	4650.00	1752.00	-	2898.00
2, 4-D + Puma super + Conventional Tillage.	3465	3930.00	1945.00	-	1985.00
2, 4-D + Topik + Conventional Tillage	3727	6550.00	1747.00	-	4803.00
Weedy Check + Zero Tillage	3003	-690.00	-	+3600.00	2910.00
Weedy Check + Conventional Tillage	3072	0	0	-	-

Price of Buctril-M 1500 ml ha^{-1} @ Rs. 290 per pack of 500 ml.
Price of Puma super 1250 ml ha^{-1} @ Rs. 490 per pack of 500 ml.
Price of Topik 250 g ha^{-1} @ Rs. 460 per pack of 112 g.
Price of 2,4-D 1750 g ha^{-1} @ Rs. 180 per pack of 450 g.
Cost of Land Preparation = Rs. 3600 ha^{-1}.
Price of Wheat = Rs 10 kg^{-1}.

ACKNOWLEDGEMENTS

The allocation of funds for this research by the Pakistan Agricultural Research Council, Islamabad under Agricultural Linkages Program, is gratefully acknowledged.

LITERATURE CITED

Anonymous. 2004. Water matters for sustainable agriculture: A collection of case studies. CropLife International pp.12.

Aslam M., Ahmad M., Hashmi N.I., Chatta M.Q. and Veen M.V. 1991. Zero-tillage wheat pilot production programme for the Punjab rice-wheat system. PARC, Islamabad, Pakistan.

Aslam M., Majid A. and Gill M.A. 1999. Zero-tillage wheat production technology: prospects and threats. J. Sci. Tech. Develop., 18(3), 17-23.

Bricker B. 1991. MSTATC: A microcomputer programme for design management and analysis of agronomic research experiments. Crop and Science Department, MSU East Lancing MI 48824, USA.

Feldman, Alzugaray, Torres and Lewis. 1988. Gap colonization by weeds in a wheat crop grown under different cultivation regimes. Weed Res., 38(1):35-45.

Hassan G., Khan H., Marwat K.B. and Khan M.A. 2003a. Studies on weed dynamics in soil seed bank of rice-based cropping system of Pakistan. Paper read at "First Int. Weed Sci. Conf. October 23-26, 2003 at Agril. Univ. Peshawar, Pakistan. Abst. No.26".

Hassan G., Saeed M., Khan H. and Marwat K.B. 2003b. Dormancy studies in some major weeds of rice-based cropping system of Pakistan. Paper read at "First Int. Weed Sci. Conf. October 23-26, 2003 at Agril. Univ. Peshawar, Pakistan. Abst. No.27".

Hassan G., Khan N.U., Khan S.U. and Khan H. 2003c. Efficacy of herbicides on weed density and grain yield of no till wheat. Paper read at "First Int. Weed Sci. Conf. October 23-26, 2003 at Agril. Univ. Peshawar, Pakistan. Abst. No.1".

Hobbs P.R., Mann C.E. and Buttler L. 1988. A perspective on research needs for rice-wheat rotation. In A.R. Klott, (Ed.) Wheat Production (pp.197-211). CIMMYT, Mexico.

Hobbs P.R. and Gupta R. 2002. Resource conserving technologies for wheat in the rice-wheat system. *In* Ladha (ed.) Improving the productivity and sustainability of rice-wheat system: Issues and Impacts. ASA Special Publications, ASA, Madison, Wisconsin, USA.

Jan H. Muhammad A. Ali, A. 2004. Studies on weed control in potatato in Pakhal Plains of Mansehra. Pak. J. Weed Sci. Res., 10(3-4):101-104.

Khan I., Hassan G. and Marwat K.B. 2002. Efficacy of different herbicides for controlling weeds in wheat crop-II. Weed dynamics and herbicides. Pak. J. Weed Res., 8(1-2):41-47.

Khan N. Hassan G., Marwat K.B. and Khan M.A. 2003. Efficacy of different herbicides for controlling weeds in wheat crop at different times of application-II Asian J. Plant Sci., 2(3):310-313.

Khan N.U., Khan S.U. and Hassan G. 2004. Herbicides effect on weed flora and grain yield of zero vs. conventional tillage wheat. Paper read at 4th Int. Weed Sci. Congr. (IWSC) June 20-24, 2004 Durban, South Africa. S13MT17P04, Abstt. No. 300.

Khan N.U., Khan S.U., Hassan G., Khakwani A.A. and Nawaz Q. 2001. Studies on chemical weed control measures in wheat (*T. aestivum* L.). Online J. Biol. Sci., 1(7):584-586.

Malik R.K., Gills G. and Hobbs P.R. 1998. Herbicide resistance—a major issue for sustaining wheat productivity in rice-wheat cropping system in the Indo-Gangetic Plains, RWC paper series 3, 36 pp., New Delhi India.

Mann R.A. and Ashraf M. 2003. Effect of resource-conserving tillage technology on weeds in wheat crop. Paper read at "First Int. Weed Sci. Conf. October 23-26, 2003 at Agril. Univ. Peshawar, Pakistan. Abst. No.5".

Mann R.A., Ashraf M. and Hassan G. 2004.Wheat establishment with zero-tillage for integrated weed management. Pak. J. Weed Sci. Res., 10(1-2)17-24.

Phillips S.H. 1980. No-tillage, past and present. In R.E. Philips, G.W. Thomas and R.L. Blevins (Ed.), No-tillage Research: research reports and reviews. Pp: 1-6. Lexington, University of Kentucky.

Singh S., Yadav A., Malik R.K. and Singh H. 2002. Long-term effects of zero tillage sowing techniques on weed flora and productivity of wheat in rice-wheat cropping zones of Indo-Gangetic plains. Proc. Int. Workshop, Hissar, India, 4-6 March 2002, CCSHA, Hissar, India Pp. 155-167.

Streit B., Rieger S.B., Stamp P. and Riccher W. 2003. Weed population in winter wheat as affected by crop sequence, intensity of tillage and time of herbicide application in a cool and humid climate. Weed Res., 43(1):20.

Integrated nutrient and weed management for higher production of tomato

A. K. Mukherjee, Sukanta Khanra, R. K. Ghosh and M. A. Sarkar
Department of Agronomy, Faculty of Agriculture
Bidhan Chandra Krishi Viswavidyalaya
Nadia-741252, West Bengal, India
sukanta.khanta@rediffmail.com

Abstract: A field experiment was conducted at 'C' Block Farm, Kalyani, West Bengal during the *rabi* season (2002-2003) on sandy clay loam soil pH 6.8, to study the efficacy of the chemical herbicides in combination with macro and micronutrients on the yield of transplanted *rabi* tomato cv. Abinash-II. The experiment was laid out in a split plot design with six nutrient management (recommended dose 150:100:80 kg ha^{-1} N, P_2O_5, K_2O respectively, NPK + Zintrac (70% Zn) at 0.6 l ha^{-1}, NPK+ Bortrac (15% B) at 2.5 l ha^{-1}, NPK + Seniphos (31% P, 5.6% Ca) at 5.0 l ha^{-1}, NPK+ Stopit (16% Ca) at 0.6 l ha^{-1}, NPK+ Zinphos (18.7% P, 14% Zn, 6.4% K) at 4.0 l ha^{-1}) placed on main plots and weed management (propaquizafop at 100 ml ha^{-1} at 2 days after transplanting, oxyfluorfen at 100 ml ha^{-1} at 20 days after transplanting, and weedy check) on sub plots, having three replications. Foliar applied nutrients were applied at 15 and 30 days after transplanting. The application of oxyfluorfen gave significantly higher yield (33.11 t ha^{-1}), which was closely followed by Propaquizafop (33.08 t ha^{-1}), than that of weedy check. Among the different nutrient management treatments Bortrac recorded higher production followed by Zintrac, Stopit, Seniphos, and Zinphos, in decreasing order. Bortrac (34.15 t ha^{-1}) and Zintrac (31.92 t ha^{-1}) treatments also showed significant higher fruit yields than NPK treated plots. Bortrac x propaquizafop showed significant influence on fruit yield. NPK + Bortrac in combination with propaquizafop gave the highest yield of tomato (39.66 t ha^{-1}).

Key words: Herbicide, nutrient management, tomato, weed management.

INTRODUCTION

Vegetable based industries are emerging as powerful engines for economic growth in rural India. Now the time has come to educate, enrich, and empower the farmers. A key step in their economic development will be to diversify their cereal-based production system to include more cash crops, including vegetables.

Vegetable fields are usually infested by wide spectrum of broad leaf weeds. Weeds take up 30-40 percent of plant nutrients from the soil, thus reducing crop yield (Mani and Gautam 1976). They also harbor insect pests and harmful microorganisms. Tomato is a wide spaced crop, requires intensive management and grown under irrigated condition so different weed species grow throughout the cropping season. One of the earliest management practices to improve productivity of tomato is weed management. Weeds can be controlled by the adoption of several methods including physical, cultural, chemical and recently biological. In most cases hand weeding is generally practiced to control weeds but it is tedious, time consuming and expensive because of high labor cost. In addition, non-availability of labor during weeding at time causes serious set back in timely weed control. Moreover, regeneration of some sedges and new flushes of weeds aggravate the weed problem.

Farmers tend to over fertilizer in vegetables resulting in the production of low quality fruits. In intensive cropping system with vegetables, a number of crops are grown each year on the same piece of land. Accordingly, the nutrient supply of each crop needs to be balanced through the use of macro and micronutrients. Vegetable production requires management of nutrient supply and optimum nutrient balance for higher production. Among the micronutrients, boron, zinc and manganese deserve special attention. A positive correlation has been observed between boron and flower number, number of abnormal flower and fruit weight. Reduced root growth, swollen hypocotyls and cotyledons, and cracking of tomato fruits are due to boron deficiency in high pH soil. Zinc deficiency is also aggravated by phosphorous application. Keeping these in view, the experiment was conducted to determine the effects of weed management and application of macro and micronutrients on tomato fruit yield.

MATERIALS AND METHODS

The field experiment was conducted during 2002 – 2003 *rabi* season at 'C' block Farm, Kalyani, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The farm is located very closely to the Tropic of Cancer, approximately 23.5^0N latitude and 89.0^0E longitude at 9.75 m above mean sea level. The experimental field is alluvial and has sandy clay loam soil. The soil has the following characteristics: pH 6.8, total N 0.059 %, available P_2O_5 18.05 kg ha^{-1}, available K_2O 180.85 kg ha^{-1}, available Zn 0.64 ppm, available B 0.70 ppm, available Ca 4.22 Ca mol (P^+) kg^{-1}. The experimental site has a sub-tropical humid climate with moderate temperature ranging from 24-37^0C. The annual rainfall ranges from 1300 mm to 1500 mm with much of the rainfall received in June to mid October. The relative humidity is high during monsoon and low during winter. The area can be categorized into three distinct phases, viz. i) winter or *rabi* season (November to February), (ii) dry and warm summer or pre-*kharif* season (March to May) and (iii) wet or *kharif* season (June to October). The experiment was laid out in 'split plot' design with two factors i.e. nutrient management (main plot) and weed management (subplot), replicated thrice. The net plot size of each sub-plot was 3 m x 3 m (9 m^2). Six nutrient management treatments consisting of different macro and micronutrients served as main plots as follows: N_1 = Recommended dose of N P K (150:100:80 kg ha^{-1} N, P_2O_5, K_2O) + Zintrac (70 % Zn) at 0.6 litre ha^{-1}, N_2 = Recommended dose of N P K+ Bortrac (15 % B) at 2.5 litre ha^{-1}, N_3 = Recommended dose of N P K + Seniphos (31 % P and 5.6 % Ca) at 5 litre ha^{-1}, N_4 = Recommended dose of N P K + Stopit (16 % Ca) at 160 ml ha^{-1}, N_5 = Recommended dose of N P K + Zinphos (18.7 % P, 14 % Zn, 6.4 % K) at 4 litre ha^{-1}, N_6 = Recommended dose of N P K (150:100:80 kg ha^{-1} N, P_2O_5, K_2O). The weed management treatments imposed in each sub plot are as follows: W_1 = Propaquizafop at 100 g ha^{-1} applied at 2 DAT, W_2 = Oxyfluorfen at 100 g ha^{-1} applied at 20 DAT, and W_3 = Weedy check.

RESULTS AND DISCUSSION

Weed flora

Different types of weed flora were observed in the experimental field during the course of experimentation. The most common weeds were *Cynodon dactylon, Digitaria sanguinalis, Echinochloa colona, Eleusine indica* (grasses), *Cyperus rotundus* (sedges), *Physalis minima, Chenopodium album, Melilotus alba, Amaranthus viridis, and Solanum nigrum* (broad-leaved weeds).

Dry weight of grass weeds at harvest

Weed management had significant effect on dry weight of grass weeds. Among the different weed management treatments, oxyfluorfen recorded the lowest dry weed weight (3.25 g m^{-2}) which significantly differed from other weed management treatments. Propaquizafop also significantly reduced grass weed population and dry weight at harvest. Nutrient management did not influence the dry weight of grass weeds. The interaction effect of nutrient management and weed management, however, was found to be significant. At all levels of nutrient management, weed management had a significant effect on dry weight of grass weeds. Among these oxyflourfen proved to be the best (Table 1).

Table 1. Effect of nutrient and weed management on dry weight (g m^{-2}) of grasses at harvest.

Weed management	Nutrient management						
	N_1	N_2	N_3	N_4	N_5	N_6	Mean
W_1	6.89	4.76	4.33	5.90	5.92	5.69	5.58
W_2	2.33	2.80	2.46	4.46	3.63	3.86	3.25
W_3	8.73	8.80	8.56	8.16	6.76	8.04	8.17
Mean	5.98	5.45	5.11	6.17	5.43	5.86	
	N	W	N × W	W × N			
S.Em (±)	0.503	0.367	0.908	0.890			
C.D. (0.05)	1.58	1.07	2.46	2.66			

Dry weight of sedges at harvest

Weed management similarly had a significant effect on the dry weight of sedges (Table 2). Lowest dry weight was recorded in oxyflourfen (14.24 g m^{-2}) and comparable with proquizafop. The weedy check had significantly higher sedge dry weight than oxyflourfen and proquizafop. Nutrient management did not influence on the dry weight of sedge weight. Interaction effect of nutrient management and weed management, however, was significant. At all levels of nutrient management, weed management had significant effect on sedge dry weight. Oxyflourfen effectively controlled the sedges.

Table 2. Effect of nutrient and weed management on dry weight (g m^{-2}) of sedges at harvest.

Weed management	Nutrient management						
	N_1	N_2	N_3	N_4	N_5	N_6	Mean
W_1	18.86	15.31	19.72	17.48	16.20	15.20	17.13
W_2	14.87	16.33	13.17	13.44	15.60	12.06	14.24
W_3	27.26	26.33	23.48	23.22	24.82	25.63	25.12
Mean	20.33	19.32	18.79	18.04	18.87	17.63	
	N	W	N × W	W × N			
S.Em (±)	1.26	1.14	2.73	2.56			
C.D. (0.05)	3.96	3.25	7.94	7.61			

Dry weight of broadleaved weeds at harvest

Table 3 shows that weed management significantly affected the dry weight of broad-leaved weeds. Lowest weed dry weight was recorded in oxyfluorfen (1.32 g m^{-2}). The weedy treatment had the highest broadleaved weed weight (6.65 g m^{-2}). Nutrient management alone did not significantly influence the broadleaved weed dry weight. Interaction effect of nutrient management and weed management was significant. Oxyflourfen was observed to control broadleaved weeds effectively.

Table 3. Effect of nutrient and weed management on dry weight (g m^{-2}) of broadleaved weed at harvest.

Weed management	Nutrient management						
	N_1	N_2	N_3	N_4	N_5	N_6	Mean
W_1	3.20	3.61	3.35	3.54	2.82	3.14	3.27
W_2	1.58	0.94	1.27	1.50	1.60	1.00	1.32
W_3	7.39	6.14	6.71	5.58	6.88	7.24	6.65
Mean	4.05	3.56	3.77	3.54	3.76	3.79	
	N	W	N × W	W × N			
S.Em (±)	0.527	0.387	0.950	0.936			
C.D. (0.05)	1.66	1.13	2.76	2.80			

Fruit yield

Fruit yield of tomato was significantly influenced by nutrient management (Table 4). Greater availability of nutrients favored the growth and yield attributing characters and ultimately fruit yield of tomato. Highest fruit yield (34.15 t ha^{-1}) was recorded when tomato was treated with Bortrac along with the recommended dose of NPK (N_2). This treatment also produced the highest number of fruits per plant and fruit weight. Bortrac (N_2), Zintrac (N_1) and Stopit (N_4) had significantly higher yield than the NPK treatment alone (N_6). Yield reduction (10.18 %) was observed in Zinphos (N_5) compared with Zintrac (N_1) which may have been caused by zinc aggravated by phosphorus application. Similar type of result was also observed by Ryan et al. (1967). Yield reduction was also observed in Seniphos (N_3) compared with Stopit (N_4).

Application of herbicide significantly increased fruit yield of tomato. Highest fruit yield (33.11 t ha^{-1}) was obtained from oxyfluorfen (W_2) followed by the propaquizafop (W_1) (33.08 t ha^{-1}). Significant yield reduction was observed in the weedy check due to greater crop weed competition. Fruit yield was highest under oxyfluorfen treated plot because weeds were controlled more efficiently than propaquizafop. This finding corroborates the work of Eaton et al. (1990), Dobrazanski et al. (1989), Nandal and Singh (1993), Abdel-Aal and El-haroun (1990). The interaction effect between nutrient management and weed management was statistically significant on fruit yield. At all the levels of nutrient management, propaquizafop (W_1) and oxyfluorfen (W_2) had comparable yields but significantly higher than the weedy check. Highest fruit yield (39.66 t ha^{-1}) was obtained from the interaction of Bortrac with propaquizafop (N_2 x W_1). Least fruit yield 21.48 t ha^{-1} was obtained with the combination of the recommended dose of NPK and the weedy check.

Table 4. Effect of nutrient and weed management on fruit yield (t ha^{-1}) of tomato.

Weed management	Nutrient management						
	N_1	N_2	N_3	N_4	N_5	N_6	Mean
W_1	32.17	39.66	30.71	34.21	30.07	31.61	33.08
W_2	34.05	32.67	36.49	32.71	32.79	29.99	33.11
W_3	29.56	30.12	24.61	26.39	23.17	21.48	25.89
Mean	31.92	34.15	30.60	31.10	28.67	27.62	
	N	W	N × W	W × N			
S.Em (±)	1.05	1.01	2.70	3.08			
C.D. (0.05)	3.30	2.94	7.86	9.36			

LITERATURE CITED

Abdel-Aal S. M. and El-Haroun M. S. 1990. Efficiency of some herbicides on weed control and yield of onion (*Allium cepa* L.) *Egyptian J. Agron.*, 15: 1-2, 35-44.

Dobrzanski A., Anyszka Z. and Palczynski J. 1989. Oxyfluorfen (Goal 2E) for weed control in vegetable crops grown from transplants. *Biuletyn-Warzywniczy*, No. 2, Supplement, 139-143.

Eaton W., Coffey D. L., Mullins C. A. and Rhodes G.N. Jr. 1990. Weed control with oxyfluorfen in transplanted broccoli. *Tennessee Farm and Home Sclence*, No. 154: 17-21.

Mani V. S. and Gautam K. C. 1976. A national strategy for weed control. Pesticides, 10(6): 15.

Nandal T. R. and Singh A. K. 1993. Relative efficacy of herbicides for weed control in seed crop of okra (*Abelmoschus esculentus* (L.) Moench.). Integrated weed management for sustainable agriculture. *Proceedings of an Indian Society of Weed Science International Symposium,* Hisar, India, 18-20 November 1993, Vol. III, 213-215.

Ryan P., Lee J. and Peebles T.F. 1967. Trace element in relation to soil units in Europe. (Working party on soil classification and survey of the European Commission on Agriculture). F. A. O. of the United Nation. Rome, World Soil Resources, Report 31.

Effect of integrated weed management in chickpea (*Cicer arietinum*) + mustard (*Brassica juncea*) intercropping system under rainfed condition

G. Sounda* S. S. Mondal, Mithun Saha, S. S. Nayek and P. Mondal
Department of Agronomy,Bidhan Chandra Krishi Viswavidyalaya
Mohanpur, Nadia, West Bengal
shyam_mondal2003@yahoo.co.in

Abstract: The study was carried out to evaluate the effect of integrated weed management in chickpea (*Cicer arietinum* cv.Mahmaya) + mustard (*Brassica juncea* cv. Bhagirathi) intercropping system under rain-fed condition. The experiment was conducted during 2003-2004 in *rabi* season at Instructional Farm, Jaguli, B.C.K.V. The experiment was laid out in Randomized Block Design with nine treatments, replicated thrice. The predominant weed flora composed of, *Chenopodium album*, *Anagalis arvensis*, *Melilotus alba*, and *Asphodelus* sp., weas present in the experimental field. Application of pendimethalin at 0.75 kg a.i ha^{-1} or fluchloralin at1.5 kg a.i. ha^{-1} along with one hand weeding at 45 DAS was highly effective in controlling weed. Higher weed control efficiency (43.44) of chickpea and mustard was obtained with the application of fluchloralin at 1.5 kg a.i. ha^{-1} along with one hand weeding at 45 DAS. The result revealed that fluchloralin at 1.5 kg ai. ha^{-1} along with one hand weeding at 45 DAS produced significantly higher seed yield of chickpea (1957 kg ha^{-1}) and mustard (537 kg ha^{-1}) which was followed by pendimethalin at 0.75 kg a.i ha^{-1} along with one hand weeding at 45 DAS. Both herbicides produced no adverse effect on nodule formation of legume crops.

Key words: Chick pea, fluchloralin, intercropping, pendimethalin, mustard, weed control efficiency.

INTRODUCTION

Intercropping has been recognized as a potential system where all the growth factors like light, water, nutrients and space are utilized more efficiently than monoculture system. The system also provides an immense scope to control weed more efficiently and economically. Mustard, being a widely spaced crop with slow growth and limited lateral spread in the initial stages, provides opportunity for growing chickpea as intercrop. The suppression efficacy depends largely on the nature of the component crops in an intercropping system. A quick growing component crop with enough canopy may be suitable for this purpose. Very little work has been reported on weed management in general intercropping system or pulse based intercropping system. Therefore, this study was carried out to evaluate the effect of integrated weed management in chickpea (*Cicer arietinum*) + mustard (*Brassica juncea*) intercropping system under rain-fed condition.

MATERIALS AND METHODS

The experiment was conducted during 2003-2004 *rabi* season at Instructional Farm, Jaguli, B.C.K.V. The experiment was laid out in Randomized Block Design with nine treatments, replicated thrice. The soil of the experimental field was sandy clay loam with medium available N (0.07), available P_2O_5 (28.4 kg ha^{-1}), available K_2O (132.5 kg ha^{-1}). The varieties used in the experimentation were Mahamaya-1 for chickpea and Bhagirathi for mustard. Three herbicides combined with hand weeding were evaluated in inter cropping system.

RESULTS AND DISCUSSION

Weed flora

During the crop season the predominant weed flora composed of *Chenopodium album, Anagalis arvensis*, *Melilotus alba*, and *Asphodelus* sp. was present in the experimental field.

Effect of herbicide on weed and crop

Application of pendimethalin at 0.75 kg a.i ha^{-1} or fluchloralin at 1.5 kg a.i. ha^{-1} along with one hand weeding at 45 DAS was highly effective in controlling weeds (Table 1). Higher weed control efficiency (43.44) of chickpea and mustard was obtained with the application of fluchloralin at 1.5 kg a.i. ha^{-1} along with one hand weeding at 45 DAS. The findings corroborated the report of Varsney (1997). The result revealed that fluchloralin at 1.5 kg a.i. ha^{-1} along with one hand weeding at 45 DAS produced significantly higher seed yield of chickpea (19.57 q ha^{-1}) and mustard (5.37 q ha^{-1}) which was followed by pendimethalin at 0.75 kg a.i ha^{-1} along with one hand weeding at 45 DAS. The results are in conformity with the findings of Arya (2004). Significantly higher dry weight of nodules and leaf area index of chickpea were recorded with the application of fluchloralin at 1.5 kg a.i. ha^{-1} along with one hand weeding at 45 DAS as compared to weedy check.

Application of fluchloralin at 1.5 kg a.i. ha^{-1} or pendimethalin at 0.75 kg a.i. ha^{-1} along with one hand weeding at 45 DAS was found to be superior in controlling weeds and did not produce any adverse effect on growth characters as well as root nodules under chickpea + mustard intercropping system in rain-fed condition.

Table 1. Effect of weed control treatments on growth parameters, dry weight of weeds, root nodules, weed control efficiency and seed yield of both the crops in inter cropping system

Treatment	Leaf area index	Dry weight of root nodules (mg)	Dry weight of weed m^{-2} (g)		Weed control efficiency	Seed yield	
			60 DAS	At harvest		Chickpea q ha^{-1}	Mustard q ha^{-1}
Weedy check (sole chickpea)	1.8	108.5	7.3	9.3		10.59	
Weedy check (inter cropping)	2.1	128.6	5.03	7.8	16.12	10.68	2.50
Two hand weeding (25, 45 DAS)	2.2	142.0	4.82	7.2	22.58	12.09	3.23
Pendimethalin @ 0.75 kg a.i ha^{-1}	2.4	172.5	3.7	6.5	30.10	14.72	4.61
Pendimethalin @ 0.75 kg a.i ha^{-1} + 1 HW at 45 DAS	2.7	177.6	3.20	5.79	37.74	17.38	4.80
Metolachlor@0.50 kg a.i. ha^{-1}	2.2	150.2	4.3	7.03	24.40	15.49	3.92
Metolachlor @ 0.50 kg a.i. ha^{-1} + 1 HW at 45 DAS	2.5	160.6	4.01	6.31	32.15	18.82	4.37
Fluchloralin @ 1.5 kg a.i. ha^{-1}	2.30	175.8	3.40	6.20	33.5	17.73	4.79
Fluchloralin @1.5 kg a.i. ha^{-1} + 1HW at 45 DAS	2.8	184.3	3	5.26	43.44	19.57	5.37
CD (P= 0.05)	.03	5.4	0.31	0.80		2.08	1.53

LITERATURE CITED

Varsney J.G. 1997. Effect of mulches and solarization on weed infestation in rainfed chick pea. Annual Report. 1996-97. Indian Institute of pulse Research, Kanpur. Pages 56-57.

Arya R.L. 2004. Integrated weed management in chickpea (*Cicer arietinum*) + mustard (*Brassica juncea)* intercropping system under rainfed condition. Indian Journal of Agronomy, 49(2): 98-100.

Rotation and tillage effects on Roundup ready canola (*Brassica napus*) persistence in the seed bank

R.E. Blackshaw[1], K.N. Harker[2], G.W. Clayton[2], J.T. O'Donovan[3], E.N. Johnson[4], Y. Gan[5], G. P. Lafond[6], R.B. Irvine[7]
[1]Agriculture and Agri-Food Canada, Lethbridge, Alberta, Canada T1J 4B1
blackshaw@agr.gc.ca
Agriculture and Agri-Food Canada Research Centres, [2]Lacombe, [3]Beaverlodge, [4]Scott, [5]Swift Current, [6]Indian Head, [7]Brandon, Canada

Abstract: Roundup Ready (RR) canola is widely grown in Canada. Concerns exist about the management of volunteer plants in subsequent years. A field study was conducted over four years at eight locations in Canada to determine the effect of various crop rotation and tillage systems on the emergence and seed bank persistence of RR canola. Rotations consisted of continuous cropping versus alternating crop and fallow years. Tillage consisted of conventional, minimum, and zero tillage. A known amount of RR canola seed was broadcast on the soil surface in the fall of 2000 and volunteer canola populations were monitored in three subsequent years. RR canola in the soil seed bank was determined at the conclusion of the experiment. Tillage compared with zero tillage often encouraged earlier and greater emergence of RR canola plants the following spring. However, persistence over time increased slightly with tillage and may be related to induction of secondary dormancy. Inclusion of fallow in the rotation did not decrease persistence compared with continuous cropping. The majority of volunteer RR canola emerged in the first year after canola production with only small populations present in the second year. Soil seed bank data at the conclusion of the study indicated that only 0.1% viable RR canola seed was present three years after canola production.

Key words: Canola, herbicide resistant crops, seed bank, seed persistence, volunteer crops.

INTRODUCTION

RR canola (*Brassica napus*) was introduced in 1996 and is currently grown on over 2 million ha annually in Canada (Canola Council of Canada 2001; Stringham et al. 2003). Farmers chose RR canola because it offered markedly better weed control at similar or lower costs and postemergence glyphosate was a good fit in zero tillage production systems (Derksen et al. 1999; Harker et al. 2000). Of course, the biggest reason for adoption is that farmers are realizing greater profits from RR canola (Canola Council of Canada 2001).

Harvest losses of canola can be quite large (Bowerman 1984; Gulden et al. 2003); thus farmers are often confronted with the task of controlling volunteer canola in succeeding crops. Control of volunteer RR canola in subsequent years is usually successfully accomplished using herbicides such as 2,4-D or bromoxynil. However, concerns exist over the number of years that control of volunteer RR canola may be required.

A field study was initiated at eight locations across the major canola growing region of Canada to determine the effect of various crop rotation and tillage systems on the emergence and seed bank persistence of RR canola.

MATERIALS AND METHODS

A field experiment was conducted over four years at eight locations representing the major soil types and climatic conditions of the major canola regions in Canada to determine the effect of various crop rotation and tillage systems on the emergence and seed bank persistence of RR canola. Rotations consisted of continuous cropping versus alternating crop and fallow years. Tillage consisted of low disturbance seeding (LDS) (zero tillage), high disturbance seeding (HDS) (no tillage before planting but utilizing V-shaped sweeps on the seeding equipment), and conventional tillage (CT) (tillage the previous fall and immediately before planting spring crops). Additionally, the LDS treatment was conducted at three spring seed dates (early, normal or late) to better assess environmental effects on RR canola emergence. Early, normal and late seed dates were late April, mid-May, and late-May to early June, respectively.

Volunteer RR canola was controlled before planting following crops with 2,4-D at 560 g ai ha^{-1} in the LDS treatments and with tillage in the HDS and CT treatments. Additionally, 2,4-D and tillage were used to control canola in chemical fallow and tilled fallow, respectively. Commercial mixtures of bromoxynil:MCPA at 280:280 g ai ha^{-1} in barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*), and imazethapyr:imazamox at 15:15 g ai ha^{-1} in field pea *(Pisum sativum)*, were applied in-crop to control volunteer canola. All herbicides were applied with small plot sprayers delivering 100 L ha^{-1} at 205 kPa.

A known amount of RR canola seed (770 seeds m^{-2}) was broadcast in October, 2000. Volunteer RR canola populations were counted in twenty randomly placed 0.25 m^2 quadrats per plot a) before planting, b) before applying in-crop herbicides, c) before harvest, and d) post harvest in each of three subsequent years. Additionally, RR canola in the soil seed bank was determined at the conclusion of the experiment. Twenty-five soil cores (8 cm diameter by 10 cm deep) were randomly collected from each plot, bulked, air-dried, placed in polyethylene bags and stored for 3 months at 1 C. Seed determinations were conducted using three cycles of the greenhouse emergence method outlined previously (Blackshaw et al. 2000).

RESULTS AND DISCUSSION

Volunteer RR canola populations averaged over the eight field locations in the three subsequent years after canola production are presented in Figure 1. Conventional tillage compared with LDS often encouraged earlier and greater emergence of RR canola plants the following spring. However, persistence over time increased slightly with tillage and may be related to induced secondary dormancy (Gruber et al. 2004; Pekrun and Lutman 1998). Inclusion of fallow in the rotation did not decrease persistence compared with continuous cropping.

The majority of volunteer RR canola emerged in the first year after canola production (2001) with only low densities present in the second year (2002) (Figure 1). Volunteer RR canola densities tended to be greatest at the pre in-crop herbicide assessment date; thus farmers need to make control of volunteer RR canola populations a priority at this time of the growing season. RR canola emerging in July and August did not produce viable seed before the onset of killing frosts in September and October. No volunteer RR canola plants occurred in the third year after canola production (2003).

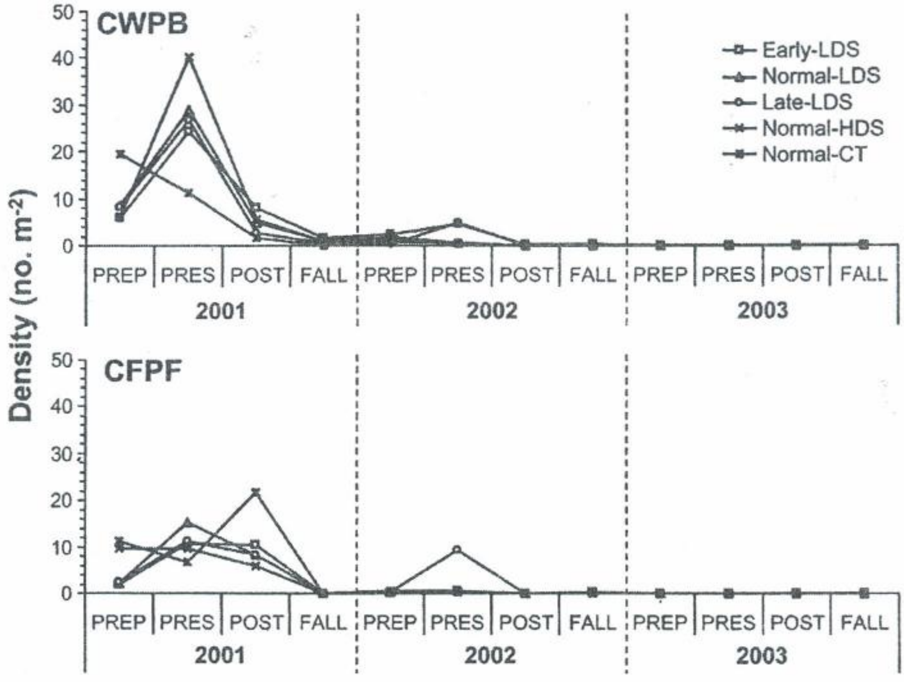


Figure 1. Mean volunteer Roundup Ready (RR) canola populations averaged over eight locations as affected by various crop rotations, tillage systems, and seed dates in three subsequent years after RR canola production. C = canola; W = wheat; P = field pea;

B = barley; F = fallow; PREP = preplant; PRES = before in-crop herbicides; POST = post in-crop herbicides; and FALL = post harvest (October).

Seed bank determinations of RR canola at the conclusion of the study indicated that several locations had no viable RR canola seed in the soil. Averaged over the eight locations, there was only 0.1% viable RR canola seed present three years after canola production (data not shown).

In conclusion, study findings indicate that farmers can expect the majority of volunteer RR canola plants to be present in their fields the first year after growing canola and densities will likely be sufficiently high to warrant control measures in most situations. However, volunteer RR canola densities in the second year after canola production were much lower and may only require targeted control measures if marketing concerns exist over the possibility of canola seed being present in the harvested crop.

LITERATURE CITED

Blackshaw, R.E., Semach, G.P. and O'Donovan, J.T. 2000. Utilization of wheat seed rate to manage redstem filaree (*Erodium cicutarium*) in a zero-till cropping system. Weed Technology, 14: 389-396.

Bowerman, P. 1984. Comparison of harvesting methods of oilseed rape. Aspects of Applied Biology, 6: 157-165.

Canola Council of Canada. 2001. An agronomic and economic assessment of transgenic canola. http://www.canola-council.org

Derksen, D.A., Harker, K.N. and Blackshaw, R.E. 1999. Herbicide tolerant crops and weed population dynamics in western Canada. Proc. Brighton Crop Protection Conference – Weeds – 1999, United Kingdom. pp. 417-424.

Gruber, S., Pekrun, C. and Claupein, W. 2004. Population dynamics of volunteer oilseed rape (*Brassica napus* L.) affected by tillage. European Journal of Agronomy, 20: 351-361.

Gulden, R.H., Shirtliffe, S.J. and Thomas, A.G. 2003. Harvest losses of canola (*Brassica napus*) cause large seedbank inputs. Weed Science, 51: 83-86.

Harker, K.N., Blackshaw, R.E., Kirkland, K.J., Derksen, D.A. and Wall, D. 2000. Herbicide-tolerant canola: weed control and yield comparisons in western Canada. Canadian Journal of Plant Science, 80: 647-654.

Pekrun, C. and Lutman, P.J.W. 1998. The influence of post-harvest cultivation on the persistence of volunteer oilseed rape. Aspects of Applied Biology, 51: 113–118.

Stringham, G.R., Ripley, V.L., Love, H.K. and Mitchell, A. 2003. Transgenic herbicide tolerant canola – the Canadian experience. Crop Science, 43: 1590-1593.

Weed management in integrated rice + fish + poultry farming system

RM. Kathiresan*, R. Anbhazhagan and S.P.Padmapriya
Department of Agronomy, Annamalai University
Annamalainagar, Tamilnadu, INDIA – 608 002
rm.kathiresan@sify.com

Abstract: Integration of farming elements offer multiple benefits such as diversified farm productivity, enhanced economic and dietary standards of resource poor farmers, enriched soil fertility status, and employment generation. Besides these advantages, farming systems approach also offers scope for using the component elements as bio-control agents for sustainable management of weeds and pests in cereal-based small holder farms. Studies at Annamalai University, Department of Agronomy reveal that integrating fish culture compliments weed control by 19.95 % and poultry rearing by 17.52 % in transplanted rice. Among the herbivorous fish species, grass carp exhibited a more voracious feeding habit on all the three types of weeds, viz., sedges (31.82% biomass reduction), grasses (33.17% biomass reduction) and broad leaf weeds (28.75% biomass reduction) compared with common carp and tilapia. This integrated farming system of rice + fish + poultry was also compatible with rice weed control measures, producing additive response in terms of weed control and enhanced grain yields. Rice herbicide oxyfluorfen at 0.25 kg ha^{-1} performed better in reducing weed competition and favoring rice yield in integrated rice + fish + poultry farming system.

Key words: Bio-agents, integrated farming system, rice weed control

INTRODUCTION

Rice had always been a compulsory crop rather than an optional one for farmers in the coastal rice tracts of India. The whole tract on the eastern coast extending from West Bengal to Cape Comerin of Tamil Nadu and that on the western coast comprising Kerala and Karnataka depend on monsoon rains as the main source of irrigation, wherein the distribution of rainfall is irregular with heavy down pour during a particular and shorter period of the year leading to inundation and flooding. Further, drainage of water into the sea also becomes difficult during these periods as the sea backlashes with heavy tidal incursions. Added to this situation, most of these rice tracts have heavy textured soil types, making water percolation difficult. All these result in stagnation of water during the cropping seasons of these tracts. Among the choices of crops for cultivation, rice alone has the unique feature of withstanding water stagnation for a longer period; all other crops die within a very shorter period of water stagnation. Thus, the farmers of these regions are compelled to grow rice during the cropping seasons, despite the fact that the economic margin from rice is very little and even inadequate to support their livelihood. They are also undernourished due to poor economic status, underemployment and unemployment.

Diversification of agricultural activities, which links farm-based enterprises with cultivation, would help the farmers to get more income and generate additional employment. The farming system approach was observed as a resource management strategy for achieving economic and sustainable agricultural production to meet the diverse requirement of farm household while preserving the resource base and maintaining high environmental quality.

The herbivorous feeding habits of many fish species in intensive rice cum fish culture has been reported to offer the opportunity of an ideal biological weed control. Several weed species were effectively controlled by fish culture. Further, poultry waste has been reported to be detrimental to pests and weed infestation in many crops. Hence, the integration of fish + poultry in rice may help sustainable weed management. At the same time, the impact of use of herbicides on these component enterprises needs to be studied and documented.

MATERIALS AND METHODS

Studies regarding the impact of herbivorous fish species on rice weeds were taken up under green house condition. Cement pots with dimension 60 cm x 45 cm x 45 cm were procured with necessary provisions at the bottom for slow and safe draining of water. These pots were filled with water up to ¾th of the height. Fingerlings of uniform size (10 cm long) from different species as listed in the treatment schedule were released in these pots @ six per pot. Every morning, 10 g of cut leaves and stem of different weed species as listed in the treatment schedule were added to the water in the pots for feeding by the fish fingerlings. The fish fingerlings were transferred to pots exclusively kept for transfer purposes in the next morning for a short while. Afterwards, the treatment pots were drained slowly and the weed biomass left over (after feeding by the fish for 24 hrs) were gathered and weighed. The weight reduction in weed biomass due to feeding by fish fingerlings were computed in comparison with a control, where in the same quantity of weed biomass was added to water in another pot without any fish. The fish species tried were mainly herbivores, viz., grass carp (*Ctenopharyngodon idella*), tilapia sp (*Sarotherodon niloticus*) and common carp (*Cyprinus carpio*). Weeds for experimentation were selected in such a way to represent all the three morphological groups, viz., grasses, sedges and broad leaf weeds. They were *Echinochloa* sp., *Eclipta alba* and *Cyperus rotundus*, respectively.

The impact of poultry waste on rice weeds was studied through a micro plot experiment conducted at Annamalai University Experimental Farm. The soil was clayey loam and the treatments comprising an unweeded control, half the quantity of poultry waste (worked out from average poultry droppings that was added to unit area of rice field in integrated rice + fish + poultry unit during last season) i.e. 3.9 g day^{-1} m^{-2}, normal rate of poultry voiding i.e. 7.8 g day^{-1} m^{-2} and double the rate of poultry voiding i.e. 15.6 g day^{-1} m^{-2}, and addition of these rates of poultry manure followed by herbicide butachlor 1.25 kg ha^{-1}, were compared in microplots of 1 m^2 area. The treatments were replicated thrice in randomized block design. Observations included weed biomass and weed control index.

The field experiment was conducted to evolve a wholistic weed control programme for rice + fish + poultry farming system 2003 and 2004 Annamalai University Experiment Farm. The field unit consisted of individual treatment plots, 6.5 m x 6.2 m. In all the treatments, trenches of 1 m depth and 0.65 m width were dug using 10% of the total area under rice to serve as a permanent shelter for fish fingerlings that moved out into the field in the morning and evening. Irrigation was scheduled to fill the trenches and maintain 5 cm depth of water in the field throughout the crop duration. Poultry sheds, 3 in x 2.5 in x 4 in were installed in all the plots, which were supported by concrete poles on all the four sides. The length of the concrete poles was eight ft of which four feet were buried into the soil and remaining half protruded above the soil. For the treatments that consisted pressmud application, pressmud at l0 t ha^{-1} was incorporated into the respective plots during field preparation. The recommended fertilizer dose of 150 kg N, 50 kg P_2O_5, and 50 kg K_2O was applied for all the treatment plots except for pressmud applied plots where the nutrients supplement through pressmud was deducted from the fertilizer dose. The entire doses of fertilizers were applied as basal. The rice cultivar Bapatla was transplanted using 25 days old seedling at a spacing of 20 cm x 10 cm. Missing hills were replanted at 7 DAT, using the seedlings of same age. Azolla was inoculated in the respective treatment plots @ 1 t ha^{-1} one week after transplanting. The treatments were unweeded control, hand weeded twice, pressmud (10 t ha^{-1}) + azolla at (1 t ha^{-1}), butachlor (1.5 kg ha^{-1}), anilophos (0.75 kg ha^{-1}) and oxyfluorfen (0.25 kg ha^{-1}). The herbicides were sprayed using 500 L ha^{-1} of spray fluid and a high volume knapsack sprayer fitted with flood jet deflector nozzle at 12 psi of pressure. The fingerlings of common crop, tilapia and grass carp at 12 of each were released in each trench 12 days after herbicide spraying. Vencob broiler birds were reared in cages, 4 birds cage^{-1}. Observations included weed count, weed dry matter and grain yield.

RESULTS AND DISCUSSION

Percentage reduction in the biomass of weeds was recorded and presented in Table 1. Among the three fish species grass carp was the most voracious feeder contributing significantly higher biomass reduction in the three weed species, viz., 33.17 % of *Echinochloa* sp., 31.82 % of *C. rotundus* and 28.75 % of *E. alba*. Poly culture combinations involving grass carp proved to be voracious in reducing weed biomass in magnitudes next to grass carp alone. However, these combinations were superior to individual as well as combinations involving common carp and Tilapia (excluding grass carp). Tilapia alone had the least feeding magnitude and weed biomass reduction: 15.48 % of *Echinochloa*, 14.00 % of *C. rotundus* and 14.59 % of *E. alba*.

Table 1. Percentage reduction in biomass of weeds.

Fish species	Biomass reduction %		
	Echinochloa sp	*Cyperus rotundus*	*Eclipta alba*
Grass carp	35.17 (33.17)	34.34 (31.82)	32.42 (28.75)
Tilapia	23.17 (15.48)	21.97 (14.00)	22.46 (14.59)
Common carp	28.23 (22.37)	27.17 (20.86)	25.10 (18.00)
Grass carp & Tilapia	27.29 (21.02)	26.42 (19.80)	24.14 (16.73)
Grass carp & common carp	32.03 (28.13)	30.12 (25.18)	28.51 (22.78)
Tilapia & common carp	26.89 (20.46)	25.65 (18.74)	23.59 (16.01)
Grass carp, Tilapia & common carp	29.10 (23.65)	27.72 (0.86)	27.77 (21.71)
Control	-	-	-
SE_D	0.72	0.70	0.68
CD (P=0.05)	1.45	1.40	1.37

Figures in parenthesis are original values

Grass carp has been reported to be non-specific on floristic composition, preferring a wide range of submerged plants (Jana and Choudhari 1983). Grass carp is a quick growing fish living on water plants preferring succulent submerged difficult to control weeds and its flesh was highly priced in China (Dahama 1996). These reports conform with the present finding of more voracious feeding habit of grass carp compared to common carp as well as Tilapia. This could be due to its inherent genetic growth potential and demanding intake requirements and co-incidence of bio-chemical constituents of weeds that are inducing the feed preference of the fish.

Weed control index was highest (54.98 %) in the double voiding rate of poultry manure along with herbicide application (Table 2). However, this treatment was on par with the normal voiding rate of poultry manure along with herbicide. These treatments were significantly superior over the other treatments. Application of butachlor controlled the early emergence of weed, while addition of poultry manure in a slower and phased manner contributed to suppression of weeds that emerged after the decline of herbicidal persistence, thereby reducing the weed DMP.

Table 2. Effect of poultry manure on weed dry matter production (kg ha^{-1}) and weed control index (%).

Treatments	Weed DMP at 60 DAT (kg ha^{-1})	WCI (%)
T_1 – Control	1090.12	-
T_2 – 3.9 g day^{-1}	1015.47	15.17 (6.85)
T_3 – 7.8 g day^{-1}	968.19	19.53 (11.18)
T_4 – 15.6 g day^{-1}	920.36	23.24 (15.57)
T_5 – butachlor alone	693.61	37.09 (36.37)
T_6 – T_2 + butachlor	569.97	43.69 (47.71)
T_7 – T_3 + butachlor	537.46	45.40 (50.70)
T_8 – T_4 + butachlor	490.72	47.86 (54.98)
SE_D	35.57	2.10
CD (P=0.05)	71.14	4.20

Figures in parenthesis are original values

In the field experiment, the weed flora comprised predominantly of *Leptochloa chinensis, Marsilea quadrifolia, Sphenoclea zeylanica* and *Cyperus iria* where as *Echinochloa colona, Bergia capensis, E. alba, Fimbristylis littoralis* and *C. rotundus* occurred rarely in negligible proportions. Least weed DMP of 124.96 kg ha^{-1} was recorded in oxyfluorfen @ 0.25 kg ha^{-1} (T_6), which was significantly superior over the other treatments (Table 3). Butachlor @ 1.5 kg ha^{-1} (T_4) and anilophos @ 0.75 kg ha^{-1} (T_5) treatments were on par with each other. The unweeded control (T_1) registered highest weed DMP, 550.23 kg ha^{-1}. Oxyfluorfen, being a protox inhibitor herbicide causing membrane damage and cell death due to blockage in psi and formation of AOS (active oxygen species), successfully controlled emerging and established weed seedlings with a wide spectrum of activity covering many species including the perennial *M. quadrifolia,* while, the other herbicides were active on emerging seeds and seedlings of annuals alone and failed to effectively control the perennial *Marsilea* and already emerged seedlings of other annual species. This contributed to the superior performance of oxyfluorfen over the other two herbicides, viz., anilophos and butachlor. This conforms to the earlier reports of Baradhan et al. (1995) and Kathiresan and Gurusamy (1996). Weed control index of 77.29 (Table. 3) was observed to be higher in oxyfluorfen @ 0.25 kg ha^{-1} (T_6), which was significantly superior over the rest of the treatments. Because of the lesser number of weed population and lesser weed DMP, this treatment recorded the highest weed control index.

Table 3. Effect of different weed control treatments on weed characters and grain yield of rice in rice + fish + poultry farming system.

Treatments	Weed DMP (kg ha^{-1})	Weed control index (%)	Grain yield (t ha^{-1})
T_1 – Unweeded control	550.23	-	3.16
T_2 – Hand weeded twice	251.34	47.48 (54.32)	4.02
T_3 - Pressmud @ 10 t ha^{-1} + Azolla @ 1 t ha^{-1}	341.48	38.15 (37.93)	3.59
T_4 - butachlor @ 1.5 kg ha^{-1}	180.52	55.05 (67.19)	5.09
T_5 - anilophos @ 0.75 kg ha^{-1}	204.76	52.41 (62.79)	4.56
T_6 - oxyfluorfen @ 0.25 kg ha^{-1}	124.96	61.53 (77.29)	5.63
SE_D	15.83	1.31	0.19
CD	31.65	2.61	0.39

Figures in parentheses are original values before arc – sine transformation

LITERATURE CITED

Baradhan G., Thiruvarasan E. and Kathiresan R.M. 1995. Integrated weed management in direct sown rice. In Abstract of papers, VI Bienn. Conf. ISWS, Annamalainagar, Tamilnadu, p.26.

Dahama A.K. 1996. Organic farming for sustainable agriculture. Agro Botanical Publishers, India, p. 128.

Gunasekaran A.S. and RM. Kathiresan 2003. Integrated weed management in rice + fish + poultry farming system. Nineteenth Asian Pacific Weed Science Society Conference, 17-21, Mar 2003. Manila, Philippines. pp. 115-121.

Jana S. and M.A. Choudhari. 1983. Aquatic weed problems in West Bengal, India. Weeds Today, 14(1): 9.

Kathiresan RM. and A. Gurusamy. 1996. Herbicide tolerance in rice cultivars. In : Abstract of papers, second International Weed Control Congress, Copenhagen, 3: 955-962.

Seed set control of wild radish (*Raphanus raphanistrum*) using a blanket wiper

A. Cheam[1]*, S. Lee[1], R. Vargas[1], B. Rayner[1], J. Peirce[1], D. Lemerle[2], E. Koetz[2], and A. Storrie[3]
[1]Department of Agriculture Western Australia, South Perth, Australia 6151
[2]New South Wales Department of Primary Industries, Wagga Wagga, Australia 2650
[3]New South Wales Department of Primary Industries, Tamworth, Australia 2340
*acheam@agric.wa.gov.au

Abstract: The use of a blanket wiper for applying the herbicides paraquat and glyphosate by wiping them directly onto the wild radish plants growing above a lupin crop canopy was investigated in Western Australia. The research aimed mainly to identify the best timing to obtain maximum seed set prevention of wild radish as part of an integrated programme for managing this aggressive weed, which is currently being recognised as the worst broadleaf weed of Australian agriculture. It was shown that the best control of wild radish seed set occurred when the weed was at early flowering and pod development stage before formation of the embryo in the developing seed. The degree of control decreased after embryo formation. Identification of this criterion has been found to be a valuable tool to farmers in facilitating decisions where timing of control measures is critical in the seed set management of wild radish. Despite the inevitable yield loss of the crop due to herbicide damage, seed set prevention is an effective investment in future weed control.

Key words: Blanket wiper, seed set, wild radish.

INTRODUCTION

Wild radish (*Raphanus raphanistrum* L.) is a very important weedy species worldwide and is the principal broadleaf weed in Australian agriculture (Cheam and Code 1995; Alemseged et al. 2001). In Western Australia, the worst wild radish problem is encountered. It is an aggressive weed of widespread occurrence causing severe reductions in crop yield and quality. In recent years, herbicide resistance in wild radish is becoming increasingly common in Australia (Preston et al.. 1999), especially Western Australia. Populations resistant to Groups B, C, F and I herbicides have been documented (Cheam et al.2003; Walsh et al. 2004). As the number of viable herbicide options diminish, there is an urgency in the need to control its seed production to prevent the return of viable seeds to the seed bank. This is especially critical if farmers are to maintain crop production in areas now infested with resistant wild radish, as well as in other areas where resistance is not yet evident to delay the build-up of resistance.

In this paper, we report the use of a blanket wiper for applying the desiccant herbicides paraquat and glyphosate for controlling wild radish seed set. The principle of weed wiping is not new because herbicide-impregnated wipers have been in use for some time to control tall weeds which grow above the crop or pasture. While blanket weed wipers have a role to play in controlling tall weeds, their performance on wild radish in a lupin crop however, has not been adequately investigated. A thorough investigation is considered necessary because the growing of lupins in Western Australia has been building up the wild radish numbers very quickly. At the same time it increases the risk to herbicide resistance because of the limited in-crop herbicide choices against wild radish in lupins.

MATERIALS AND METHODS

The aim of this experiment wais to determine the effectiveness of seed set control of wild radish using blanket wiping with desiccant herbicides on different maturity stages of wild radish growing in a lupin crop. At the same time, the extent of crop damage, if any, was evaluated.

Prior to the blanket wiping work, four stages of wild radish development were identified for the herbicide treatments. These were:

Stage 1: Early flowering and pod development with newly-formed thin pods.
Stage 2: Pods green and soft, seed development at ovule stage without embryo.
Stage 3: Pods still green and watery, presence of newly-formed embryo in developing seed.
Stage 4: Pods turned woody, presence of well-developed embryo in seed.

The herbicide treatments included paraquat (Gramoxone 250) at 800 mL ha^{-1} (200 g ai ha^{-1}) and 4 L ha^{-1} (1000 g ai ha^{-1}) and glyphosate (Roundup CT) at 1.0 L ha^{-1} (450 g ai ha^{-1}) and 5 L ha^{-1} (2250 g ai ha^{-1}). The high rates of paraquat and glyphosate were included with the aim of preventing the regeneration of wild radish.

The experimental design was a randomised complete block with four replicates of 17 treatment combinations including an unsprayed control. The treatment combinations included four herbicide treatments at four timings of application corresponding with the four growth stages of wild radish development. The plot size for each treatment combination was 3 m by 20 m to accommodate the 2 m width of the blanket wiper.

Samples of the treated wild radish plants were harvested at the end of the season to determine viable seed production. The lupin crop was harvested to determine grain yields.

RESULTS AND DISCUSSION

The data in Table 1 confirmed that the two most effective timings to blanket wipe coincided with stages 1 and 2 of wild radish development before the formation of embryo in the developing seed.

Table 1. Per cent seed set control of wild radish at four timings of blanket wiping.

Herbicide	Time of blanket wiping in relation to wild radish stages			
	Stage 1	Stage 2	Stage 3	Stage 4
Gramoxone 800 mL	100	72.0	50.0	19.1
Gramoxone 4 L	100	83.6	37.3	20.1
Roundup 1 L	100	88.7	38.0	16.2
Roundup 5 L	100	84.2	40.3	19.7
LSD (P = 0.05): Herbicide x time = 3.3				

At stage 1, 100 per cent seed set control was achieved irrespective of herbicide treatment. At stage 2, seed set control ranged from 72 to 89 per cent. The later the growth stage of wild radish at the time of blanket wiping, the poorer was the seed set control. At stages 3 and 4, up to 50 and 20 per cent seed set control, respectively, were achieved. The most critical stage to control seed set of wild radish is therefore before formation of the embryo in the developing seed. This is a robust criterion for determining seed set control timing in wild radish. The presence or absence of embryo can be easily determined in the field by breaking up the pods between the nails of the thumb and forefinger to expose the developing seed. The window of opportunity for applying seed set control measures has been found to be quite favourable based on side-studies involving the tagging of wild radish flowers to monitor embryo development. The pre-embryo stage lasts on average one month from the time of first flower. Based on embryo development, this new rating system has been found to be a highly valuable tool to farmers in facilitating decisions where timing of control measures is critical in the seed set management of wild radish. Of the two chemicals, Roundup gave better control than Gramoxone at the lower standard rate of application, with no subsequent regeneration of wild radish.

Setbacks of this technique included the escape from treatments of wild radish plants that were below the crop canopy at the time of blanket wiping and the recovery of Gramoxone-treated plants. Crop damage by both herbicides is still an issue as shown in the lupin yield data (table 2). The more damaging effects of Roundup than Gramoxone was evident, especially at the high rate. This could be attributed to the lack of recovery of the crop following damage by the Roundup, which is a translocated herbicide. The damage was most severe at the earliest application timing, with 61.5% yield loss.

Table 2. Lupin yield (t ha^{-1}) following blanket wiping at four growth stages of wild radish. Per cent yield loss compared to control is shown within brackets.

Herbicide	Stage 1	Stage 2	Stage 3	Stage 4
Gramoxone 800 mL	1.50 (17.6)	1.29 (29.1)	1.35 (25.8)	1.53 (15.9)
Gramoxone 4 L	1.54 (15.4)	1.26 (30.8)	1.41 (22.5)	1.71 (6.0)
Roundup 1 L	1.23 (32.4)	1.31 (28.0)	1.26 (30.8)	1.63 (10.4)
Roundup 5 L	0.70 (61.5)	1.13 (37.9)	1.12 (38.5)	1.15 (36.8)
Yield of untreated 1.82 t ha^{-1}				
LSD (P = 0.05): Herbicide x time = 0.20				

Crop damage by blanket wiping could be attributed to several reasons. Even after all precautions have been taken to set wiper above the crop canopy, crop damage is still inevitable because not all the crop plants are of uniform height. This is despite ensuring that wiping is done when the height difference between weed and crop is at a maximum, within the recommended 20-30 cm difference. Further, the wiper pushes weeds into contact with the crop leading to herbicide contacting the crop or herbicide dripping off the weeds onto the crop. Dripping is a particular problem with wipers when the herbicide flow is not carefully controlled. Despite these setbacks, blanket wiping still has a place in the integrated management of weeds, especially when there is a vast difference in height between weeds and crops. Timing is critical, as illustrated in this study. The technique has been successfully used for controlling tall-growing weeds in pasture (Rayner 1995; Rayner and Peirce 1996). Improvement on the design of the various wiping machines to minimise crop damage is ongoing.

ACKNOWLEDGEMENTS

We thank the Department of Agriculture Western Australia and the Cooperative Research Centre for Australian Weed Management for funding this research. We also thank Mr Zulkifli and Ms Majewski for providing competent technical assistance.

LITERATURE CITED

Alemseged Y., Jones R.E. and Medd R.W. 2001. A farmer survey of weed management and herbicide resistance problems of winter crops in Australia. Plant Protection Quarterly, 16: 21-25.

Cheam A.H. and Code G.R. 1995. The Biology of Australian Weeds 24. *Raphanus raphanistrum* L. Plant Protection Quarterly, 10: 2-13.

Cheam A., Lee S., Nicholson D. and Clarke M. 2003. Managing a biotype of wild radish (*Raphanus raphanistrum*) resistant to diflufenican and triazines. Proceedings19th Asian-Pacific Weed Science Society Conference, Manila, pp. 766-772.

Preston C., Roush R. and Powles S. 1999. Herbicide resistance in weeds of southern Australia: why are we the worst in the world?. Proceedings 12th Australian Weeds Conference, Hobart, pp. 454-459.

Rayner B.J. 1995. Wiping out tall weeds. Journal of Agriculture Western Australia, 36 (1) 4th Series: 18-19.

Rayner B.J. and Peirce J.R. 1996. Weed control in Western Australia using blanket wipers. Proceedings 11th Australian Weeds Conference, Melbourne, pp. 66-68.

Walsh M.J., Powles S.B., Beard B.R., Parkin B.T. and Porter S.A. 2004. Multiple-herbicide resistance across four modes of action in wild radish (*Raphanus raphanistrum*). Weed Science, 52:8-13.

Herbicide and tillage effects on weed control in Cavalcade (*Centrosema pascuorum* cv. Cavalcade)

R.J.Eastick*, N.J.Hartley, M.N.Hearnden, C.C.Martin
Northern Territory Department of Business, Industry and Resource Development
Darwin, Australia, 0801
rowena.eastick@nt.gov.au

Abstract: Cavalcade (*Centrosema pascuorum* cv.Cavalcade) is the most commonly grown legume for hay and pasture in northern Australia. Weed invasion, particularly by broadleaf weeds, which are difficult to control with selective in-crop herbicide, is a major production constraint in this crop. An experiment was conducted over two years to evaluate 11 herbicide treatments in Cavalcade, sown using conventional tillage in the initial year, and sown using either conventional or no-till practices in the subsequent year. Cavalcade, broadleaf weed and grass weed biomass were measured early and late in the growing season to determine herbicide efficacy on weed control, and, in the second year, the interaction with tillage treatment. There was a significant herbicide effect in the initial year, where results showed that the imidazolinone herbicides, particularly imazethapyr applied pre-emergence, significantly reduced weed biomass. There were significant herbicide and tillage main effects on weed biomass in the second year, although effects varied with weed category and time of biomass harvest. Generally, the use of no-till practices reduced both broadleaf and grass weed yields from the conventionally tilled treatments. These results contributed to the development of an integrated weed management strategy utilising chemical and cultural control methods for Cavalcade production systems in the Northern Territory.

Key words: Cavalcade, extension, herbicide, imidazolinone, mulch, tillage.

INTRODUCTION

The major legume species grown for hay and pasture in the Northern Territory (NT), Australia, is *Centrosema pascuorum* cv. Cavalcade. Weed invasion, particularly by broadleaf weeds, which are difficult to selectively control with in-crop herbicides, is a major constraint to production, reducing yields and decreasing quality and subsequent saleability. Cavalcade is a relatively recent introduction to agriculture in northern Australia, and the world, and its use had been limited prior to the mid-1990s due to low seed availability and unfamiliarity with the species (Cameron 2005). As demand for a Cavalcade industry increased, there was a need to evaluate suitable herbicides for efficient weed control in Cavalcade. There had been few previous studies on weed management strategies, and no herbicides were registered for use in this crop.

Plot trials preceding this experiment had identified a number of potentially suitable herbicides (Eastick unpublished data). The most promising was imazethapyr, a broad-spectrum herbicide that controls many annual and perennial broadleaf and grass weed species when applied pre- or post-emergence (Curran et al. 1992). The majority of early literature on imazethapyr considered efficacy in soybean and peanut crops in the United States. There was no literature available on herbicide use in Cavalcade, or on imazethapyr efficacy in the NT, and more information was required about efficacy on different weed species, how this varied between pre- and post-emergent applications, and its phototoxicity to Cavalcade under a range of conditions. Other potentially suitable herbicides were imazapic and imazamox, in the same imidazolinone group and with similar crop use as imazethapyr, and diflufenican and pendimethalin.

However, chemical control practices are only one method in a suite of weed control options, and it is recognised that sustainable production systems should be based on an integrated weed management strategy, including practices such as reduced tillage methods, mulch management, and crop rotation. Cultivation is commonly used to control weeds, and may be necessary in a crop establishment year to sow into a good seedbed where there has been no previous cropping history. However, it can expose the soil surface to erosion, particularly during heavy rainfall, characteristic of the wet season in northern Australia (Taylor and Tulloch 1985), and bare ground may also result in high soil temperatures non-conducive to seedling establishment. No-till practices are advocated for sustainable farming systems in the NT (O'Gara 1998). Brecke and Shilling (1996) discussed converse studies reporting the potential of no-till systems to reduce weed impact, while on the other hand, no-till crops producing decreased yield due to reduced herbicide efficacy in the presence of plant residues. Weed dynamics had been observed to differ between no-till and conventional till systems in northern Australia, where soil disturbance stimulated germination of some hard-seeded species, such as senna (*Senna obtusifolia*) and calopo (*Calopogonium mucunoides*). Mulch retained on the soil surface as a component of a no-till production strategy may reduce weed emergence (Teasdale and Mohler 2000), but can intercept herbicide, reducing its efficacy (Mills and Witt 1989). In the second year, this experiment compared conventional tillage and no-till systems on weed dynamics and the interaction with herbicide activity in a Cavalcade production system.

The project commenced in the 1997-98 wet season to identify herbicides suitable for use on Cavalcade, and to compare the effects of conventional and no-till systems on the efficacy and phytotoxicity of these herbicides. These results formed the basis of the development of an integrated weed management strategy for sustainable Cavalcade production in the NT, and field days conducted at this site aided in the extension to local farmers for increased awareness and uptake of sustainable weed management strategies in their production systems.

MATERIALS AND METHODS

An experiment was conducted in the 1997-98 and 1998-99 wet seasons on a commercial property, Mt. Keppler Station, approximately 120 km south of Darwin, in the Northern Territory, Australia. The soil was an alluvial Red Earth sandy clay loam, slightly acidic and with extremely low organic matter (Olsen 1982). The experimental design was a randomized complete block with 11 treatments (Table 1) and four blocks in the initial year. Plots were 8 m by 10 m with Cavalcade sown in 50 cm rows. In the second year, the design was modified to a split-plot layout, where plot width was divided in half to incorporate the addition of tillage treatment, with no-till and conventional till as the levels of the main plot factor. The sub-plot factor was herbicide where treatments remained as for the previous season.

The paddock was initially ploughed and harrowed in late October 1997 to reduce the large biomass (>10 t ha^{-1}) of stands of predominantly gamba grass (*Andropogon gayanus*), grader grass (*Themeda quadrivalvis*), Hamil Guinea grass (*Panicum maximum* cv Hamil), senna, and calopo, in preparation for sowing Cavalcade. The area was fertilised (200 kg ha^{-1} of 0-10-20+trace), cultivated and sown with Cavalcade (12 kg ha^{-1}) on 11 December 1997. Pre-emergent herbicides were applied immediately after sowing with a 4 m tractor-mounted boom delivering 100 L ha^{-1}. The post-emergent herbicide treatments were applied 18 days after sowing (DAS), when Cavalcade was at the three-five true leaf stage. Weeds ranged from two to seven leaf stage and grasses were up to 20 cm tall.

In the second season, the area was sprayed with glyphosate (360 g L^{-1}) (6 L ha^{-1} + 0.5% LI 700®) on 22 October 1998, then again to the no-till strips only, on 11 December, when the conventional tillage strips were disced in preparation for sowing. Fertiliser (200 kg ha^{-1} 0-10-20 + trace) was applied, the conventional tillage strips were cultivated, the site sown with Cavalcade (16 kg ha^{-1}) and the pre-emergent herbicide treatments were applied on 15 December at the same rates as used in the previous season. The post-emergent herbicide treatments were applied 21 DAS.

Biomass harvests were taken twice; at 30 DAS to determine early weed suppression and phytotoxicity to Cavalcade, and at the end of the growing season as indicative of final yield when cut for hay. Harvests for the first year were taken on 13 January 1998 (at 30 DAS), and on 17 March (at 90 DAS). This was earlier in the season than intended, but it was necessary to prevent the grader grass, a declared weed species, from seeding. Harvests for the second year were done on 14 January 1999 (30 DAS) and on 5 May 1999 (140 DAS). Biomass samples were separated into Cavalcade, grass weed and broadleaf weed, and weights were recorded.

A main effects analyses of variance (ANOVA) model was used to determine herbicide effect in the initial year of the experiment. A split-plot ANOVA was used to analyse herbicide and tillage effects in the second year. Data were transformed when necessary to meet variance assumptions. Dunnett's tests were used for post-hoc comparisons to the crop only, and crop and weed controls.

Table 1. Herbicide treatments assessed in Cavalcade over two seasons.

Treatment	Rate Applied	Active Ingredient (a.i.)	a.i. applied (g ha^{-1})
Crop only (Hand weeded)			
Weed only (Cavalcade removed)			
Crop and weed (Unsprayed control)			
Spinnaker® Pre-emergence	300 ml ha^{-1}	imazethapyr 240 g L^{-1}	72
Spinnaker® Post-emergence	"	"	
Flame® Pre-emergence	200 ml ha^{-1}	imazapic 240 g L^{-1}	48
Flame® Post-emergence	"	"	
Raptor® Pre-emergence	50 g ha^{-1}	imazamox 700 g kg^{-1}	35
Raptor® Post-emergence	"	"	
Stomp® Pre-emergence	3 L ha^{-1}	pendimethalin 330gL^{-1}	1000
Brodal® Pre-emergence	200 ml ha^{-1}	diflufenican 500 g L^{-1}	100

RESULTS AND DISCUSSION

Year 1. There was a significant effect of herbicide treatment ($P<0.0001$) on early Cavalcade yield. The crop only, as expected, and the Spinnaker® pre- and Raptor® pre- treatments had significantly greater early Cavalcade yields than the crop and weed control. The Flame® post- and Brodal® treatments had significantly lower yields than the crop only treatment, but this did not transfer to any significantly lower yields when compared to the crop and weed control. At final harvest, with the exception of the crop only treatment, there were no significant herbicide treatment effects on Cavalcade yield, when compared to the crop and weed control.

The major weeds that emerged and established in all plots were grader grass, Hamil Guinea grass, gamba grass, calopo, crowsfoot grass (*Eleusine indica*) and summer grasses (*Brachiaria* spp and *Digitaria* spp). Broadleaf weeds were not as invasive as the grasses, but included senna, flannel weed (*Sida cordifolia*), sida (*Sida acuta*) and hyptis (*Hyptis suaveolens*).

There was no significant herbicide effect on broadleaf weed biomass at either early or final harvest when compared to the crop and weed control. There were significant treatment effects on grass weed biomass at both harvest times ($P<0.0001$ and $P=0.002$ respectively). Spinnaker® pre-, Flame® pre-, Flame® post- and Raptor® post- significantly reduced grass weed biomass at early harvest, but only the Flame® post- was effective at final harvest, although this was associated with increased Cavalcade damage. It was difficult to quantify the reduction in Cavalcade yield due to phytotoxicity, as was observed with the Flame® post- treatment, or to competition from weeds, as was observed with the Brodal® treatment. It was important to determine if the herbicide treatments could adequately control grass weeds so that expensive post-emergence grass selective herbicides, often logistically difficult to apply due to paddock access over the wet season, would be unnecessary. In hindsight, a grass selective herbicide applied approximately four to six weeks after post-emergent herbicide application may have allowed a better apportioning of the effect of herbicide phytotoxicity and weed competition on reduced Cavalcade yield.

Combining the grass and broadleaf weed biomass, all herbicide treatments, except for Stomp® and Brodal®, significantly reduced early total weed biomass compared with the crop and weed control. At final harvest, only the Spinnaker® post-, Flame® pre-, Flame® post- and Raptor® post- continued to produce a significant reduction in total weed biomass than the crop and weed control. Figure 1 illustrates trends in relative biomass between Cavalcade, broadleaf and grass weed at time of final harvest.

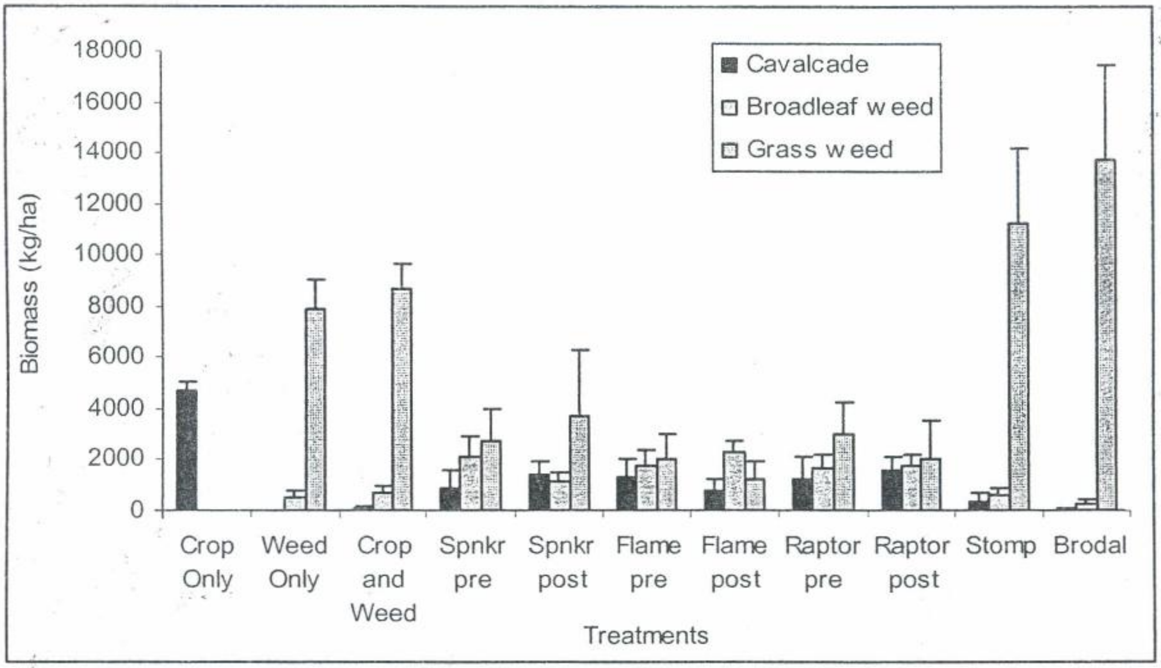


Figure 1. Cavalcade, broadleaf weed and grass weed biomass at final harvest in year 1. (Spnkr; Spinnaker®, Error bars indicate one standard error of the sample mean).

The relative higher efficacy on final total weed biomass of the imidazolinone post-emergent treatments to the pre-emergent treatments may have been due to differences in length of residual activity of the herbicides. Degradation of imidazolinones is primarily by microbial action, enhanced in moist, warm soils (Devlin et al. 1992). Above average rainfall immediately after pre-emergent treatment application (227 mm in 2 weeks), and the longer exposure to environmental and climatic conditions may have contributed to accelerated degradation of the pre-emergent herbicides, resulting in late season establishment of weed species, particularly grass weeds. Other studies have also found that control of monocot weeds by imazethapyr diminished over the season (Buhler and Proost 1992). Imazethapyr is considered to possess considerable residual activity as evidenced by recropping recommendations such as 34 months for canola in Australian soils (Holloway 2001), and Flame® is considered to have greater residual activity (Devlin et al. 1992). However, grass pastures sown in subsequent wet seasons after imazethapyr application have shown no evidence of crop damage, suggesting that herbicide degradation is relatively rapid in northern Australian tropical wet season conditions. A second season was required to further evaluate efficacy of herbicides in Cavalcade cropping systems, and how this may interact with no-tillage farming systems.

Year 2. There was no significant herbicide or tillage effect on early Cavalcade yield when compared to the crop and weed control. There was both a tillage effect (P=0.019) and a herbicide effect (P<0.0001) on final Cavalcade yield. There was significantly less Cavalcade in the conventional tillage treatments than the no-tillage treatments at final harvest.

Spinnaker® pre- and post-, Flame® pre- and Raptor® pre- produced significantly greater final Cavalcade yields than the crop and weed control. This differed from the previous season, where there was no herbicide effect at final harvest, perhaps due to more rainfall between time of pre-emergent herbicide application and harvest. Variation on imidazolinone efficacy between seasons is consistent with findings from numerous authors, including Mills and Witt (1991), Curren et al. (1992) and Hollaway (2001), where this was generally attributed to differences in rainfall. Spinnaker® pre- was the only treatment that provided an increase in Cavalcade yield in each of the two years of this experiment, although this differed between early and late harvest between years. Thus it, was considered the most promising for further studies to enable recommendation of this herbicide to commercial production systems.

There was a significant effect of both tillage and herbicide on early broadleaf weed biomass (P<0.0001 and P=0.004 respectively). The tillage effect revealed no significant difference in broadleaf weed compared with the crop and weed control, but when compared to the weed only treatment, no-tillage produced significantly less broadleaf weeds at early harvest. Spinnaker® pre-, Flame® pre- and Raptor® pre- resulted in significantly less broadleaf weed than in the crop and weed control. At final harvest, there was no significant reduction in broadleaf weed biomass for either main effect when compared to the crop and weed control.

Results on grass weed biomass were consistent with the broadleaf weed results. There was both a tillage and herbicide main effect on initial grass weed biomass (P<0.0001) and P=0.012 respectively). Consistent with the broadleaf weed results, there was less early grass weed biomass in the no-tillage than conventional tillage treatments when compared to the weed only treatment. The Spinnaker® pre-, Flame® pre- and Raptor® pre- treatments had lower early grass weed biomass than the crop and weed control. At final harvest, the only significant result was lower grass biomass in the Spinnaker® pre- treatment.

Analyses of total weed biomass showed that there was both a herbicide and tillage main effect (P<0.0001 and P=0.002 respectively; Figure 2) with results for the early total weed biomass mirroring those of both the initial broadleaf and the grass weed harvest results. However, at final harvest, there was a significant herbicide effect (P<0.0001) where Spinnaker® pre-, Spinnaker® post-, and Flame® pre- resulted in lower total weed biomass compared to the crop and weed treatment.

The decrease in Cavalcade yield under conventional-till suggests that no-tillage may benefit Cavalcade establishment for cultural reasons, such as reduced soil temperatures, but also when considered in conjunction with weed biomass results because of a reduction in weed competition. The no-till treatment consistently produced less weeds, both grass weed and broadleaf weed, than the conventional treatment for the early harvest, although this did not extend to the final harvest time. Senna was a major broadleaf weed at this site, and is considered the most significant broadleaf weed in Cavalcade crops in the NT. The greater weed biomass, including senna, under the conventional till treatments was consistent with findings by Brecke and Shilling (1996) who found that senna was more prominent in tilled than untilled soil.

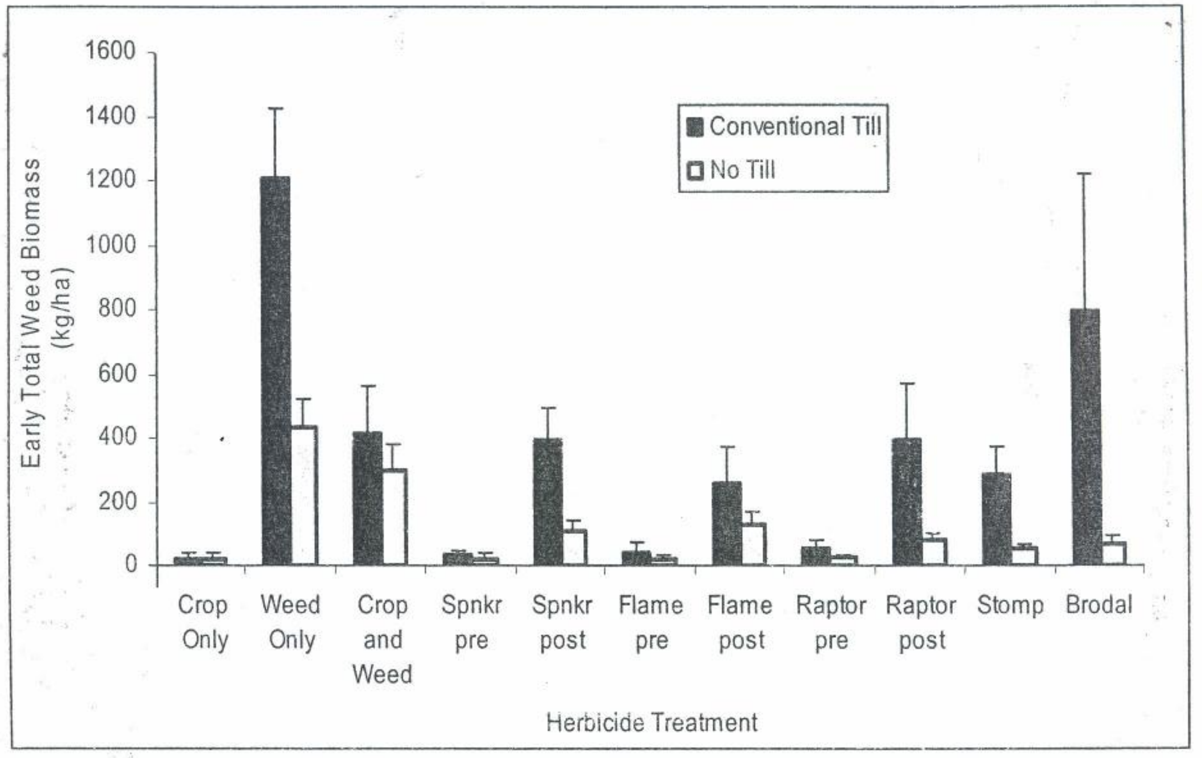


Figure 2. Tillage and Herbicide effect on total weed biomass at time of early harvest in Year 2 (Spnkr; Spinnaker®. Error bars indicate one standard error of the sample mean).

Overall, imazethapyr applied post-plant pre-emergence provided the most effective and consistent weed control of the herbicides assessed, although efficacy was variable with season, and the use of no-tillage practices aided in reducing total weed biomass, particularly in the initial stages of Cavalcade establishment. This experiment contributed to increased farmer awareness of the efficacy of imazethapyr and benefits of no-till practices for weed management in Cavalcade production, and results formed the basis for development of an integrated weed management strategy, incorporating chemical, physical and cultural weed control practices. This experiment further proceeded (Eastick 2004) to examine the subsequent role of a grass rotation in this system, effectively adding another weed control option to strengthen the sustainability of a Cavalcade production system in northern Australia.

LITERATURE CITED

Brecke B.J. and Shilling, D.G. 1996. Effect of crop species, tillage, and rye (*Secale cereale*) mulch on sicklepod (*Senna obtusifolia*). Weed Science, 44:133-136.

Buhler D.D. and Proost R.T. 1992. Influence of application time on bioactivity of imazethapyr in no-tillage soybean (*Glycine max*). Weed Science, 40:122-126.

Cameron A.G. 2005 (Accepted). Centrosema pascuorum in Australia's Northern Territory: a tropical forage legume success story. XX International Grassland Congress 2005, Dublin.

Curran W.S., Liebl R.A. and Simmons F.W. 1992. Effects of tillage and application method on clomazone, imazaquin, and imazethapyr persistence. Weed Science, 40;482-489.

Devlin D.L., Peterson D.E. and Regehr D.L. 1992. Residual herbicides, degradation and recropping intervals. Kansas State University. April 1992.

Eastick R.J. 2004. Weed Management Strategies in Cavalcade. Research conducted at Mt. Keppler Station, 1997-2004. Technical Bulletin No.317. Northern Territory Deptartment of Business, Industry and Resource Development.

Holloway K.L. and Noy D.M. 2001. Imazethapyr recropping recommendations for canola are suitable for Australia's neutral-alkaline soils. Victorian Institute for Dryland Agriculture. www.regional.org.au/au/asa/2001/6/cholloway.htm

Mills J.A. and Witt W.W. 1989. Effect of tillage systems on the efficacy and phytotoxicity of imazaquin and imazethapyr in soybean (*Glycine max*). Weed Science, 37:233-238.

Mills J.A. and Witt W.W. 1991. Dissipation of imazaquin and imazethapyr under conventional and no-tillage soybean (*Glycine max*). Weed Technology, 5:586-591.

O'Gara F.P. 1998. Striking the Balance: Sustainable Farming and Grazing Systems for the Semi-arid Tropics of the Northern Territory.Northern Territory Department of Primary Industry and Fisheries, Berrimah Farm Strath Road Berrimah NT.

Olsen C.J. 1982. The soils of part of the upper Adelaide River floodplain. Technical Report No.4. Conservation Commission of the Northern Territory, Darwin, NT.

Taylor J.A. and Tulloch D. (1985). Rainfall in the wet-dry tropics: Extreme events at Darwin and similarities between years during the period 1870-1983. Australian Journal of Ecology, 10: 281-295.

Teasdale J.R. and Mohler C.L. 2000. The quantitative relationship between weed emergence and the physical properties of mulches. Weed Science, 48:385-392.

Impact of Passali kodi (*Andredera cordifolia*) weed infestation on the productivity of high-grown tea in Sri Lanka

K. G. Prematilake
Low Country Station, Tea Research Institute, Ratnapura, Sri Lanka.
gaminiprem@yahoo.co.uk

Abstract: *Andredera cordifolia* weed, which is locally known as Passali kodi is found at high elevations in tea plantations. It is widespread in many tea estates covering the surface of tea bushes thereby interfering with plucking. Though it can be controlled with higher dosages of some herbicides recommended for common weeds, it is highly hazardous to the tea bush. Hence, the weed must be removed manually by tea pluckers while harvesting tea. Therefore, a study was conducted to investigate the effect of removal of *A. cordifolia* shoots from tea canopy at different frequencies of 2, 4, 6, 8, 10 and 12 weeks on the growth and yields of tea and the additional time required for the removal of weed shoots, at Balangoda estate (1200 m AMSL) in Ratnapura during 2001-2003. Made tea yield and pruned tea shoot weight were not significantly affected ($p>0.05$) by weed harvesting intervals. However, the fresh and dry weight of weed shoots significantly increased ($p<0.01$) when harvested at 2 and 4 week and; 2, 4 and 6 week intervals compared with other harvesting intervals during 2001-2 and 2003, respectively. However, the highest mean weed shoot dry weight (g bush^{-1} round^{-1}) was recorded from plots harvested at 12 week intervals. The highest and the least time spent additionally for harvesting of weed shoots at two and eight week intervals were 9.82 and 1.04 hrs. 100 m^{-2} year^{-1}, respectively. These were almost 25.43% and 2.70% increase, respectively, when compared with the total annual time spent for harvesting of tea alone from 100 m^{2} area. Therefore, removal of *A. cordifolia* shoots from tea canopy every eight weeks is more appropriate, thereby the harvesting efficiency of the plucker is not severely affected.

Key words: *Andredera cordifolia,* harvesting interval, interference, plucking efficiency, tea, yield

INTRODUCTION

Weed management in tea plantations is a critically important operation, as grow profusely interfering with tea (*Camellia sinensis* [L.] Kuntze) for basic requirements. The effect of weeds on tea is primarily competition for moisture and nutrients (Eden 1940). Wettasinghe (1971 a, b) reported that there was a yield decline of 5-9% in clonal tea due to weeds. Moreover, weeds disturb the major field operations such as plucking, pruning, fertilizer application so on. At present, weed control is the second most expensive field operation after harvesting of tea and thus, it accounts for 10-15% of the cost of field operations and 4-5% of cost of production of tea (Prematilake 2003, a).

Although a broad spectrum of weeds could be easily controlled by manual and chemical methods, some weed species such as *Andredera cordifolia* and *Spermacoce hispida* have become a problem in tea plantations as they are very difficult to control by these methods (Prematilake 2003, b)

A. cordifolia Ten. (Steenis), (local name: Passalai kodi or Wal nivithi) (Ranamukaarachchi et al, 2000) has become widespread in some mid- and high-grown tea plantations in Sri Lanka. It is an environmental weed in eastern Australia, New Zealand and South Africa (Anon. 2003). The weed is a vine, which climbs through the tea bush reaching the upper tea canopy, grows vigorously and covers the plucking table disturbing the growth of tea shoots and interfering with plucking. The weed is propagated mainly by mature bulbils (propagules) and readily germinates on the litter and grows aggressively under favourable conditions (Ranamukaarachchi et al. 1997 and Prematilake 2003c). Thus, suppressing the weed growth at seedling stage would be the only way to mitigate this weed menace in tea fields. However, manual removal of the weed is rather difficult and more costly operation. On the other hand, the weed cannot be effectively managed by herbicides as the weed could withstand normal dosages of common herbicides and due to the risk of possible damages on tea bushes with higher dosages of herbicides (Prematilake 2003c). Thus, in estates where there is a severe infestation of the weed, tea pluckers are deployed to hand pull the shoots from the plucking table during harvesting of tea.

Therefore, an understanding of the growth habit of *A. cordifolia* and its interference with tea when both grow in association will provide insights as to when and how the weed should be managed at a minimum cost. Therefore, the objectives of the present study are to investigate the impact of *A. cordifolia* that grows in association with tea for various time durations, on the growth and yield of mature tea and on the plucker's efficiency in terms of the additional time to be spent for the removal of weed shoots from tea canopy.

MATERIALS AND METHODS

A field experiment was conducted at the 'Balangoda group' estate (elevation 1200 m AMSL, latitude: 6^0 41'.N & longitude 80^0 24' E) in the Ratnapura district, during the period from August 2001 to September 2003. The soil type is an Ultisol sandy loam. The annual rainfall is 2500-3000 mm and the mean ambient temperature is 26 ^{0}C. A mature tea field (clone DN 777 planted at a spacing of 1.05 X 0.6 m) heavily infested with *A. cordifolia* vines covering the upper tea canopy, was selected at its mature phase of growth. Plots of size 7 x 6 m were demarcated to accommodate seven treatments in four replications in a Randomized Complete Block Design.

Treatment Combinations

Manual harvesting of the shoots of *A. cordifolia* from the canopy of tea at intervals of 2, 4, 6, 8, 10 and 12 weeks was considered as "Treatments". An 'untreated control' was also maintained. All types of weeds except for *A. cordifolia,* were hand pulled from all the plots prior to imposition of treatments and later at regular intervals as and when necessary. In addition, in the 'untreated control' plots all yams, bulbils and seedlings and mature vines of A. *cordifolia* were totally removed manually from the base of tea plants and inter-rows of tea prior to the experiment and subsequently at weekly intervals in order to avoid any interference of the weed with tea.

Growth Assessments

i) *A. cordifolia*:

a) The fresh shoots of *A. cordifolia* harvested at intervals from each plot according to the treatment, was weighed and a sample of 500 g was obtained from each plot and dried for 48 h at 65^0C for dry weight measurements.
b) Time spent for manual removal of *A. cordifolia* shoots from each plot was also recorded.

ii) Tea:

a) The weight of tea flush was measured weekly from each plot and the total annual made tea yield per hectare was calculated.
b) Time spent for harvesting of tea from 'untreated control' plots was also recorded.
c) Tea bush count was also taken from each plot.
d) Pruning weight was recorded from five tea bushes selected randomly from each plot at the end of the study in September, 2003.

Statistical analysis

All data were subjected to analysis of variance (ANOVA) using SAS computer package (SAS Institute Inc, Cary, North Carolina, and USA). Mean treatment values were separated using Least Significant Difference (LSD).

RESULTS AND DISCUSSION

1. Yield of *A. cordifolia* shoots.

The total shoot fresh and dry weight harvested during the year 2001-2002 were significantly greater ($p<0.01$) when shoots were removed more frequently at intervals of 2 and 4 weeks than those at less frequent intervals exceeding 6 weeks (Table 1 a). The highest mean shoot weight (i. e., g tea^{-1} bush round^{-1}) was recorded when shoots were removed at 12 week intervals and this was comparable to that of 4 week intervals. The dry weight recorded with manual removal of shoots at 4-12 week intervals was also comparable.

The total shoot fresh weight during the year 2003 was significantly greater ($p<0.01$) when the shoots were harvested at intervals of 2-6 weeks than that of 8 and 12 weeks (Table 1 b). On the other hand, the shoot dry weights were comparable at all harvesting intervals. The highest mean shoot fresh and dry weights were recorded when shoots were removed at 12 week intervals and the shoot dry weight in plots harvested at 6-12 week intervals was comparable.

The overall shoot yield recorded for the test period from 2001-2003 under different harvesting intervals had a similar trend to that of 2001-2002 and 2003 (Fig. 1). A significantly greater shoot dry weight ($p<0.05$) was recorded from plots harvested at intervals of 2-6 weeks than that when harvested at less frequent intervals exceeding 8 weeks. The highest mean shoot fresh weight (g bush^{-1} round^{-1}) was recorded at 12 week intervals and

Table 1a. The total and mean shoot weight under various intervals of harvesting of *A. cordifolia* shoots from the affected tea canopies during the year 2001-02.

Treatment	Shoot Fresh weight		Shoot Dry weight	
	kg 100 m^{-2}	g bush^{-1} round^{-1}	kg 100 m^{-2}	g bush^{-1} round^{-1}
Harvesting every 2 weeks	71.61 a	17.50 cd	9.64 ab	2.27 bc
Harvesting every 4 weeks	70.88 a	37.75 ab	10.85a	5.66 ab
Harvesting every 6 weeks	42.68 b	31.25 bc	6.24 bc	4.56 abc
Harvesting every 8 weeks	23.68 bc	24.75 cd	3.78 cd	3.93 abc
Harvesting every 10 weeks	26.13 bc	22.00 bc	4.86 cd	4.09 ab
Harvesting every 12 weeks	33.43 b	50.25 a	5.27 cd	7.88 a
Control	9.25 c	6.52 c	1.72 d	0.56 c
LSD ($P<0.05$)	20.38	11.82	3.95	3.47

Means followed by common letters are significantly different at the 5% level this was significantly greater than all other treatments. The mean dry weight at all intervals except for 2 weeks was comparable.

Higher total shoot biomass of *A. cordifolia* produced in plots where shoots were removed at intervals of 2-6 weeks was attributed to the number of harvesting rounds which was greater than that of less frequent intervals. Further, the growth of auxiliary buds may have been induced after apical dominance was removed in remaining vines at each harvesting, resulting in a higher weight. Regular removal of

A. cordifolia shoots growing above the tea canopy while harvesting tea results in multiple shooting of the weed leading to a fast growth covering the plucking table, particularly under wet weather (Anon. 1997). This also agrees with previous findings on tea which showed that more frequent plucking of shoots results in higher tea yield. Higher tea yield was recorded when harvested at 4 day intervals that at 7 days (Wijeratna 2000). Moderate weed biomass production with shoot removal at 8 and 10 week intervals might be due to the slow growth or of growth temporary cessation as a result of coincidence with long dry spell (Fig. 3) or time of formation of bulbils on the stem nodes. The highest mean weed shoot weight (g $bush^{-1}round^{-1}$) recorded with less frequent interval of 12 weeks was also due to the retention of more shoots on the tea canopy over the 3 month period. The mature bulbils, which are produced on mature stem nodes, dropped off to the primary frames or base of the tea bush. These also germinate and grow from time to time and thus growth of such new vines might also have attributed for this higher mean shoot weight.

Table 1b. The total and mean shoot weight under various intervals of harvesting of *A. cordifolia* shoots from the affected tea canopies during the year 2003.

Treatment	Shoot Fresh weight		Shoot Dry weight	
	kg 100 m^{-2}	g $bush^{-1}$ $round^{-1}$	kg 100 m^{-2}	g $bush^{-1}$ $round^{-1}$
Harvesting every 2 weeks	36.46 a	18.25 cd	4.84 a	2.42 bc
Harvesting every 4 weeks	28.88 ab	31.0 bcd	4.43 a	4.77 bc
Harvesting every 6 weeks	29.74 ab	44.0 ab	3.80 a	5.63 abc
Harvesting every 8 weeks	22.98 bc	38.5 bc	3.61 a	6.04 ab
Harvesting every 10 weeks	14.70 c	26.0 cde	2.81 ab	4.45 abc
Harvesting every 12 weeks	18.80 c	55.0 a	3.08 a	8.96 a
Control	4.68 d	3.25 d	0.87 b	0.60 c
LSD (P=0.05)	9.78	9.95	2.1	3.47

Means followed by common letters are significantly different at the 5% level

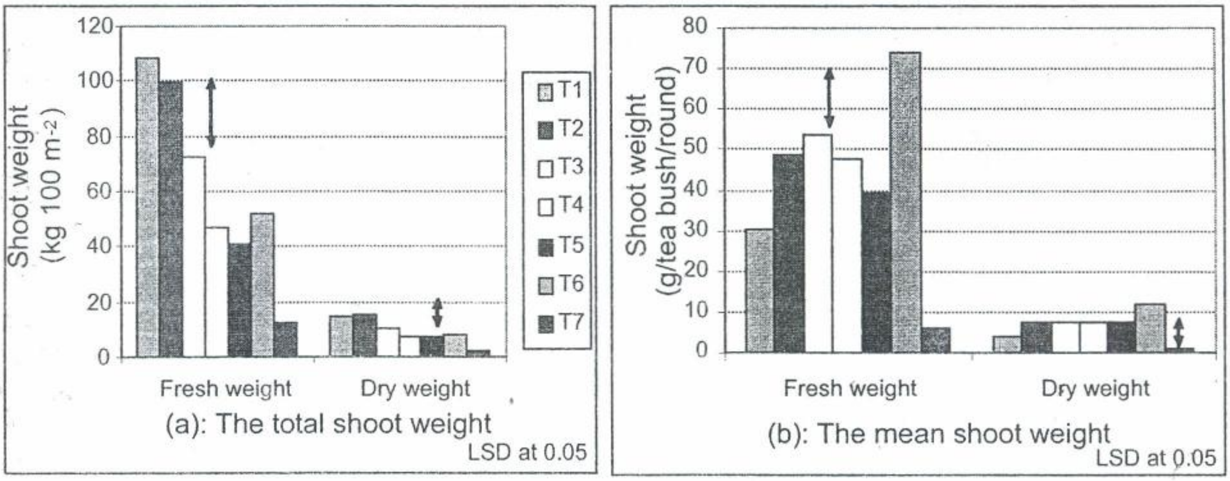
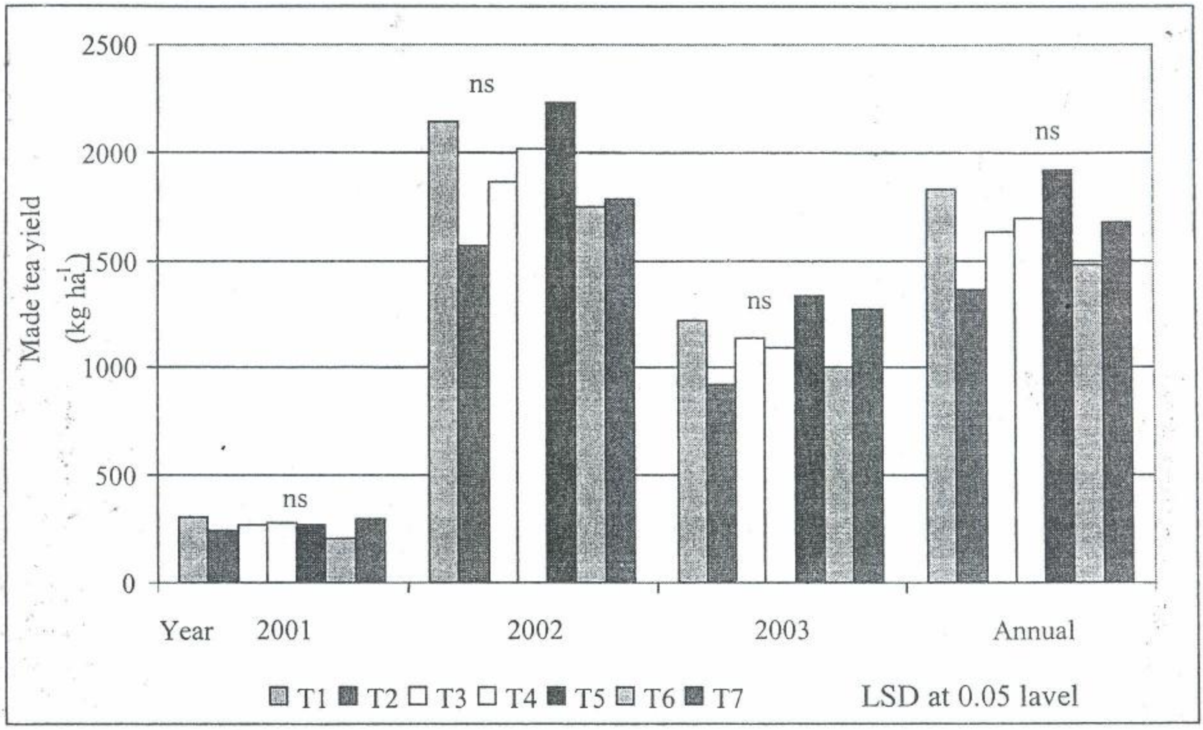


Figure 1. The overall and mean shoot weights under various intervals of harvesting of *A. cordifolia* shoots from the affected tea canopies during the period of 2001-2003. T1- Harvesting every 2 weeks (w), T2 - Harvesting every 4 w, T3 - Harvesting every 6 w, T4 - Harvesting every 8 w, T5 - Harvesting every 10 w, T6 -Harvesting every 12 w, T7 - Control.



Harvesting of wed shoots (T1) Every two wks, (T2) Every four wks, (T3) Every six wks, (T4) Every eight wks, (T5) Every ten wks,(T6) Every twelve wks, and (T7) Control.

Figure 2. Made tea yield under the various intervals of harvesting of A. cordifolia shoots from tea canopy.

2. Made tea yield

The made tea yields recorded during 2001, 2002 and 2003 and the annual yield (mean of two years) were not significantly ($P>0.05$) affected by any of the interval of harvesting of *A. cordifolia* shoots (Figure 2). However, the yield recorded under the treatment of every 4 weeks was the lowest. Mean fresh weight of tea (g bush^{-1} round^{-1}) and total pruning weight were also not affected significantly by the treatments (Table 2).

Tea yield in the experimental site was generally low compared to other fields of the same estate. This may be attributed to the character of the cultivar and soil fertility status. Further, lower rainfall received during the test period may have affected the growth of tea as well as *A. cordifolia*. As depicted in Fig. 3, there were trough and peaks in the rainfall pattern. A severe dry spell coupled with blowing are experienced from June to September, causing the growth of both tea and weed to cease temporarily and recover only with the onset of rains from September onwards. The monthly wet days also ranged from 5-11 during this dry spell as against 12-25 the rest of the period. Thus, the low competition of *A. cordifolia* on tea even when shoots were removed at 12 week intervals may be attributed to the weather conditions that prevailed during the test period. In this context, any interference with tea to an extent that there was a yield loss, could have been expected if the interval of harvesting was further extended beyond 2 weeks. On the other hand, since the root system of the weed has been confined to the shallow layer of litter (Prematilake 2003, c) competition with tea for soil nutrients and water may be minimum.

Table 2. Mean tea bush yield and dry weight of pruning as affected by various intervals of harvesting of *A. cordifolia* shoots from tea canopy.

Treatment	Fresh weight of tea (g bush^{-1} round^{-1})	Dry weight of pruned shoots (g bush^{-1})
Harvesting every 2 weeks	16.9	1022
Harvesting every 4 weeks	15.9	807
Harvesting every 6 weeks	18.4	820
Harvesting every 8 weeks	16.8	945
Harvesting every 10 weeks	16.3	1170
Harvesting every 12 weeks	17.2	835
Control	15.7	949
LSD (P=0.05)	ns	ns

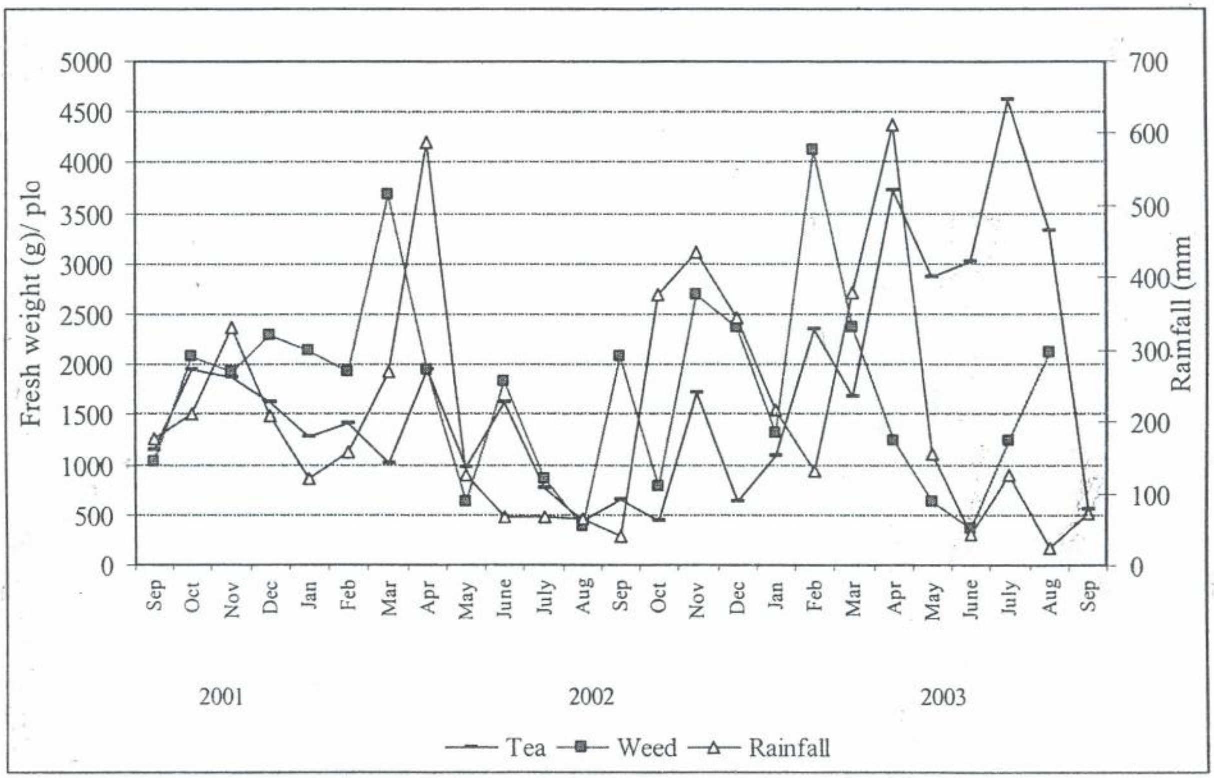


Figure 3. Relationship between monthly rainfall and yield of Tea and A. cordifolia weed.

The maximum and minimum weed harvesting rounds were observed at 2 and 12 week intervals, respectively (Table 3). Likewise, two-week intervals had the highest total time required for removal of shoots over two year test period, but gradually decreased with increased time interval. However, in keeping with the weed shoot weight, the mean time (min. round^{-1} 100 m^{-2}) for shoot harvesting was also more or less the same under 2, 4 and 6 weeks intervals (Figure 1). The time that spent in a year on the removal of weed shoots from the tea canopy was reduced by one half and one-third at 4 and 6 weeks intervals, respectively, compared to that of 2 week intervals. When both the least mean time (min. round^{-1} 100 m^{-2}) and minimum number of rounds per year were considered, weed shoot harvesting at 8 week intervals incurred a minimum time of 1.04 h yr^{-1} 100 m^{-2}. Accordingly, the additional time spent for weed shoot removal at eight and two-week intervals, in relation to the time required for harvesting of tea alone was 2.7% and 25.4 %, respectively. Therefore, it is more appropriate, if *A. cordifolia* shoots are removed at 8 week intervals rather than at every time tea harvest, i.e., every week, so that harvesting efficiency of the plucker is not affected by an additional task of weed shoot removal.

Table 3. Additional time required for harvesting of *A. cordifolia* shoots from tea canopy at different intervals.

Treatment	For the entire period of 2001-03		Time spent round^{-1} (min 100m^{-2})	No. of rounds year^{-1}	Time spent for		Relative** additional time %
	No. of rounds	Total time spent (hrs.100m^{-2})			weed^{+} (hrs. yr^{-1} 100m^{-2})	for tea* (hrs. yr^{-1} 100m^{-2})	
	45.	16.99	22.65	26.0	9.817	-	25.43
	26	9.48	21.88	13.0	4.740	-	12.28
	18	6.36	21.20	8.5	3.003	-	7.78
	13	2.09	9.63	6.5	1.044	-	2.70
	12	3.17	15.85	5.2	1.374	-	3.56
	9	2.77	18.49	4.34	1.338	-	3.47
	-	-	-	-	-	38.593	

Time spent for harvesting of: +: *A. cordifolia* shoots; *: Tea;

** : Additional time required for the removal of *A. cordifolia* shoots alone from tea canopy as the percentage of the total time required for harvesting of tea alone.

ACKNOWLEDGEMENTS

Author wishes to thank to the Director, Tea Research Institute, Mr. P.B. Ekanayake, Officer in-Charge, Mid Country Station of TRI and the Manager, Balangoda estate and his field staff for extending their fullest cooperation in carrying out this investigation.

LITERATURE CITED

Anon. 1997. Studies on Passali kodi weed and control of problem weeds, Report of the Agronomy Division, Annual Report, Tea Research Institute of Sri Lanka 1997: 29-31, 37-38.

Anon. 2003. Madeira vine (*Anredera cordifolia*), Biological control. Natural Resources, Mines and Energy, Queensland Government, Australia, http://www.nrm.qld.gov.au/alan_fletcher /aboutus.html.

Eden T. 1940. Studies in the yield of tea IV – The effect of cultivation and weeds on crop. *Empire Journal of Experimental Agriculture* VIII, 269-279.

Prematikale K.G. 2003a. Weed management in tea, Recent Developments, Tropical Agricultural Research and Extension (TARE) International Journal of the Faculty of Agriculture, University of Ruhuna, Sri Lanka.6.98-107.

Prematikale K. G. 2003b. Weed management in tea in Sri Lanka in Twentieth Century, Tea Research in Sri Lanka, ed, W.W.D. Modder, Tea Research Institute of Sri Lanka p 63-72.

Prematilake K. G. 2003c. Management of Passali kodi (*Andredera cordifolia*) in tea fields, Tea Bulletin, Vol.18, No. 1 & 2, 20-23.

Ranamukaarachchi S. L., Marambe B, Prematilake K. G. and Perera P. 2000. An interim report on the progress of the collaborative research project on biological and management studies of *Andredera cordifolia* in tea plantations, submitted to the Council for Agricultural Research Projects (CARP).

Ranamukaarachchi S. L., De Silva M. S. D. L, Perera B, Weerasuriy, A, Marambe B. and Nissanke S.P. 1997. Problem of *Andredera basselloides* and *Talinum paniculatum* in tea plantations, "TRI UPDATE", 2 (2), Tea Research. Institute of Sri Lanka.

Wettasinghe D.T. 1971a. Report of the Research Officer for the low country and Kottawa sub station for 1969. *Annual Report* of the Tea Research Institute, Ceylon, 145-167.

Wettasinghe D.T. 1971b. Report of the Research Officer for the low country station for 1970. *Ann. Rep.* Tea Res. Inst. Ceylon, 126-142.

Wijerathne M. A. 2000. Shoot Growth and Harvesting of Tea, Tea Research Institute of Sri Lanka.

Impact of some weed management strategies on the productivity of tea plantations in Sri Lanka

P.B.Ekanayake[1], K.G.Prematilaka[2] and A.P.D.A.Jayasekara[3]
[1 & 3]Tea Research Institute, Mid Country Station, Kandy, Sri Lanka
pb_tri@yahoo.com
[2]Tea Research Institute, Low country Station, Ratnapura, Sri Lanka
gaminiprem@yahoo.co.uk

Abstract: Weed management is one of the important field operations, incurs 4-5% of the total cost of production, includes manual, chemical, cultural, ecological and biological methods, practiced in rotation throughout the year. Chemical methods are widely used due to convenience and labour shortage. An experiment was conducted to investigate the long-term effects of continuous application of some recommended herbicides on vegetatively propagated tea for a period of 6 years. Results indicate that systemic herbicides tested adversely affect growth, yield, microbial and earthworm population. However, the effect was minimal with paraquat. Manual weeding and chemical weeding with paraquat in rotation could be advocated to sustain the productivity and maintain an eco-friendly environment in tea plantations.

Key words: Environment, herbicides, productivity, tea, weed management

INTRODUCTION

Weed management is one of important field operation and presently growers heavily depend on chemicals to control weeds in tea lands due to labour shortage for manual weeding (Prematilaka, et.al 2004). Wide range of herbicides is recommended to control broad spectrum of weeds in tea lands at present (Ekanayake 1994). These include paraquat, 2, 4-D, MCPA, diuron, oxyfluorfen, glyphosate, sulphosate and glufosinate ammonium. However, herbicides are becoming costly, in addition, there is a growing concern regarding phytotoxic effects on the tea bush, presence of residues in the end product, development of resistance (Marambe et.al 2002 & 2003) and the possibility of environmental pollution (Ekanayake 1994). The harvested product of tea is a tender shoot with two to three leaves removed at regular intervals (Wijeratna 2001). Therefore, it is necessary to minimize the use of herbicides for weed control in tea plantations. This could be achieved by adopting an integrated approach where manual, cultural and chemical methods are harnessed to manage weeds through out the year (Prematilaka 2003).

The objective of this study is to investigate the long-term effects of continuous use of some recommended herbicides on growth, yield and soil organisms in the tea environment. This information will be useful in formulating eco-friendly and cost-effective weed management strategy.

MATERIALS AND METHODS

The experiment was carried out for a period of six years commencing from 1994 in a field planted with vegetatively propagated tea, cultivar TRI 2023 at Galphele Estate, Panwila (710 m AMSL) in the Matale District. Tea was brought into plucking in 1995 and formative pruning was done in the year 2000. The soils in the site belong to Red Yellow Podsolic great soil group, which, according to USDA soil taxonomy, is categorized under Ultisols (Mapa et al. 1999). The soils are sandy, deep, well drained and the slope of the land varied from 15-20%. Following methods of weed management were imposed as treatments.

Treatments

T1 - Manual weeding every month
T2 - Manual weeding every 2 months
T3 - Manual weeding every 3 months
T4 - Chemical weeding with Paraquat @ 1.1 L in 550 L of water per ha
T5 - Chemical weeding with Glyphosate @ 1.65 – 2.75 L in 550 L of water per ha
T6 - Chemical weeding with Sulphosate @ 1.65 – 2.75 L in 550 L of water per ha
T7 - Chemical weeding with Paraquat @ 1.1 L + 2 4 D @ 1.2 kg in 550 L of water per ha
T8 - Chemical weeding with Paraquat @ 1.1 L + 2 4 D @ 1.2 kg + Diuron@ 1.2 kg in 550 L of water per ha
T9 - Slash weeding

The experiment design was Randomized Complete Block Design with four replications where the plot size was 20 m^2 having 25 plants per plot. Manual weeding was done by pulling the weeds by hand. As most of the weeds were tender, they were retained *in-situ* on plots weeded manually every month. However, the weeds in plots weeded every 2 months and 3 months were removed and taken out of the plots. The weeds in slash weeded plots were also retained *in-situ*. During first three years, manual weeding was carried out according to the schedule, i.e. 12, 6 and 4 rounds per year for T1, T2 and T3 treatments, respectively. However, after two years, when inter row space had covered by tea canopy, frequency of manual weeding was reduced (Table 1). Slash weeding was done before the flowering of weeds, accordingly, 4, 3 & 2 rounds of slash weeding was done during 1st & 2nd years, 3rd & 4th years and 5th & 6th years respectively. Number of chemical weeding rounds for each of the treatments T4 – T8 is indicated in the Table 1. Chemicals were sprayed along inter rows of tea using a knapsack sprayer. Two different nozzles, i.e. yellow nozzle with low discharge rate, during early stage prior to plucking and blue nozzle with moderate discharge rate after commencement of plucking were used. Discharge pressure of 1 bar (14 psi) was maintained with help of a pressure gauge. The weeds that survived or escaped chemical weeding were removed manually.

Table 1 – Frequency of application of treatments from 1995 – 2000

Treatment	1995	1996	1997	1998	1999	2000
T1	12	12	12	06	05	03
T2	06	06	06	04	04	03
T3	04	04	04	03	03	03
T4	06	04	04	04	04	04
T5	04	03	03	03	03	03
T6	04	03	03	03	03	03
T7	05	03	03	03	03	03
T8	03	03	02	02	02	02
T9	05	04	03	03	03	02

The plant height and dry weight of tea shoots removed during centering (1st pruning) done in April 1995 and cut across (2nd pruning) done in October 1995 were recorded to assess the growth. Yield of tea was recorded at each plucking carried out on weekly intervals. Thickness of the layer of maintenance foliage was measured in 1997, 1998 and 1999, i.e. 3, 4 and 5 years after commencement of treatments, respectively. At the end of the first cycle (duration from planting to first formative pruning), girth at the collar of the tea bush, dry weight of pruning and tippings (shoots removed 4 – 5 months after recovery from pruning at a given height) were recorded. During last year of the cycle (6th year), organic carbon content was determined using Walkley and Black

(1934) method and microbial C content was determined using Chloroform extraction method (Sparling et al. *1990*). An assessment on earthworm population was carried out prior to treatment application, 3 and 5 years after commencement of treatments and 7th year, i.e. 1 year after final treatment application by counting the emergence of earthworms on applying one Liter of 0.55% formaldehyde on a 30 cm^2 surface area. The data was analyzed using the package SAS (Statistical Analytical System).

RESULTS AND DISCUSSION

Plant height and dry weight of shoots

There was no significant difference ($P > 0.05$) in plant height and dry weight of shoots between any of the treatments at the end of 12 and 18 months after planting. This indicates that there is no impact of the treatments on growth during early stage.

Yield of tea

There was no yield difference ($p > 0.05$) between any of the treatments during first two years of plucking (Table 2). However, in the third year there was a reduction ($p.<0.05$) in yield due to chemical weeding where plots treated with paraquat and sulphosate recorded lowest yields compared to manual weeding at monthly intervals and slash weeding. Though, other chemical weeding treatments had indicated a yield reduction, the differences were not significant ($p>0.05$). During the 4th year there was a significant yield reduction in plots chemically weeded with glyphosate, sulphosate and cocktail mixture of paraquat+diuron+ 2, 4-D compare to manual weeding at monthly intervals and slash weeding. There was significantly ($p<0.05$) lower yield in plots weeded with glyphosate and sulphosate compare to all other treatments.

Table 2 – Effect of methods of weed management on 1st cycle yield ($kg.ha^{-1}$)

Treatment	1995	1996	1997	1998	1999	2000	Cycle mean
T 1	2346a	2950a	4456ab	3384a	3493a	3657a	3381a
T2	2098a	2983a	4056bc	3055abc	3316ab	3308ab	3136b
T3	1978a	2975a	4196abc	3044abc	3378ab	3206abc	3129b
T4	2049a	2715a	3896c	3032abc	3186abc	3151abc	3012bc
T5	2050a	2732a	4123abc	2600d	2846bc	2673bc	2837de
T6	2035a	2747a	3834c	2552d	2756bc	2626bc	2592e
T7	2142a	2914a	4160abc	2976bc	3161abc	3163abc	3086bc
T8	2109a	2875a	4184abc	2803c	2778bc	2573d	2903cd
T9	2231a	3177a	4507a	3170ab	3089ab	2735bc	3151b

Means followed by common letters are significantly different at the 5% level

The yield data in the 5th and 6th year follow similar trend where there was a significant yield reduction in plots weeded chemically with glyphosate, sulphosate and cocktail mixture of paraquat + 2, 4-D + diuron compare to manual weeding at monthly intervals.

The mean cycle yield also indicates that there was significant yield reduction ($p<0.05$) in plots treated with glyphosate and sulphosate when compared with other treatments. Higher yield was obtained from plots weeded manually at monthly intervals compare to all other treatments. There was no yield difference between plots weeded manually at 2 and 3 month intervals, slash weeding and plots weeded chemically with paraquat and cocktail mixture of Paraquat + 2, 4-D.

The yield during latter part of the cycle and the mean cycle yield indicate that there was a significant yield reduction in all plots weeded with glyphosate, sulphosate and cocktail mixture of Paraquat+2,4-D+Diuron. Increased yield in plots manually weeded every month could be attributed to absence of competition from weeds throughout the period.

Thickness of the maintenance foliage

In 1997 and 1998, except for plots treated with paraquat and cocktail mixture of paraquat+2,4-D, there was a significant ($p<0.05$) reduction in the maintenance foliage in all other chemical weeding treatments compare to manual and slash weeding. However, measurements in 1999, i.e.5 years after commencement of treatments, indicate that there was a significant reduction in the thickness of maintenance foliage in all chemically treated plots compare to manual methods (Fig.1). This may be due to the effect of contamination of peripheral shoots of tea with herbicides. Yield reduction (Table 2) during latter part of the cycle may be attributed to the reduction in the thickness of the maintenance foliage.

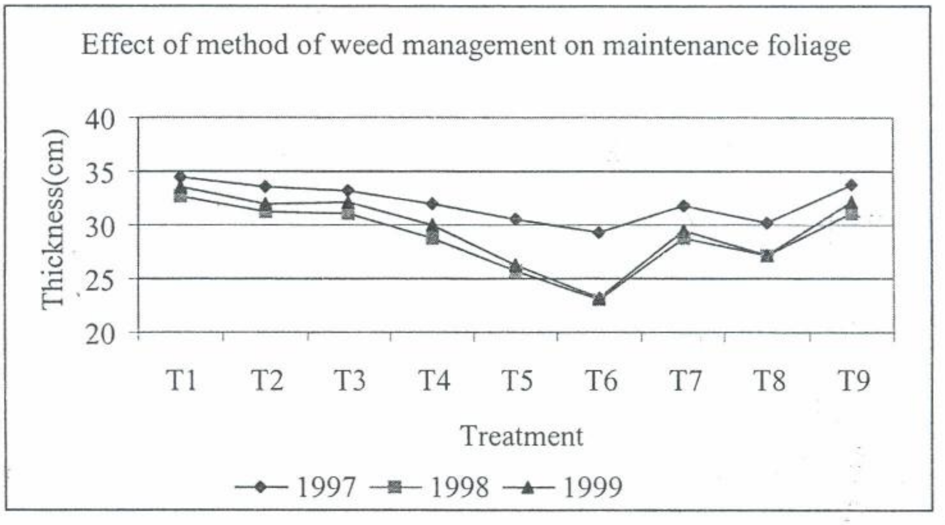


Figure 1 – Effect of method of weed management on thickness of maintenance foliage

Assessments at the end of the cycle

(a) Growth assessment

At the end of the cycle, tea was pruned at a height of 50-60 cm. Dry weight of prunings, girth at the collar and tipping weights after re-growth of shoots are indicated in Fig.2 and 3 respectively. Measurements indicate that continuous use of all herbicides affected the growth and girthing. Plots treated with glyphosate and sulphosate had significantly lower girth compared to all other treatments, while plots treated with cocktail mixtures had significantly lower girth than all manual methods of weeding.

However, there was no difference in girth measurements between chemical weeding with paraquat, slash weeding and manual weeding at every 3 months. Manual weeding every month (T1) indicate significantly higher girthing than all other treatments. There was a significantly lower pruning dry weight in plots treated with glyphosate and sulphosate compare to all manual methods of weeding. There was no significant difference in the pruning weight between plots treated with paraquat and manual methods. These trends are also reflected in dry weight of tippings (Fig.3).

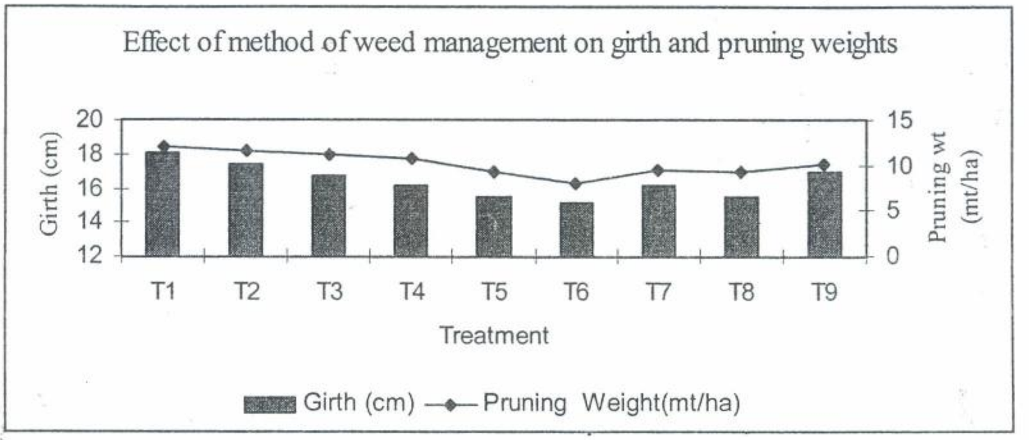


Figure 2 – Effect of method of weed management on girth and pruning weights

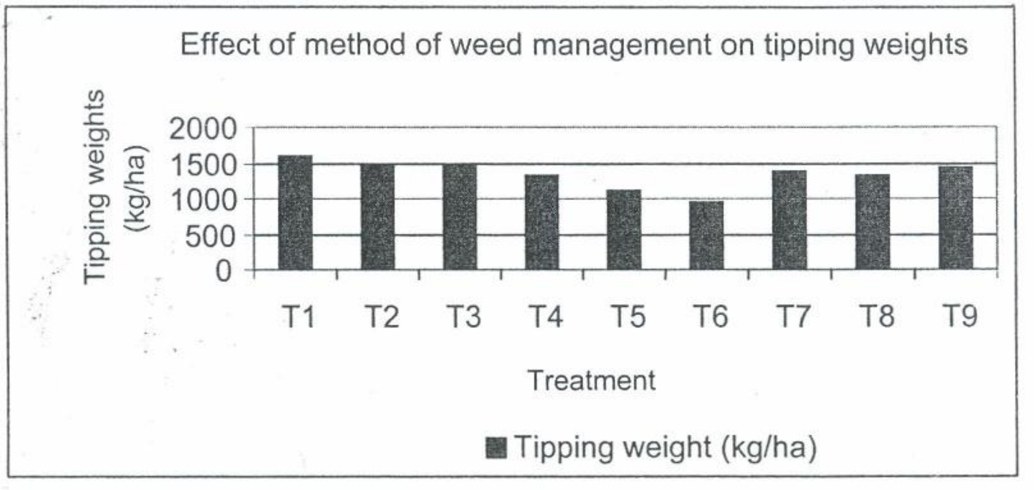


Figure 3 – Effect of method of weed management on tipping weights

(b) Soil Measurements

Soil Organic Carbon and Microbial Carbon

Soil organic carbon and microbial carbon were analyzed at the end of the cycle by taking a composite sample for each treatment. The results, though not analyzed statistically clearly indicate that plots treated with glyphosate and sulphosate exhibited low microbial activity and hence the lowest microbial carbon status (Figure 4). There was low soil organic carbon content in plots manually weeded every 2 and 3 months compare to plots weeded every month. This may be attributed to the removal of weeds from plots weeded every 2 and 3 months compare to retention of weeds in plots manually weeded every month where there was a higher organic carbon content. Except in plots weeded with diuron where the organic carbon content was low, there was no difference between other treatments. Analysis of microbial carbon content also follows the same trend. It is evident that chemical weeding with both glyphosate and sulphosate had reduced microbial population, which may be attributed to low weed biomass on which microbes can survive

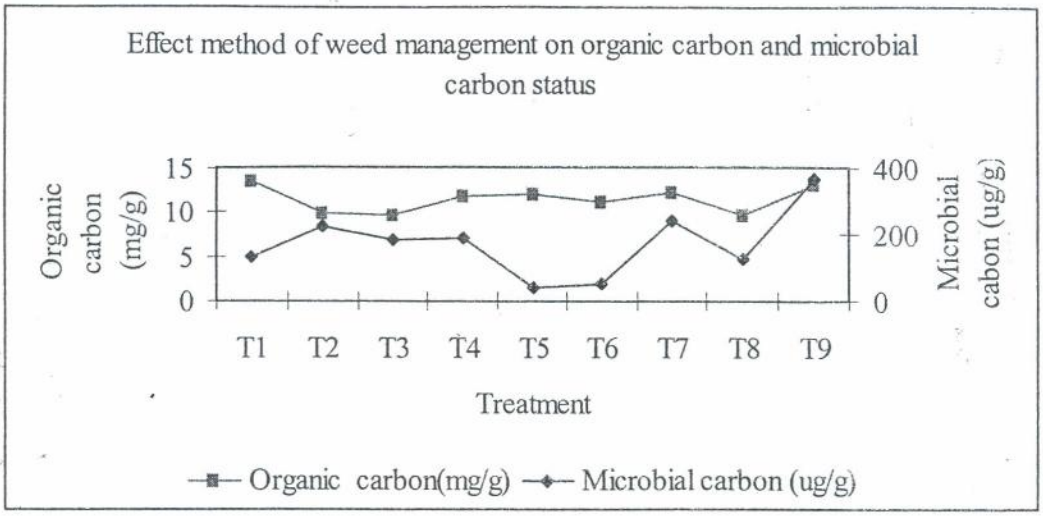


Figure 4 – Effect of method of weed management on organic carbon and microbial carbon status

Earthworm activity

Earthworm population was also assessed prior to treatment application, 3rd year 5th year and a year after final application. Results indicate that compared to manual methods, chemical methods had significantly reduced the activity of earthworms and hence exhibited a low population of earthworms (Figure 5). Among chemicals, all systemic herbicides significantly reduced the earthworm population than paraquat treatment. In the glyphosate and sulphosate treatments, this may be attributed to depletion of organic matter which is basic food source of worms. Even one year after the final treatment application the earthworm population remained low.

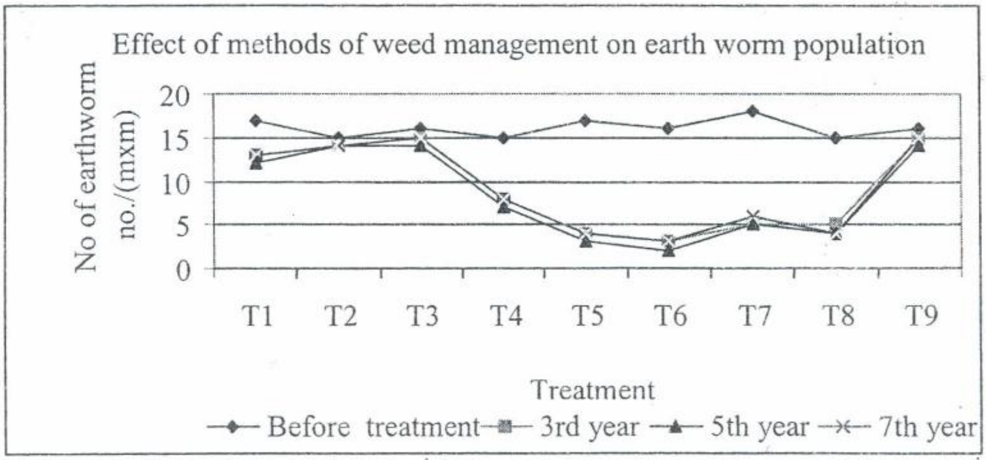


Figure 5 - Effect of methods of weed management on earthworm population

Based on the results, it appears that manual weeding is the best option to sustain the growth and yield of tea that is also eco-friendly in relation to microbial and earthworm population. Further, systemic herbicides and cocktail mixtures at the rate of 4 rounds per application per year adversely affect the growth, yield, recovery from pruning of tea and population of microorganisms and earthworms. However, contact herbicide (paraquat) at the rate of 4 applications per year is comparable with manual weeding. This study reveals that repeated application of systemic herbicides affect productivity which substantiate the recommendation that limit the annual application of systemic herbicides in tea (Anon 2000). Therefore, it is advisable to follow an integrated approach on weed management that includes all manual, chemical and cultural methods.

ACKNOWLEDGMENTS

The assistance received from Mrs. S.N. Wijesekara, Experimental Officer, Agronomy Division, Tea Research Institute of Sri Lanka is greatly appreciated.

REFERENCES

Anon.2000. A cautionary Note. TRI Guidelines on use of glyphosate in tea, Tea Research Institute of Sri Lanka

Ekanayake P B. 1994. Weed management in tea plantations, Weed management for developing countries, FAO Plant production and protection paper, 120 FAO, Rome: 360-363

Mapa,R.B; Somasiri.S and Nagarajah.S. 1999 Soils of the wet zone of Sri Lanka, Morphology, Characterization and Classification. Special publication No:1 Soil Science Society of Sri lanka.29-30

Marambe B; Jayaweera, J.M.A.K and Hitinayake, H.M.G.S.B 2003. Paraquat-resistant *Crassocephelum crepidiodes* in Sri Lanka. Proceedings of the 19th Asian-Pacific Weed Science Society (APWSS) Conference held in Manila, Philippines on 17th –21st March 782-787

Marambe B; Nissanka, S.P; de Silva.L; Anandacoomraswamy, A and Priyantha, M.G.D.L 2002. Occurrence of paraquat-resistant *Erigeron sumatrensis* (Retz.) in up country tea lands of Sri Lanka.Journal of Plant Diseases and Protection XVIII, 973-978

Prematilaka K.G and Ekanayake P.B.2004. Be cautious in use of glyphosate on tea plantations. Journal of the National Institute of Plantation Management 20 (2), 1-7.

Prematilaka K.G 2003.Weed management in tea in Sri Lanka. In W.W.D.Modder, (ed). Twentieth Century Tea Research in Sri Lanka. Pages 63-72

Sparling G P; Felthans C W; Raynolds J; Westa W and Singletan P. 1990. Estimation of soil microbial carbon by fumigation extraction method, use on soil of high organic matter content and a re-assessment of the CEC factor. Soil Biology & Bio Chemistry 22, 301-307

Walkley A and I.A.Blak.1934.An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science 34:29-38

Wijeratna M.A.2001 Shoot growth and harvesting of tea, Tea Research Institute of Sri Lanka. Pages 45

Biodiversity and Plant Extinction

Assessment of sulfonylurea herbicides to the diversity of aquatic plant in paddy farming system

T. S. Park[1], C. S. Kim[1], B. C. Moon[1] and O. D. Kwon[2]

[1]National Institute of Agricultural Science and Technology, RDA, Suwon 441-707, Korea, jlpark@rda.go.kr

[2]Chonnam Agricultural Research and Extension Service, Naju 520-830

Abstract: These studies were conducted to evaluate the response of some aquatic plants to sulfonylurea (SU) herbicides which have been used widely in rice-cropping areas in Korea, and the possibility of using them as indicator species for biodiversity conservation. The distribution of main aquatic plants in paddy farming system was the clear difference between Chonnam and Gangwon provinces where SU-herbicides and butachlor have been used extensively for many years, respectively. The GR_{50} values of bensulfuron-methyl (BSM) and pyrazosulfuron-ethyl (PSE) to *M. korsakowii, M. quadrifolia* and *S. natans* were relatively very low compared with those of butachlor and molinate. Three aquatic plants tested were inhibited by water samples collected from irrigation ditches of rice fields where were treated with pyrazosulfuron/fentrazamide and azimsulfuron/molinate. The concentration of PSE and azimsulfuron analyzed from water samples were 0.6 and 0.4 ppb, respectively.

Key words: Aquatic plant, herbicide, sulfonylurea

INTRODUCTION

The rapid decline of agricultural labor since the 1980's Korea modernized the pattern of rice cultivation, such as infant-seedling transplantation, direct seeding, no-tillage cultivation and other technologies which led to the reduction of production cost in rice cultivation (Kim *et al*, 200). However, without herbicides, it is impossible to reduce rice production cost. Furthermore, if it had not been for sulfonylurea (SU) herbicides which have high herbicidal activity with a low application rate and good crop selectivity, the new techniques of rice cultivation would be failed because of weeds (Itoh *et al*, 1987, Ueji *et al*, 2001) It is widely anticipated that the use of SU-herbicides is likely to increase more steeply with the increase of arable land per farmhouse due to rice import (Aida *et al* 20040. In contrast, abundant food and improved quality of life because of safe food and various advanced technologies such as sustainable agriculture, organic farming, low input farming, environmentally harmonious farming will still be used up to now. The biodiversity in the rural ecosystems may have been threatened by the loss of habitats and water pollution as a result of the various agricultural chemicals used in rice fields. Aquatic plants surviving mainly in paddy fields, irrigation ditches, and irrigation ponds can be affected seriously by herbicides used in paddy fields. However, susceptibilities of aquatic plants to herbicides have been hardly studied. These studies were conducted to evaluate the response of some aquatic plants to SU-herbicides which have been used widely in rice-cropping areas in Korea and Japan, and the possibility of using them as indicator species for biodiversity conservation.

MATERIALS AND METHODS

Survey procedures

A survey system was developed and used to ascertain the distribution of aquatic plants by regional groups according to herbicides used in paddy farming system of Korea. The survey area was divided into Chonnam and Kangwon provinces where SU-herbicides and butachlor have been used for many years, respectively. The survey centers in Chonnam and Kangwon provinces were Naju(35°01'N, 126°51'E) and Pyeongchang(37°31'N, 128°33'E), respectively. Twenty sample areas in each province, and 20 sites for each sample area, were surveyed in July, 2000 and 2004, respectively. Sampling sites were: paddy fields, irrigation ditches and irrigation ponds.

Experimental plants

Three aquatic plants, *Monochoria korsakowii, Marsilea quadrifolia* and *Salvinia natans* were used in this study. Seeds of *M. korsakowii* were obtained from the reservoir in Pyeongchang (37°31'N, 128°33'E), Kangwon province where herbicides have never been used. Plants of *M. quadrifolia* and *S. natans* were obtained from irrigation pond in Changnyeong (35°28'N, 128°31'E), Kangwon province

Exposure experiments to herbicides

The experiment was conducted with three replications under a growth chamber (E-15, Conviron's, canada) maintained at 27/22 (day/night), and 12 hrs photoperiod (day/night). Twenty germinated seeds of *M. korsakowii* having plumule of 2~3mm and 15 plants of *M. quadrifolia* having rhizome of 3 cm length with a terminal bud were transplanted to plastic pots(20cm×20cm×15cm) filled with paddy soil(clay loam) 10 days before herbicide application, respectively. Fifteen plants of *S. natans* with 4~6 leaves were transplanted to plastic pots(20cm×20cm×15cm) filled with culture solution 3 days before herbicides application. The water level was maintained at 5 cm above the soil.

The application rates of four herbicides were 1/100, 1/50, 1/25, 1/10 and 1 time of the recommended dose of the respective herbicides. For *M. korsakowii*, 1/500, 1/100, 1/50, 1/10, 1/5 and and 1 time of the recommended dose for *M. quadrifolia* and *S. natans*. All the plants were collected 20 days after herbicide application and were oven-dried for 2 days at 60 to determine biomass. Data were expressed as percentage of untreated control to standardize herbicides tested. GR_{50} values were calculated from exhibiting 50% reduction of dry weight against each aquatic plant treated with different herbicide rates, and all treatments for each measurement were in triplicates.

Response of the aquatic plant to herbicides runoff from rice fields

This experiment was conducted to investigate impact assessment of herbicide runoff from paddy fields to aquatic plants. Water samples were collected 15 days after herbicides application from irrigation ditches which PSE/fentrazamide and azimsulfuron/molinate had been used in rice fields of 20 and 15 ha, respectively. The number of internodes and dry weight of *M. quadrifolia* were determined 20 days after application with water sampled from irrigation ditches. The concentrations of herbicides in sampled water were analyzed by the standard method of respective herbicides.

RESULTS AND DISCUSSIONS

Survey of aquatic plants

The biodiversity including aquatic plants in paddy farming system has been threatened due to the loss of habitats and water pollution caused by the runoff of agrochemicals and the pavement of irrigation ditch, and others and most especially because of herbicides. However, aquatic plants can be affected differently according to herbicides used.

Tables 1a and 1b show distribution of main aquatic plants in paddy farming system of Chonnam and Gangwon provinces where SU-herbicides and butachlor have been used extensively for many years, respectively.

The aquatic plants seen in Kangwon were much more varied compared to the two provinces. but were also observed in paddy, irrigation ditch and pond. Nine species of aquatic plants listed as threatened species by the Environment Agency of Japan were confirmed in Kangwon province. Six species of these nine aquatic plants occurred in rice fields. However, 10 species which include only three threatened species as listed by the Environment Agency of Japan were confirmed in Chonnam province.

Table 1a. Distribution of main aquatic plants in paddy farming system of Chonnam province, Korea

Family	Species[a]	Distribution		
		Paddy	Irrigation	
			Ditch	Pond
Azollaceae	**Azolla imbricata* (Roxb.)Nakai	O	O	O
Commelinaceae	*Aneilema keisak* Hassk.	O	O	
Lemnaceae	*Spirodela polyrhiza* (Linn) Schleiden	O	O	O
Lythraceae	**Rotala leptopetala* (Blume) Koehne var. *Littorea*(Mig.) Koehne		O	
Menyanthaceae	*Nymphodes coreana* (Lveill)Hara			O
Nymphaeaceae	*Brasenia schreberi* J.F. Gmelin			O
Nymphaeaceae	*Euryale ferox* Sailsbury			O
Potamogetonaceae	*Potamogenton oxyphyllus* Mig.			O
Pontederiaceae	**Monochoria korsakowii* Regel	O	O	
Saxifragaceae	*Penthorum chinense* Pursh	O		
Trapaceae	*Trapa japonica* Flerov		O	O

[a]Asterisks indicate aquatic species listed as threatened species by the Environment Agency of Japan.

Table 1b. Distribution of main aquatic plants in paddy farming system of Kangwon province, Korea

Family	Species[a]	Distribution		
		Paddy	Irrigation	
			Ditch	Pond
Azollaceae	**Azolla imbricata* (Roxb.)Nakai	O	O	O
Commelinaceae	*Aneilema keisak* Hassk.	O	O	
Hydrocharitaceae	**Blyxa aubertii* L.C.Rich	O	O	
Hydrocharitaceae	*Blyxa japonica*	O	O	
Hydrocharitaceae	**Blyxa echinospema* Hook.f.	O	O	
Lemnaceae	*Spirodela polyrhiza* (Linn) Schleiden	O	O	O
Lythraceae	**Rotala leptopetala* (Blume) Koehne var. *Littorea*(Mig.) Koehne	O		
Marsileaceae	**Marsilea quadrifolia* L.	O	O	O
Menyanthaceae	*Nymphodes coreana* (Lveill)Hara	O		O
Nymphaeaceae	*Brasenia schreberi* J.F. Gmelin			O
Nymphaeaceae	*Euryale ferox* Sailsbury			O
Potamogetonaceae	*Potamogenton oxyphyllus* Mig.		O	O
Pontederiaceae	**Monochoria korsakowii* Regel et Maack	O	O	O
Ranunculaceae	**Ranunculus kadzusesis* Makino			O
Salviniaceae	**Salvinia natans* (L.)All.		O	O
Saxifragaceae	**Penthorum chinense* Pursh		O	
Trapaceae	*Trapa japonica* Flerov		O	O

[a]Asterisks indicate aquatic species listed as threatened species by the Environment Agency of Japan.

Exposure experiments to herbicides

The responses of *M. korsakowii* treated with the aforementioned four herbicides are shown in Fig. 1. Dry weights of *M. korsakowii* to the BSM and PSE were reduced by about 60-70% even at 1/00 times as well as almost completely reduced at 1/10 times of the recommended rate. The response of *M. korsakowii* to butachlor was less sensitive compared with the BSM and PSE: dry weights at 1/10 times and the recommended rates were reduced by about 85 % and 90%, respectively. However, of the four herbicides tested, molinate did not affect *M. korsakowii* : Dry weights of *M. korsakowii* were not affected by molinate even at the recommended rate.

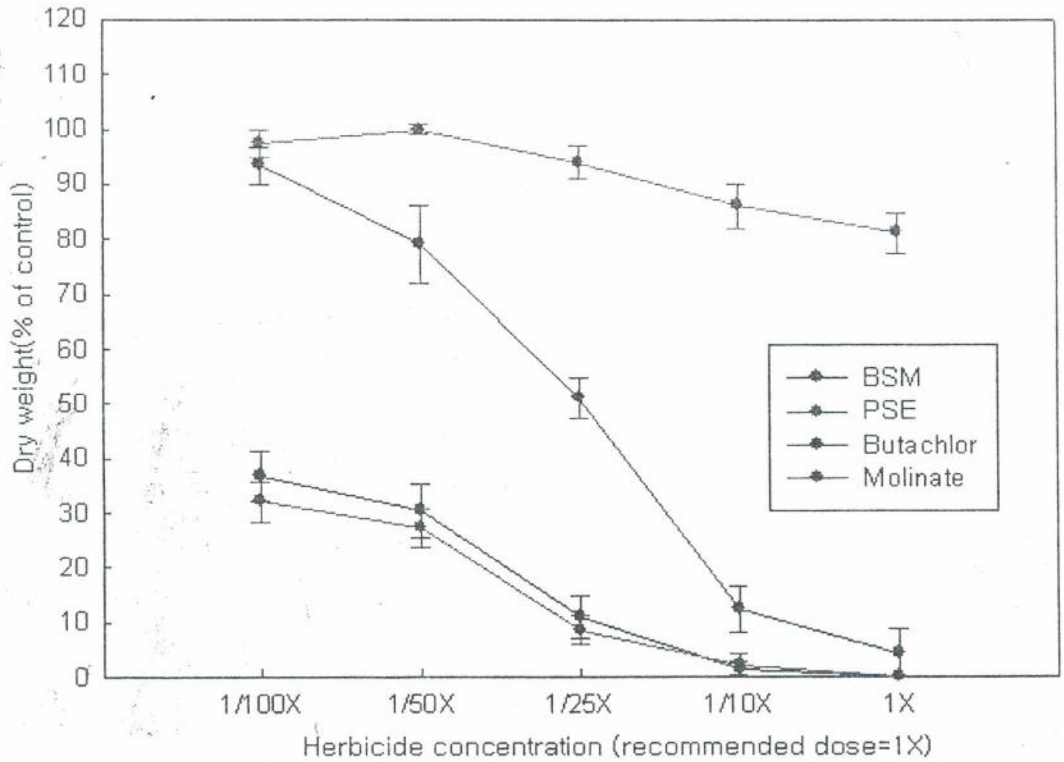


Fig. 1. Dry weight expressed as a percent of control *Monochoria korsakowii* to bensulfuron- ethyl (BSM), pyrazosulfuron-ethyl (PSE), butachlor and molinate 10 days after transplanting.

The recommended doses of BSM, PSE, butachlor and molinate are 51, 21, 1,500 and 1,500 g ai ha^{-1}, respectively. The vertical bars represent standard errors of the mean.

The survival rates of *M. korsakowii* to BSM, PSE, butachlor and molinate were somewhat different compared with the responses of dry weight to herbicides. The survival rates of *M. korsakowii* to BSM, PSE started to decrease steeply at 1/50 times of the recommended rate of each herbicide, and completely controlled at the recommended rate. However, the survival rate to butachlor and molinate were much less sensitive compared with those of BSM and PSE, especially not almost affected by molinate even at the recommended rate (Fig. 2).

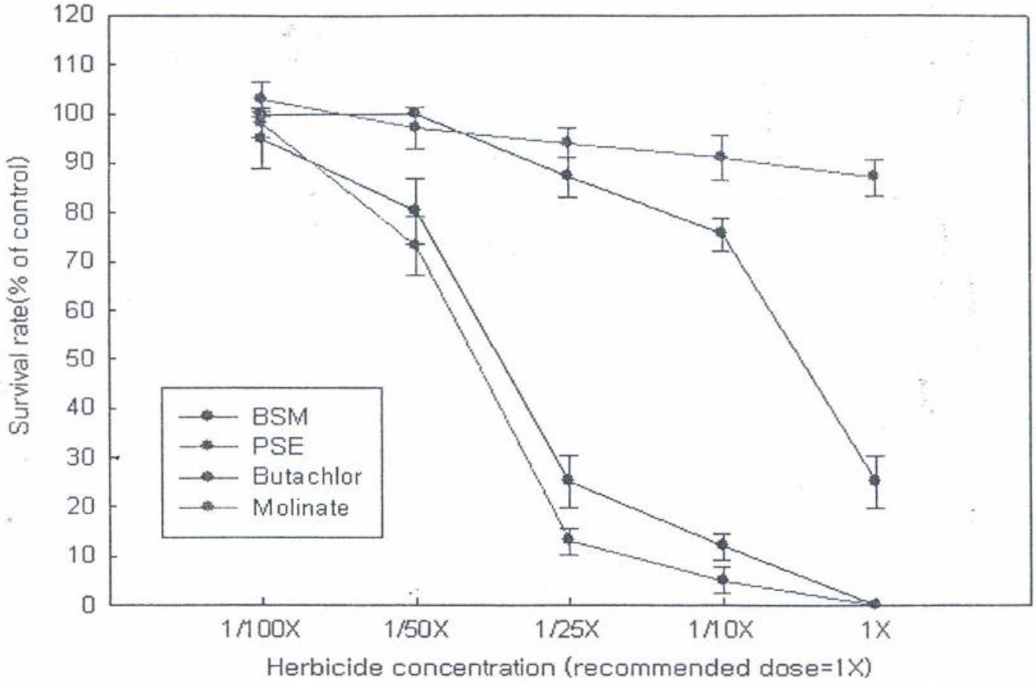


Fig. 2. Survival rate is expressed as a percent of control *Monochoria korsakowii* to bensulfuron-methyl (BSM), pyrazosulfuron-ethyl(PSE), butachlor and molinate 10 days after transplanting. The recommended doses of BSM, PSE, butachlor and molinate are 51, 21, 1,500 and 1,500 g ai ha^{-1}, respectively. The vertical bars represent standard errors of the mean.

Fig. 3 shows the dry weight expressed as a percent of control of *M. quadrifolia* to bensulfuron-methyl (BSM), pyrazosulfuron-ethyl (PSE), butachlor and molinate 10 days after transplanting. Dry weighs of *M. quadrifolia* to BSM and PSE, SU-herbicides, began to decrease sharply from 1/500 times of the recommended doses, and completely controlled at 1/10 times. In contrast, dry weighs of *M. quadrifolia* were hardly affected by butachlor and molinate enough to show 70% and 90% of untreated plant dry weights even at the recommended dose, respectively.

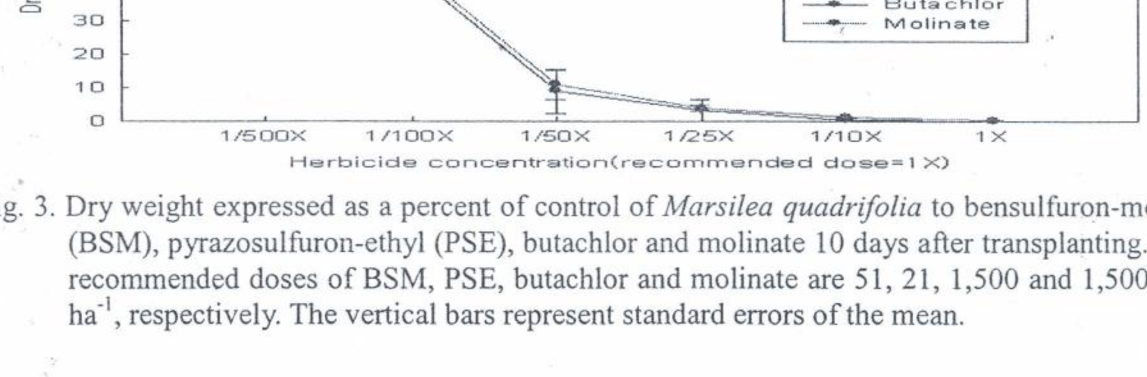


Fig. 3. Dry weight expressed as a percent of control of *Marsilea quadrifolia* to bensulfuron-methyl (BSM), pyrazosulfuron-ethyl (PSE), butachlor and molinate 10 days after transplanting. The recommended doses of BSM, PSE, butachlor and molinate are 51, 21, 1,500 and 1,500 g ai ha^{-1}, respectively. The vertical bars represent standard errors of the mean.

The response based on internodes of *M. quadrifolia* to four herbicides tested shows very similar trend compared with that of dry weight: The internodes of *M. quadrifolia* from over 1/25 times herbicide dose of BSM and PSE were almost completely inhibited, but those of butachlor and molinate ranged from approximately 75% to 90% of the control (Fig. 4).

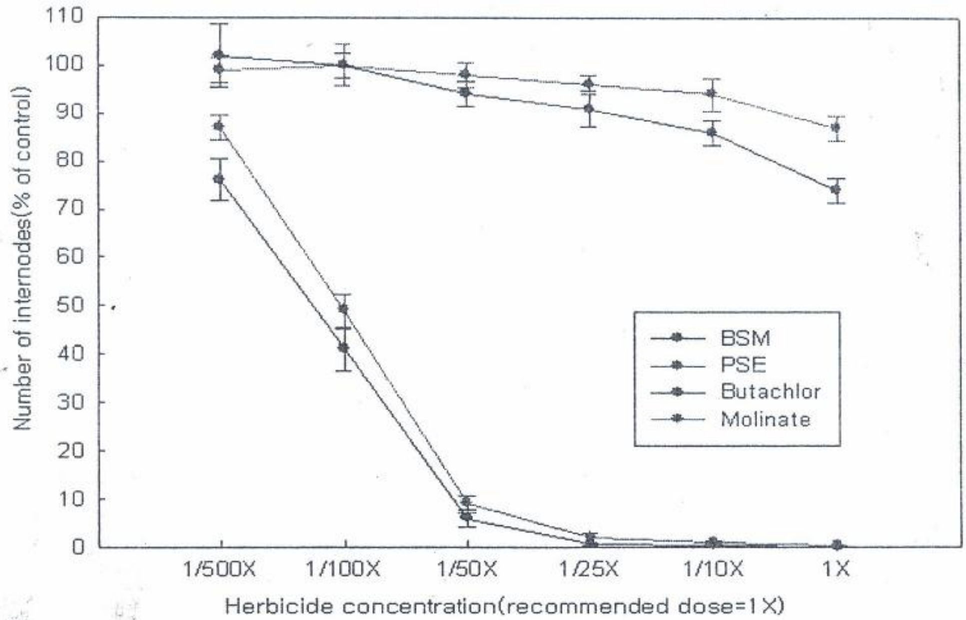


Fig. 4. Number of internodes expressed as a percent of control of *Marsilea quadrifolia* to bensulfuron-methyl (BSM), pyrazosulfuron-ethyl (PSE), butachlor and molinate 10 days after transplanting. The recommended doses of BSM, PSE, butachlor and molinate are 51, 21, 1,500 and 1,500 g ai ha^{-1}, respectively. The vertical bars represent standard errors of the mean.

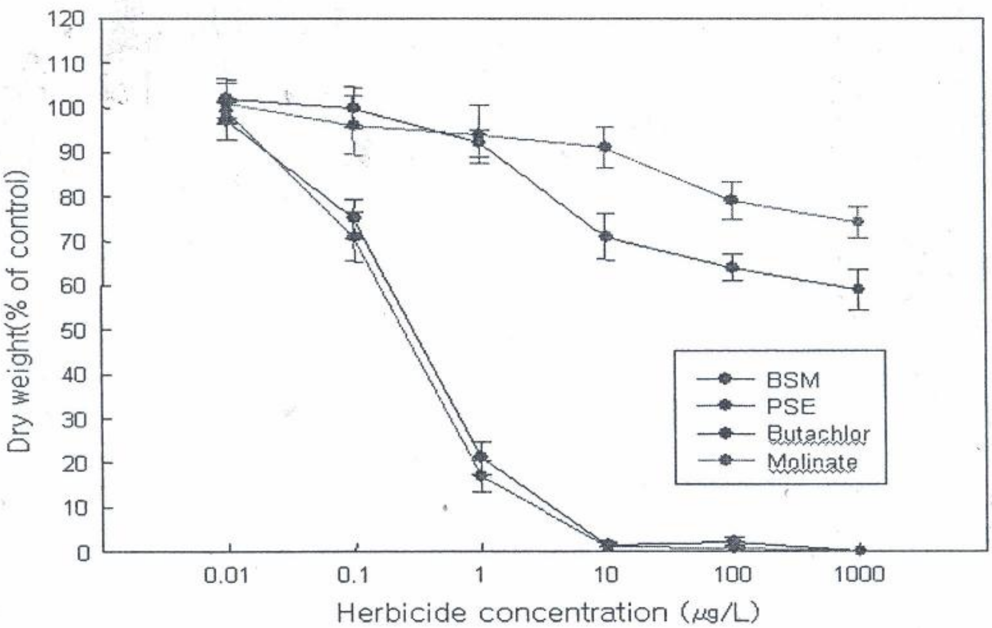


Fig. 5. Dry weight expressed as a percent of control of *Salvinia natans* to bensulfuron- methyl (BSM), pyrazosulfuron-ethyl (PSE), butachlor and molinate 10 days after transplanting. The recommended doses of BSM, PSE, butachlor and molinate are 51, 21, 1,500 and 1,500 g ai ha^{-1}, respectively. The vertical bars represent standard errors of the mean.

Dry weighs of *S. natans* to BSM and PSE, SU-herbicides, began to decrease sharply from 0.01 ppb, and controlled completely at 10ppb. Responses to butachlor were relatively much less sensitive than those of SU-herbicides tested: Dry weights ranged from 60% to 70% of the untreated plant dry weights at 10~1,000 ppb. However, dry weights of *S. natans* were hardly affected by molinate enough to show about 80% of the untreated plant dry weights even at 1,000ppb.

The number of leaves of *S. natans* per pot treated with aforementioned four herbicides has no marked difference compared with dry weights of four herbicides.: The number of leaves of plants treated with BSM and PSE, SU-herbicides was completely inhibited in 10ppb, but those treated with butachlor and molinate were approximately 60 and 80% of the untreated plant leaves (Fig. 6).

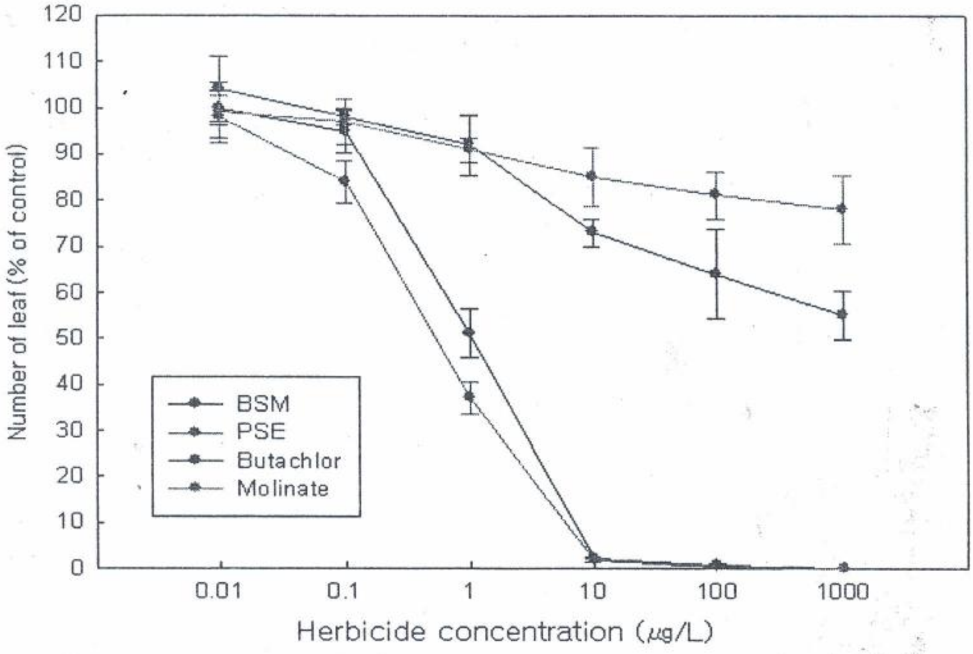


Fig. 6. The number of *S. natans* leaf expressed as a percent of control in pot treated with bensulfuron-methyl (BSM), pyrazosulfuron-ethyl (PSE), butachlor and molinate 10 days after transplanting. The recommended doses of BSM, PSE, butachlor and molinate are 51, 21, 1,500 and 1,500 g ai ha^{-1}, respectively. The vertical bars represent standard errors of the mean.

Regression equations of data in dry weights of *M. korsakowii*, *M. quadrifolia* and *S. natans* to BSM, PSE, butachlor and molinate were used to calculate GR_{50} values (Table 2). The GR_{50} values of BSM and PSE, SU-herbicides, for *M. korsakowii* were relatively very low <0.51 and <0.21 compared with 67.4 and >1,500 of butachlor and molinate, respectively. Also the GR_{50} values of BSM, PSE, butachlor and molinate for *M. quadrifolia* and *S. natans* were similar to those of *M. korsakowii*.

Table 2. Herbicide concentrations required for 50% inhibition of dry weight (GR_{50}) of *Monochoria korsakowii*, *Marsliea quadrifoli* and *Salvinia natans* to bensulfuron-methyl(BSM), pyrazosulfuron-ethyl(PSE), butachlor and molinate.

Species	GR_{50}[a]			
	BSM[1)]	PSE[2)]	Butachlor	Molinate
Monochoria orsakowii	<0.51	<0.21	67.4	>1,500
Marsilea quadrifolia	0.6	0.2	>1,500	>1,500
Salvinia natans	0.5	0.3	>1,000	>1,000

[a]The units for GR_{50} are g ai h^{-1} for *Monochoria orsakowii* and *Marsilea quadrifolia*, and ppb for *Salvinia natans*.

Table 3 shows the concentration of herbicides analyzed from water samples collected from irrigation ditches of rice fields 20 (sample 1) and 15 ha (sample2) treated with pyrazosulfuron/ fentrazamide and azimsulfuron/molinate, respectively. The concentrations of PSE and fentrazamide detected from sample 1 were 0.6 and 4.1 ppb, and those of azimsulfuron and molinate from sample 2 were 0.4 and 21.7 ppb, respectively.

Table 3. The concentration of herbicides in water samples collected from irrigation ditches 15 days after herbicides application.

Sample	Herbicide	Recommended dose in Korea (g ai ha^{-1})	Herbicide concentration in water sample (µg /L)
Sample 1[1)]	PSE	21	0.6
	Fentrazamide	300	4.1
Sample 2	Azimsulfuron	15	0.4
	Molinate	1,500-21,00	21.7

1) Sample 1 and 2 were collected from irrigation ditches treated with
2) Pyrazosulfuron (PSE)/fentrazamide and azimsulfuron/molinate in rice fields of 20 and 15 ha.

The number of internode and dry weight of *M. quadrifolia* in samples 1 and 2 were seriously inhibited (Table 4). The number of internodes of *M. quadrifolia* in samples 1 and 2 were 2.1 and 1.7%, and dry weights in samples 1 and 2 were 1.4 and 0.9% of untreated plants, respectively.

Table 4. The responses of *Marsilea quadrifolia* in water sampled from irrigation ditches 15 days after herbicides application

Sample	Number of internode	Dry weight
	----------% of control---------	
Sample 1[1)]	2.1	1.4
Sample 2	1.7	0.9

Sample 1 and 2 were collected from irrigation ditches treated with pyrazosulfuron(PSE)/ fentrazamide and azimsulfuron/molinate in rice fields of 20 and 15 ha

LITERATURE CITED

Itoh, K., 1987. Relationship between water pollution and aquatic plants on agro-ecosystem. 226-231. In "Studies on Convervation of Water Quality in Agro-Ecosystems" MAFF, Japan (in Japanese)

Itoh, K., s. Nishimura, M. Ishizaka, M. Aida and K. Takagi, 2001. Herbicidal effect of sulfonylureas for an arrowhead plant(Sagittaria trifolia forma suitensis). J. Weed Sci. & Tech. 46 (suppl.): 20-21 (in Japanese)

K. U. Kim, Tae Seon Park and Jae Eup Park. 2000. Present situation herbicide resistant paddy weeds in Korea. International workshop on biology and management of Noxious weeds for sustainable and labor saving rice production. 160-168.

M. Aida, Kazuyuki, Hiroaki Ikeda, Yasuo Ishii and Kenji Usui. 2004. Susceptible of some aquatic ferns to paddy herbicide bensulfuron-methyl. Weed biology & Management 4, 127-135.

Ueji, M. and K. Inao(2001) Rice paddy field herbicides and their effects on the environment and ecosystem. Weedy biology & Management. 1 (1): 71-79.

Effects of chemical herbicides on toxicity of nontarget fixing-nitrogen cyanobacteria in paddy fields in China

J.Y. Shen, Y. T. Lu, X. H. Wang, and G. H. Cheng
School of Agriculture and Biology, Shanghai Jiaotong University, Shanghai, China,
2678 QiXin Rd. Shangai 201101, jyshen88@sjtu.edu.cn

Abstract: The toxicity test of four kinds of herbicides on *Anabaena azotica*, *Anabaena sphaerica*, *Anabaena variabilio* and *Anabaena flos-aquae* indicated that the herbicides had the different toxicity to algae, and the algae had the different degree of sensitivity to herbicides. MCPA stimulated the growth of fixing-nitrogen algae; butachlor and acetochlor could stimulate the growth of cyanobacteria under low concentration, and showed strong toxicity as its concentration above 16 mg L-1; prometryne restrained algal growth and caused immediate death even at low concentration. However, the effect of light and agrochemical N-fertilizer on monosulfuron toxicity to algal mixotrophic growth has been studied. Under three light intensities and three urea fertilizer concentration, the seven concentrations of monosulfuron tested can significantly inhibit algal growth in a dose-dependent manner. The growth rate decreased with increasing concentration, and these effects appear to be greater at 2085 lux than 3716 lux, and 0.8 mg L-1 (N-content) than 0.2 mg L-1. It was demonstrated that different concentrations of monosulfuron had different effects on chlorophylla, biliprotein, and protein, which varied with light intensity and N-content. Therefore, selection of safe herbicides to algae is very important for agriculture to sustain development, decrease environmental deterioration, as well as increase the biodiversity of the countryside.

Key words: Growth, light, photosynthetic pigments, urea.

INTRODUCTION

Soil algae, particularly nitrogen-fixing cyanobacteria, are important photosynthetic microoganisms because they contribute to soil fertility by fixing the atmospheric nitrogen (Sinha and Kumar 1992). They are also quite sensitive to herbicides because they have many characteristics of higher plants (El-Sheekh et al. 1994). Many effects of herbicides on non-target algae, such as algal growth, photosynthesis, nitrogen fixation, and metabolic activities have been reported (Shen et al. 2004). However, little attention is given on the use of herbicides safe to nitrogen-fixing cyanobacteria.

The previous studies, however, were conducted under standard phototoxicity test condition involving only the results of photoautotrophic growth of algae. In fact, in the fields, the algae grown in soil or inland waters are mixotrophic rather than autotrophic (Ogawa and Aiba 1981), and herbicide toxicity to algae is affected by many environmental factors such as nutrient level (Mohapatra and Mohanty 1992), temperature, and light (Gaur and Singh 1991). However, little is known about the specific roles of these environmental factors.

Therefore, this research aimed at studying the effects of common herbicides on growth of nitrogen-fixing cyanobacteria and light or urea on herbicide toxicity to algae mixotrophic growth and photosynthetic pigments, attempting to compare and assess the effect of herbicides toxicity to nitrogen-fixing cyanobacteria.

MATERIALS AND METHODS

Algae were obtained from the Institute of Hydrobiology, Chinese Academy of Sciences. Axenic cultures were grown in a liquid sterilized medium at 30 ±2 ℃ under florescent light illumination of intensity 2790 lux for 14 h day^{-1}. Monosurfuron {2-nitro-N-[2-(4-methyl pyrimidine)yl]-benzol-sulfonyl urea, molecular formula is $C_{12}H_{11}N_5O_5S$}, 99.6 % of active ingredient (a.i.), was obtained from the National Pesticide Engineering Research Center, China. MCPA, butachlor, acetochlor, prometryne, and urea, technical grade, were purchased from a commercial source. Stock solutions were freshly prepared before being added to the culture medium, respectively.

The experimental cultures were first grown in 500-ml flasks containing 150 ml of sterilized medium under the same conditions as described above. Herbicides from stock solution were added to the culture medium at the desired concentration. Without herbicide and urea served as controls. Two sets of culture medium were incubated in a constant-temperature room at 30±2 ℃ to compare the effect of herbicide on mixotrophic growth of algae under different fluorescent light illumination of intensity and N-content (urea) concentrations. Each concentration was replicated three times. During the experimental period, samples were withdrawn after herbicide treatment at 0, 1, 2, 3, 4, 5, and 6 days for mixotrophic growth, and at 3, 5, and 7 days for chlorophyll a, caroteniod, and biliprotein determination, respectively.

Growth of algae was measured by recording light absorbance of the culture at 485 nm with spectrophotometer. For dry weight, corresponding cultures in triplicates were pelleted; and the pellet was washed with distilled water three times and then dried to constant weight at 105℃ for 8 h. Chlorophyll a was extracted with 90% methanol at 90 C for 3 min and estimated using absorbance at 665 nm. The algal biliproteins were extracted by repeatedly freezing and thawing the pellet in the presence of 0.05 M phosphate buffer (pH 6.7). The solution was centrifuged at 3000 g for 15min, and the absorbance at 618 nm measured. The growth rate (μ) of the algae was calculated by: $\mu=(\ln X_1-\ln X_0)/(T_1-T_0)$, where X_1 represents the absorbance at 485 nm at time T_1, and X_0 represents the absorbance at 485 nm at time T_0.

All experiments were conducted twice. Because trials of each duplicated experiment resulted in the same trend, the results were combined. Analyses of variance and regressions were performed using Microsoft Excel procedure.

RESULTS AND DISCUSSION

Effects of common herbicides on growth of nitrogen-fixing cyanobacteria

Destruction of economically important microflora by herbicides may cause ecological imbalance and a reduction in agricultural productivity. That herbicides had a significant effect on growth of non-target nitrogen-fixing cyanobacteria was illustrated in Fig. 1. MCPA, a popular herbicide, is known to stimulate growth of plant cells when it is used at low concentration. In our study, MCPA stimulated growth of algal species *Anabaena azotica* and *Anabaena sphaerica*. However, it inhibited growth of *Anabaena variabilio* that the growth rate was reduced, relative to the control, by 5.4, 12.0, 13.6 and 22.5% at 8, 16, 20 and 30 mg L^{-1} MCPA, respectively. Butachlor and acetotochor, two popular amide herbicides, stimulated growth of the three algae at low concentrations (ranging from 1 to 8 mg L^{-1}), exhibited an inhibitory effect on at higher concentrations and became toxic when the concentrations were 16 mg L^{-1}or higher. Prometryne, a triazine herbicides which inhibits photosynthesis of plant, was toxic to the algae; at 4 mg L^{-1} prometryne, growth of *Anabaena sphaerica*, *Anabaena variabilio*, and *Anabaena azotica* was reduced by 79.4, 71.2 and 69.1 %, respectively, while no growth was observed at 8 mg L^{-1}. The results clearly demonstrated that toxicity of herbicides to algae is dependent on their physiological mechanisms. To maintain ecological balance and improve rice yield, herbicides which inhibit nitrogen-fixing cyanobacteria in rice fields should not be applied to rice fields.

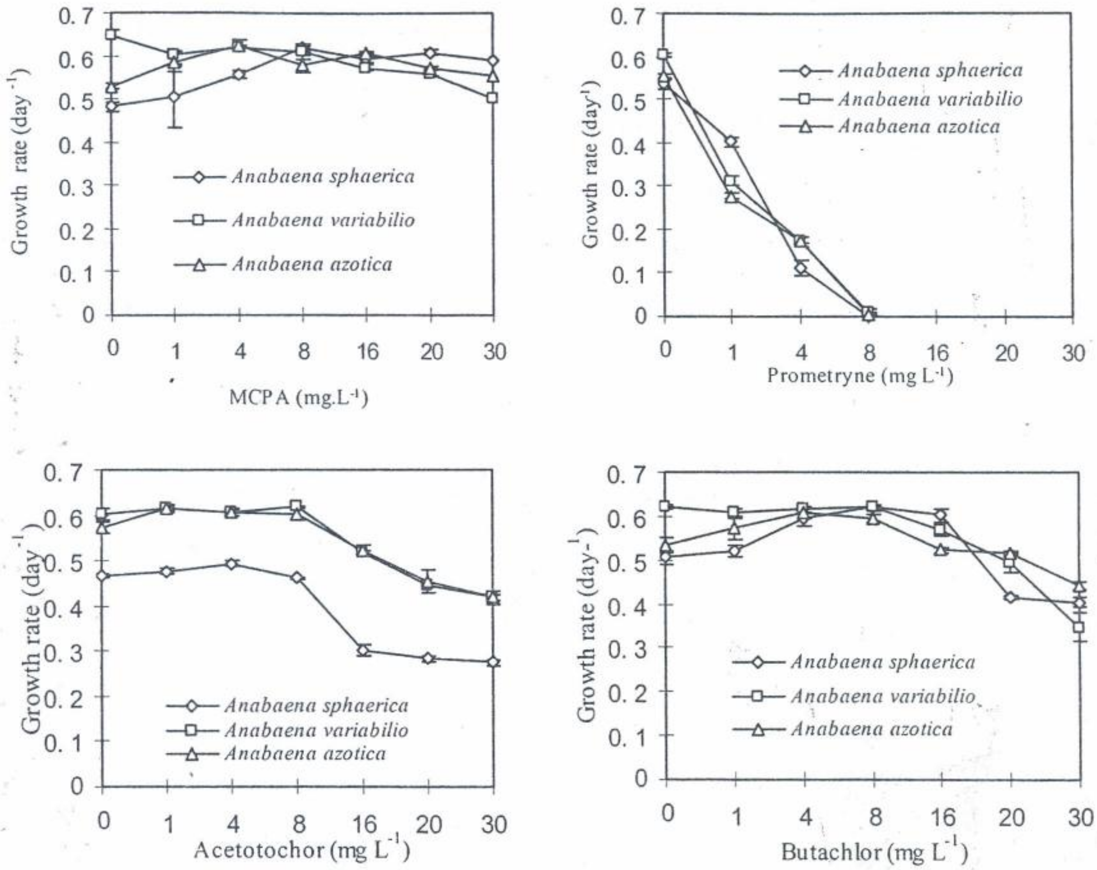


Figure1. Growth rates of nitrogen- fixing cyanobacteria treated with different herbicides after 4 days.

It is, therefore, imperative to select efficient and safe herbicides to microflora in rice field. Monosulfuron, a sulfonylurea herbicide recently developed in China, has been known to stimulate the growth algae at recommendatory concentration in rice field. For instance, under standard phytotoxicity test conditions (i.e., involving only the results of photoautotrophic growth of algae), the growth rates of *Anabaena sphaerica*, *Anabaena variabilio* and *Anabaena azotica* increased by 36.7, 38.6, and 11.9 % at 0.755 μg ml^{-1} monosulfuron, after 4 days, respectively. In the field, herbicide toxicity to algae is affected by many environmental factors such as chemical fertilizer, light, and temperature (Yan et al. 1997). The long-term effect of the herbicide on algae will naturally vary with changing light intensity (resulting from shading by the rice as it grows) and with the application of chemical fertilizers.

Effect of light on herbicide toxicity to algae mixotrophic growth and photosynthetic pigments

We performed a study to determine the effect of light on monosulfuron toxicity to mixotrophic algal growth. Our results (Table 1) showed that algal growth was stimulated as the light intensity increased and the effect of monosulfuron on growth under three light effect as the concentration increased from 0.0075 to 0.755 μg ml-1, but an inhibitory effect at concentrations above 7.549 μg ml^{-1}. *Anabaerica flor-squae* exposed to 2085 lux light was more sensitive to monosulfuron than those exposed to 3716 lux light. The effect of monosulfuron on chlorophyll a and carotenoid followed a dose-dependence manner, i.e., the chlorophyll a content decreased gradually as the concentration of monosulfuron increased from 0.0075 to 754.880 μg ml^{-1}. Of particular interest is the observation that the caroteniod content of algae treated with 0.075 and 0.755μg ml^{-1} monosulfuron under 2085 lux had a different stimulatory effect from that of treatments under 2790 and 3716 lux. The effect of monosulfuron on biliprotein content was similar to the effect on algal growth. Monosulfuron appeared to have different effects on the synthesis of the three pigments due to differences in chemical structures and other characteristics.

Table 1. Effects of monosufluron on growth and photosynthetic pigments of *Anabaerica flor-squae* after 5 days under three light intensities.

Light intensity (lux)	Concentration (μg ml^{-1})	Growth rate (day^{-1})	Chlorophyll a (μg mg^{-1} dry wt)	Carotenoid (μg mg^{-1} dry wt)	Biliprotein (μg mg^{-1} dry wt)
2085	Control	0.012	5.799	0.016	1.681
	0.008	0.006	5.900	0.021	2.457
	0.075	0.012	5.043	0.031	2.181
	0.755	0.024	3.149	0.014	1.125
	7.549	-0.046	0.276	0.019	0.436
	75.488	-0.059	0.135	0.014	0.230
	754.880	-0.095	0.024	0.004	0.036
2790	Control	0.015	6.625	0.042	3.700
	0.008	0.013	2.288	0.033	4.524
	0.075	0.014	3.161	0.013	4.350
	0.755	0.016	2.642	0.010	2.554
	7.549	-0.032	0.887	0.007	1.903
	75.488	-0.046	0.365	0.004	0.472
	754.880	-0.050	0.039	0.001	0.048
3716	Control	0.026	7.391	0.011	2.845
	0.008	0.024	6.236	0.008	2.806
	0.075	0.027	6.356	0.007	4.572
	0.755	0.030	6.104	0.005	2.846
	7.549	-0.045	3.341	0.004	1.192
	75.488	-0.089	0.580	0.004	0.314
	754.880	-0.078	0.074	0.001	0.077

Effect of urea on herbicide toxicity to algae mixotrophic growth and photosynthetic pigments

Our results (Table 2) demonstrated that chemical N-fertilizer on herbicide toxicity had a significant interactive effect on algal growth. Without herbicide, the growth rates after 7 days decreased markedly (by 40.6, 43.6, and 108.7 %) as the N-content of chemical fertilizer urea increased (from 0.05 to 0.20 to 0.80 mg L^{-1}, respectively), and no heterocyst was found. However, the content of chlorophyll a, carotenoid, and biliprotein under low intensities displayed contrary dose dependence; it had a stimulatory growth and formation of photosynthetic pigments in a dose-dependent manner (the toxicity increased with the herbicide concentration increased with its N-content from 0.05 to 0.20 mg L^{-1}. Table 3 also shows that, under three N concentrations, monosulfuron markedly inhibited the algal concentration of herbicide and/or urea, and it was clear that *Anabaerica flor-squae* grown under 0.8 mg L^{-1}N-content exhibited greater sensitivity to monosulfuron than under 0.05 mg L^{-1} N-content.

Table 2. Effects of monosufluron on growth and photosynthetic pigments of *Anabaerica flor-squae* after 7 days under different urea fertilizer concentration.

Monosulfuron ($\mu g\ ml^{-1}$)	N-Content ($mg\ L^{-1}$)	Growth rate (day^{-1})	Chlorophyll ($\mu g\ mg^{-1}$ dry	Carotenoid ($\mu g\ mg^{-1}$ dry	Biliprotein ($\mu g\ mg^{-1}$ dry
0	Control	0.076	1.801	0.016	0.530
	0.05	0.045	0.417	0.009	0.466
	0.20	0.043	0.771	0.003	0.457
	0.80	-0.007	0.002	0.003	0.448
0.0159	Control	0.083	0.901	0.008	0.281
	0.05	0.083	1.078	0.011	0.592
	0.20	0.026	1.464	0.011	1.169
	0.80	-0.005	0.147	0.001	0.075
0.0378	Control	0.085	1.300	0.012	0.401
	0.05	0.055	0.483	0.004	0.278
	0.20	0.016	0.387	0.003	0.343
	0.80	-0.050	0.230	0.001	0.020
0.0755	Control	0.088	0.937	0.007	0.334
	0.05	0.046	0.648	0.007	0.195
	0.20	0.008	0.674	0.006	0.181
	0.80	-0.089	0.194	0.000	0.000
0.1510	Control	0.070	1.338	0.012	0.665
	0.05	0.051	0.963	0.011	0.330
	0.20	0.046	0.420	0.004	0.368
	0.80	-0.011	0.272	0.002	0.248
0.3019	Control	0.081	0.860	0.006	0.344
	0.05	0.034	0.564	0.004	0.203
	0.20	0.047	0.226	0.002	0.152
	0.80	-0.078	0.048	0.000	0.015

Little is known on how lighting and chemical N-fertilizer affect the effects of herbicide on algal growth and formation of photosynthetic pigments. The results, however, have shown increased phytotoxicity to algae increased as light intensity and/or N-content of fertilizer increased. Gaur and Singh (1991) found similar results that phytotoxicity increased as light intensity and temperature increased in a study of effects of light and temperature on petroleum toxicity to *A. dolilum*. The results that monosulfuron toxicity to *Anabaerica flor-squae* increased with its concentration may be explained by a hypothesis that at a low herbicide concentration, algae might have assimilated monosulfuron as a source of organic carbon for its growth.

In summary, herbicides of paddy field have different toxicity to algae, and the algae had different degree of sensitivity to herbicides. Selection of herbicides non-harmful to microorganisms is important to maintain ecological balance and sustain agricultural productivity. Effectiveness of herbicides and its toxicity to algae depend not only on its chemical composition and dose of application but also on many environmental factors, for example its phytotoxicity increased as light intensity and N-content of chemical fertilizer increased.

ACKNOWLEDGEMENTS

We thank the Shanghai Science Committee for providing financial support for this project. We also thank all technical staffs who worked on this project.

LITERATURE CITED

EL-Sheekh M. M., Kotkat H. M. and Hammouda H. E. 1994. Atrazine herbicide on growth, photosynthesis, protein synthesis, and fatty acid composition in the unicellular green algae *Chlorella Kessler*. Ecotocxicol. Environ. Safety, 29:349-358.

Gaur J. P. and Singh A. K. 1991. Regulation influence of light and temperature on petroleum toxicity to *Anabaena doliolum*. Environ. Toxicol. Water Chem., 6: 341-350.

Mohapatra P. K. and Mohanty R. C. 1992. Differential effect of dimethoate toxicity to *Anabaena doliolum* with change in nutrient status. Bull. Environ. Contam. Toxicol., 48:223-229.

Ogawa T. and Aiba S. C. 1981. Bioenergetic analysis of mixotrophic growth in *Chlorella vulgaris* and *Scenedesmus acutus*. Biotechnol. Bioeng., 23: 1121-1132.

Shen J. Y., Lu Z. R., Lu Y. T. and Wang X. H. 2004. Progress on toxicity of nitrogen-fixing cyanobacteria to herbicides. World Pestic., 6:54-61.

Sinha R. P. and Kumar A. 1992. Screening of blue-green algae for biofertlizer. In Proceedings of the National Seminar on Organic Farming (P. S. Patil, Eds.), Pune, India. Pages 95-97.

Yan G. A., Yan X. and Wu W. 1997. Effect of the herbicide molinate on mixotrophic growth, photosynthetic pigments, and protein contect of *Anabaena sphaerica* under different light conditions. Ecotoxicol. Environ. Saf., 38: 144-149.

The development and activity of the external hyphae of *Glomus mosseae* after herbicides application

A. Pasaribu[1] and R. B. Mohamad[2]
[1]Monsanto Indonesia, Jakarta 12940 Indonesia
askif.pasaribu@monsanto.com
[2]Department of Crop Science, Universiti Putra Malaysia 43400, Selangor D.E., Malaysia

Abstract: The effect of herbicides on the development and activity of external hyphae of vesicular arbuscular mycorrhizal fungi, *Glomus mosseae* was studied in the greenhouse in 2003. The experiment was arranged in a completely randomized design (CRD) with four replicates. Four weeks after planting of peanut, alachlor (soil acting) and glyphosate (foliage acting) herbicides were applied separately as 20 mL soil drench per pot. The herbicide treatments consisted of 0.5, 1.0, 1.5, and 10 folds of the recommended rate (3.6 μg ai g^{-1} for alachlor and 2.16 μg ae g^{-1} for glyphosate). The rates were alachlor: 1.8, 3.6, 5.4, and 36 μg ai g^{-1} dry soil; glyphosate: 1.08, 2.16, 3.24, and 21.6 μg ae g^{-1} dry soil. The control treatments were not treated with herbicide and uninoculated with *G. mosseae*. At harvest, the external hyphae were stained for TB (trypan blue) and ALP (alkaline phosphatase) activity. The result showed that alachlor and glyphosate up to ten fold of the recommended rate did not affect the development and ALP activity of external hyphae of *G. mosseae*.

Key words: Active external hyphae, alachlor, alkaline phosphatase, glyphosate, vesicular-arbuscular mycorrhizal fungi.

INTRODUCTION

Vesicular-arbuscular mycorrhizal (VAM) fungi is associated with increased growth of many plant species. It is mainly due to an improvement in the phosphorus supply to the plant (Smith and Read 1997). The beneficial effect of VAM fungi on plant health and growth can be hampered by the use of pesticides. The various developmental and functional stages of VAM fungi are negatively affected by a number of pesticides (Trappe et al. 1984). Several authors have reported a range of effects of herbicides on VAM symbiosis which ranges from no adverse effects to slightly or highly toxic effects (Smith et al. 1981; Nemec and Tucker 1983; Trappe et al. 1984; Ocampo and Barea 1985). The external hyphae of VAM fungi take up and transport P to the host plant (Jakobsen et al. 1992), and acting as a source of inoculum (Sylvia 1992). P uptake into the host plant via the external hyphae was found to be hampered by some fungicides (Larsen et al. 1996; Merryweather and Fitter 1996; Kling and Jakobsen 1997).

Alkaline phosphatase (ALP) activity which is located within the phosphate-accumulating vacuoles of VAM hyphae, particularly along the fungal tonoplast (Gianinazzi et al. 1979; Smith and Gianinazzi-Pearson 1988), has been proposed as a physiological marker for analyzing the efficiency of mycorrhiza, an indicator of the proportion of hyphae involved in phosphorus metabolism in VAM symbiosis (Tisserant et al. 1993, 1996). Stains for specific fungal enzyme activities such as ALP activity can distinguish whether the structure so revealed are active or inactive VAM tissue (Kough et al. 1987; Thingstrup and Rosendahl 1994; Kjoller and Rosendahl 2000). The effect of fungicides on the metabolic activities of VAM external hyphae had been reported by several authors. For instance, the active proportion of the external hyphal lengths was decreased following fungicide treatments (Sukarno et al. 1993; Kling and Jakobsen 1997). Fungal ALP activity has been shown to be sensitive to the fungicide benomyl when applied at the recommended field rate (Thinghstrup and Rosendahl 1994). The present study aimed to evaluate the effect of herbicides on the development and ALP activity of external hyphae of *G. mosseae* in the soil.

MATERIALS AND METHODS

Whole inoculum of *Glomus mosseae* (Nicol. & Gerd.) Gerd. & Trappe UK 118 obtained from INVAM (International Culture Collection of VA Mycorrhizal Fungi) was propagated on *Sorghum bicolor* in the glasshouse pot cultures using the method of Feldmann and Idczak (1991). Alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)-acetamide] in commercial product, Lasso and glyphosate [N-(phosphonomethyl) glycine] in commercial product, Roundup from Monsanto were used in this experiment.

The experiment was conducted in the greenhouse of University of Putra Malaysia, in 2003. Black plastic pots (6 x 20 cm) were filled with 1 kg of sterilized soil:sand mixture (1:3). Inoculum of *G. mosseae* was inoculated at 10 percent by weight per pot before planting of peanut in one layer on the pot soil surface and then covered with a 5 cm soil. Seeds of *Arachis hypogaea* were surface sterilized for 2 min in 30 % aqueous hydrogen peroxide and rinsed in sterile water. Two seeds were planted into each pot. After seven days the seedlings were thinned to one plant per pot. Hoagland's solution (minus P), as nutrient sources, was applied twice a week at 20 mL per pot. The experiment was arranged in a completely randomized design (CRD) with four replicates. Four weeks after planting, alachlor and glyphosate herbicides were applied separately as 20 mL soil drench per pot. The herbicide treatments consisted of 0.5, 1.0, 1.5, and 10 folds of the recommended rates (3.6 μg ai g^{-1} for alachlor and 2.16 μg ae g^{-1} for glyphosate). The rates were alachlor: 1.8, 3.6, 5.4, and 36 μg ai g^{-1} dry soil; glyphosate: 1.08, 2.16, 3.24, and 21.6 μg ae g^{-1} dry soil. The control treatments were not treated with herbicide and not inoculated with *G. mosseae*. Plants were harvested at 3 days after herbicide application; fresh weights of shoot and root were measured. The shoot and root were then separately oven-dried at 80°C for 24 hours. After that, the dry weights of all samples were then taken. Five cores (diameter = 10 mm) of moist soil were taken with a cork borer from each pot and mixed well in a plastic bag. The extraction and measurement of external hyphae were carried out using the method of Abbott and Robson (1985).

To estimate the total external hyphal length, the hyphae was stained in trypan-blue (TB) in acidic-glycerol as described by Koske and Gemma (1989). Estimation of alkaline phosphatase (ALP)-active external hyphal length was done by ALP histochemical staining (Gianinazzi and Gianinazzi-Pearson 1992; Tisserant et al. 1993). ALP enzyme activity was determined as indicated by a violet-black stain. The filter containing hyphae either with TB or ALP stained were observed under a dissecting microscope at 250 x magnification. Total and active hyphal length was estimated by using a gridline-intersect method of Newman (1966) and Tennant (1975). The eyepiece micrometer which had 10 x 10 gridlines was used to help counting the intersections between all horizontal/vertical grid lines and hyphae at all field of filter area. Hyphal length is calculated as follows:

Hyphal length/grid (cm/ g soil) = c x n x g x a/b x 1/s
Where: c = constant (11/14), n = no. of intersections, g = grid unit, a= area of filter covered by sample (mm^2), b = area of grid (mm^2), s = soil on filter (g)

RESULTS AND DISCUSSION

Both herbicides alachlor and glyphosate in general had no negative effect on growth of peanut plant (*Arachis hypogaea* L.). The herbicides in fact were seen to increase plant growth, probably due to the short term exposure of the plants to the herbicides. Inoculation with *G. mosseae* increased fresh and dry weights of peanut shoot (Table 1).

Table 1. Fresh and dry weights of shoot and root of peanut after herbicides application.

Herbicides	Rate (µg ai/ae g^{-1} dry soil)	Shoot (g) Fresh weight	Shoot (g) Dry weight	Root (g) Fresh weight	Root (g) Dry weight
No herbicide	0	11.49 (1.36) e	2.16 (0.17) b	12.94 (2.11) abc	2.06 (0.71) ab
Alachlor	1.8	13.78 (0.70) cde	2.14 (0.14) b	12.38 (0.60) abc	1.72 (0.30) ab
	3.6	14.24 (0.65) cd	2.11 (0.24) b	13.37 (2.31) ab	2.13 (0.96) ab
	5.4	15.30 (0.29) bcd	2.45 (0.07) ab	15.17 (0.52) a	1.79 (0.30) ab
	36	15.97 (1.02) abc	2.46 (0.16) ab	11.35 (0.49) abc	2.16 (0.54) ab
Glyphosate	1.08	17.98 (0.74) a	2.66 (0.14) a	12.97 (2.70) abc	2.51 (0.93) a
	2.16	17.82 (0.95) ab	2.47 (0.10) ab	10.64 (0.71) bc	1.92 (0.32) ab
	3.24	14.53 (0.92) cd	2.41 (0.20) ab	10.20 (0.83) bc	1.47 (0.25) ab
	21.6	12.95 (1.30) de	2.13 (0.19) b	8.87 (1.42) c	1.20 (0.24) ab
Uninoculated		7.95 (0.82) f	1.37 (0.15) c	10.47 (0.39) bc	0.86 (0.08) b

Note: Means followed by the same letter in each column were not significantly different at LSD test 5%. Values in the parenthesis were standard errors with 4 replicates.

The range of total external hyphae length of *G. mosseae* in this study was from 126.62 to 164.57 cm g^{-1} (Figure 1). It is in accordance with range of maximum values reported for soil hyphae on a soil-mass basis as noted by Sylvia (1992) that are < 1 to 26 m g^{-1} of soil. Application of herbicides did not significantly influence the development of the external hyphae of *G. mosseae*. Alachlor (soil acting herbicide) and glyphosate (foliage acting herbicide) up to ten fold recommended rate did not affect the total external hyphal length. While on the active external hyphae showed that alachlor up to one and half of the recommended rate did not influence the active external hyphal length of *G. mosseae*. However, alachlor at ten fold of recommended rate (36 µg ai g^{-1}) decreased the active external hyphal length of the fungi to 23.99 cm g^{-1}. This was significantly different to no herbicide control which gave maximum active external hyphal length of 39.81 cm g^{-1}. In contrast, glyphosate up to ten fold of the recommended rate showed no significant effect on the active external hyphae length (Figure 1).

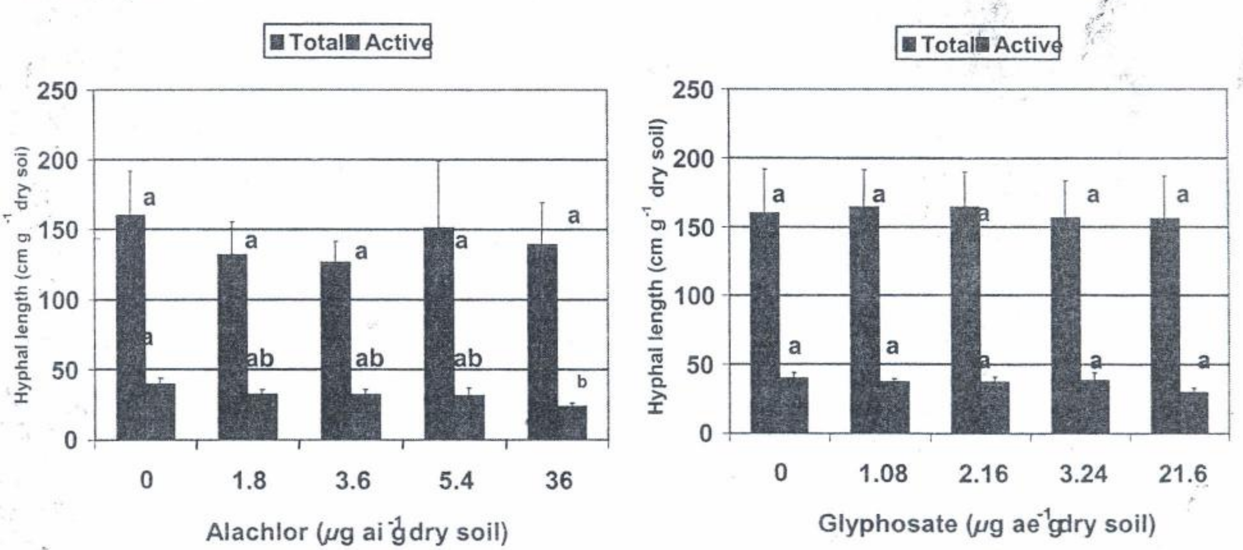


Figure 1. The effect of herbicides on the total and active external hyphae length of *G. mosseae*. Vertical bar shows standard errors with four replicates.

The proportion of alkaline phosphatase (ALP) activity of the external hyphae of *G. mosseae* was unaffected following application of alachlor and glyphosate herbicides up to ten folds of the recommended rate. ALP activity of the external hyphae ranged from 19.47% to 27.73% (Table 2).

In this study alachlor and glyphosate did not influence the development and the proportion of ALP activity of external hyphae of *G. mosseae* in the soil although some fungicide studies reported that growth of external hyphae of *Glomus* sp was reduced by application of benomyl, ridomil, and aliette and application of benomyl even reduced the activity of external hyphae of *Glomus* sp. (Sukarno et al. 1993). Kjoller and Rosendhal (2000) also reported that benomyl at 1 μg g^{-1} (recommended field dose), propiconazole at 0.21 μg g^{-1} (low application level), fenpropimorph at 125 μg g^{-1} (high rate) decreased ALP activity of external hyphae of *Glomus caledonicum*. Alachlor and glyphosate did not affect the development and ALP activity of external hyphae of *G. mosseae*. This indicated that the alachlor and glyphosate were safe to be used as soil and foliage herbicides, respectively in term of effect on *G. mosseae* which it is responsible for nutrients acquisition, propagation of the association and spore formation (St. John et al. 1983).

Table 2. The effect of herbicides on the proportion ALP activity of the external hyphae of *G. mosseae*

Herbicides	Rate (μg ai/ae g^{-1} dry soil)	Proportion ALP activity (%)
Control	0	27.73 (5.03) a
Alachlor	1.8	26.55 (3.65) a
	3.6	25.58 (1.34) a
	5.4	24.56 (4.11) a
	36	19.47 (3.59) a
Glyphosate	1.08	24.74 (4.29) a
	2.16	23.74 (2.16) a
	3.24	25.69 (3.02) a
	21.6	21.53 (4.00) a

Note: Means followed by the same letter in each column were not significantly different in LSD test at 5%. Values in the parenthesis were standard errors with 4 replicates. The proportion of ALP activity = (active external hyphal length revealed by ALP/ total external hyphal length revealed by TB) x 100%.

LITERATURE CITED

Abbott L. K. and Robson A. D. 1985. Formation of external hyphae in soil by four species of vesicular-arbuscular mycorrhizal fungi. New Phytologist, 99: 245-255.

Feldmann F. and Idczak E. 1991. Inoculum production of VAM fungi for use in tropical nurseries. In J. R. Norris, D. J. Read, and A. K. Varma (eds). Methods in Microbiology vol. 24, Techniques for the study of mycorrhiza. pp. 339-357. Academic Press, London.

Gianinazzi S., V. Gianinazzi-Pearson and Dexheimer J. 1979. Enzymatic studies on the metabolism of vesicular-arbuscular mycorrhiza. III. Ultrastructural localization of acid and alkaline phosphatase activity in onion roots infected by *Glomus mosseae* (Nicol. & Gerd.). New Phytologist, 82: 127-132.

Gianinazzi S., and Gianinazzi-Pearson V. 1992. Cytology, histochemistry and immunocytochemistry as tools for studying structure and function in endomycorrhiza. In J. R. Norris, D. J. Read, and A. K. Varma (eds). Methods in Microbiology vol. 24, Techniques for the study of mycorrhiza. Academic Press, London. Pages 109-139.

Jakobsen I., Abbott L.K. and Robson A. D. 1992. External hyphae of vesicular-arbuscular mycorrhizal fungi associated with *Trifolium subterraneum* L. 2. Hyphal transport of ^{32}P over defined distances. New Phytologist, 120: 509-516.

Kjoller R. and Rosendahl S. 2000. Effects of fungicides on arbuscular mycorrhizal fungi: differential responses in alkaline phosphatase activity of external and internal hyphae. Biology and Fertility of Soils, 31: 361-365.

Kling M. and Jakobsen I. 1997. Direct application of carbendazim and propiconazole at field rates to the external mycelium of three arbuscular mycorrhizal fungi species: effect on ^{32}P transport and succinate dehydrogenase activity. Mycorrhiza, 7: 33-37.

Koske R.E. and Gemma J.N. 1989. A modified procedures for staining roots to detect VA mycorrhizas. Mycological Research, 92:486-505.

Kough J. L., Gianinazzi-Pearson V. and Gianinazzi S. 1987. Depressed metabolic activity of vesicular-arbuscular mycorrhizal fungi after fungicide applications. New Phytologist, 106: 707-715.

Larsen J., Thingstrup I. and Jakobsen I. 1996. Benomyl inhibits phosphorus transport but not fungal alkaline phosphatase activity in a *Glomus*-cucumber symbiosis. New Phytologist, 132: 127-133.

Merryweather J. and Fitter A.H. 1996. Phosphorus nutrition of an obligately mycorrhizal plant treated with the fungicide benomyl in the field. New Phytologist, 132: 307-311.

Nemec S., and Tucker D. 1983. Effects of herbicides on endomycorrhizal fungi in Florida citrus (*Citrus* spp.) soils. Weed Science, 31: 427-431.

Newman E. I. 1966. A method of estimating total length of root in a sample. Journal of Applied Ecology, 3: 139-145.

Ocampo, J. A. and Barea J.M. 1985. Effect of carbamate herbicides on VA mycorrhizal infection and plant growth. Plant and Soil, 85:375-383.

Smith T.F., Noack A.J. and Cosh S.M. 1981. The effect of some herbicides on vesicular-arbuscular endophyte abundance in soil and on infection of host roots. Pesticide Science, 12: 91-97.

Smith S.E. and Gianinazzi-Pearson V. 1988. Physiological interactions between symbionts in vesicular-arbuscular mycorrhizal plants. Annual Review of Plant Physiology and Plant Molecular Biology, 39: 221-244.

Smith S.E. and Read D.J. 1997. Mycorrhizal Symbiosis. Academic Press. Harcourt Brace & Company Publishers, London. 605 p.

St. John T.V., Coleman D.C. and Reid C.P.P. 1983. Growth and spatial distribution of nutrient and absorbing organs: selective exploration of soil heterogenecity. Plant and Soil, 71: 487-493.

Sukarno N., Smith S.E. and Scott E.S. 1993. The effect of fungicides on vesicular-arbuscular mycorrhizal symbiosis. I. The effects on vesicular-arbuscular mycorrhizal fungi and plant growth. New Phytologist, 25: 139-147.

Sylvia D. M. 1992. Quantification of external hyphae of vesicular-arbuscular mycorrhizal fungi. Ir J. R. Norris, D. J. Read, and A. K. Varma (eds). Methods in Microbiology vol. 24 Techniques for the study of mycorrhiza. Academic Press, London. Pages 53-65.

Tennant D. 1975. A test of a modified method of estimating root length. J. Ecol., 63: 995-1001.

Thingstrup I. and Rosendahl S. 1994. Quantification of fungal activity in arbuscular mycorrhiza symbiosis by polyacrylamide gel electrophoresis and densitometry of malat dehydrogenase. Soil Biology and Biochemistry, 26: 1483-1489.

Tisserant B., Gianinazzi S. and Gianinazzi-Pearson V. 1996. Relationships between lateral roo order, arbuscular mycorrhiza development, and the physiological state of the symbioti fungus in *Platanus acerifolia*. Canadian Journal of Botany, 74: 1947-1955.

Tisserant B., Gianinazzi-Pearson V., Gianinazzi S. and Gollotte A. 1993. In planta histochemica staining of fungal alkaline phosphatase activity for analysis of efficient arbuscula mycorrhizal infections. Mycological Research, 97: 245-250.

Trappe J. M., Molina R. and Castellano M. 1984. Reactions of mycorrhizal fungi and mycorrhiz formation to pesticides. Ann. Rev. Phytopathol., 22: 331-359.

Changes of microbial activity with recommended use of herbicides in high grown tea in Sri Lanka

Guneratne H.M.A.C[1], De Silva M.S.D.L.[2], and Marambe B.[1]
[1]Dept. of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka
[2]Tea Research Institute, Talawakelle, Sri Lanka
bmarambe@pdn.ac.lk

Abstract: The present study was undertaken to determine the microbial activity of an ultisol under tea crop, as affected by the use of recommended herbicides. Five herbicides, namely Glyphosate (Round Up®, 36% a.i. 1.2 l ha^{-1} and five-fold the recommended rate), and MCPA (MCPA®, 60% a.i.; 1.75 l ha^{-1}), Paraquat (Gramoxone®, 20% a.i.; 1.1 l ha^{-1}), Diuron (Diuron®, 40% a.i.; 1.2 kg ha^{-1}), and Oxyfluorfen (Goal®, 24% a.i.; 1.2 l ha^{-1}), and two fold of recommended rates of these of herbicides were tested under laboratory conditions. In addition, both rates of Glyphosate and the recommended rates of the other herbicides were tested under field condition. The soil is classified as fine mixed tropudult. The soil microbial activity (soil microbial biomass carbon), soil respiration and net mineralization, nitrification and soil pH were measured at weekly intervals for 8 weeks.

The results showed that there was an initial suppression of microbial biomass carbon followed by rapid recovery, in herbicide treated soils under both laboratory and field conditions. Though there is a rapid increase in microbial biomass carbon of soil in Glyphosate, Paraquat and MCPA treatments in the laboratory experiment, only Glyphosate, Paraquat and Diuron at recommended rates showed a higher microbial biomass carbon in the field experiment. Nitrogen mineralization in terms of NH_4^+-N and NO_3^--N showed a similar trend to that of microbial biomass carbon with Glyphosate and Diuron when applied at the recommended rates. Soil pH in herbicide treated soil decreased with time. There were no significant differences in soil respiration. The results indicated that the recommended rates of Glyphosate, Paraquat and Diuron did not have a long-term negative impact on microbial activity under field condition where as higher rate of Glyphosate and recommended rates of MCPA and Oxyfluorfen resulted in lower microbial biomass carbon level at 60 days after treatment when compared to untreated control.

Key words: Microbial biomass carbon, Nitrification, Tea soils

INTRODUCTION

Tea is the major plantation crop in Sri Lanka, and the major foreign exchange earner, which contribute 70% of GNP with compared to agricultural sector (Central Bank, 2003). Cost of production of tea range Sri Lankan Rs 200.00 kg^{-1} made tea and of the field operations, weed control is the third most costly factor other than plucking and fertilizer application (Kulasegaram, 1980).

Yield losses in tea due to weed competition in mature vegetatively propagated tea is 5-10% and in mature seedling tea is 5-15% (Eden, 1940; Waidyanatha, 1966; Wettasinghe and Watson, 1980). Yield reduction up to 30% has been experienced in young tea (Visser, 1961). The composition of weed flora in tea fields may differ between high and low elevations as sequence of different in temperature, rainfall and soil type.

Foliar and soil application of herbicides is currently practiced in tea lands to overcome the problems of weeds. However, considerable amounts of herbicides ultimately get accumulated in soil (Phukan and Geroge, 1992). These chemicals are broken down and detoxified by the soil microbial biomass (Killham, 1984). Currently, seven herbicides are used in tea cultivation, and among them, herbicides such as Diuron and Glyphosate are restricted a maximum two rounds per annum (Anon 2003) due to their phytotoxicity on tea crop and residues on soil. Few reports are available on the impact of herbicides used in tea soils on soil biological aspects under Sri Lankan conditions (Wimaladasa and Wikramasinghe 1986; Anandacoomaraswamy *et al.*1987). The present study investigated the NH_4^+-N, NO_3^--N, and microbial biomass carbon of tea soils, which are the key factors to determine soil biological activity, as affected by the use of recommended herbicides.

MATERIALS AND METHODS

The experiment was carried out in Field No. 8 at the St. Coombs Estate, Tea Research Institute of Sri Lanka, Talawakelle. (Latitude 6^0 55' N, longitude 80^0 40' E, altitude 1382 m amsl). The soil was an ultisol (great soil group), Mattakelle series. Both field and laboratory experiments were conducted.

In the field experiment, an area with a mature plantation belonging to the tea clone DT 1, after pruning, was selected. The herbicides Glyphosate (Round Up®, 36% a.i.; 1.2 l ha^{-1}), MCPA (MCPA®, 60% a.i.; 1.75 l ha^{-1}), Paraquat (Gramoxone®, 20% a.i.; 1.1 l ha^{-1}), Diuron (Diuron®, 40% a.i.; 1.2 kg ha^{-1}), and Oxyfluorfen (Goal®, 24% a.i.;1.2 l ha^{-1}) were used at recommended dosages. In addition the herbicide Glyphosate was also used at 5-fold of the recommended dosage (Round Up®, 36% a.i.; 6 l ha^{-1}) together with a control (manual weeding at two months interval) treatment. The experiment was conducted in a RCBD with 3 replicates. Soil samples were taken at 0-15 cm depth before application of treatment, and 2, 10, 15, 20, 30, 45 and 60 days after treatment (DAT). The soil sample was sieved through a 2 mm sieved. Fresh sieved soil samples were used to analyze the microbial biomass carbon, nitrate nitrogen and ammonium nitrogen. An air-dried sieved soil sample was used to measure soil pH. An air-dried sieved soil sample was further ground in a motor and pestle to a fine powder for organic carbon analysis.

In the laboratory experiment one kg sieved soil (2 mm) was incubated at 40% field capacity under room temperature (22°C) after treatments with herbicides Glyphosate (Round Up®, 36% a.i.; 1.2 and 6 l ha^{-1}), MCPA (MCPA®, 60% a.i.; 1.75 and 3 6 l ha^{-1}), Paraquat (Gramoxone®, 20% a.i.; 1.1 and 2.2 l ha^{-1}), Diuron (Diuron®, 40% a.i.; 1.2 and 2.4 kg ha^{-1}) and Oxyfluorfen (Goal®, 24% a.i.; 1.2 and 2.4 l ha^{-1}), and an untreated control. A CRD was used as the experimental design with two replicates. Soil samples were taken 2, 5, 10, 15, 20, 30, 45 and 60 DAT for analysis.

In both experiments soil texture was measured by the Hydrometer method (Gee and Bowder, 1986), soil microbial biomass carbon by the chloroform extraction fumigation method (Sparling *et al.*, 1990), soil respiration by the field method (Black 1968), soil pH (1:2.5 soil water ratio), soil organic carbon by the modified Walky and Black method (Rayment and Higginsson, 1992), soil nitrate nitrogen and soil ammonium nitrogen by the Distillation method. Data were analyzed using SAS computer software package.

RESULTS AND DISCUSSION

Microbial process such as net mineralization, nitrification, soil microbial biomass carbon, and soil respiration as affected by herbicide treatments under both laboratory and field conditions are discussed in this paper. The tested soil at the St. Coomb's Estate was a clayey loam, with 41.2% sand, 43.1% clay, and 15.6% silt.

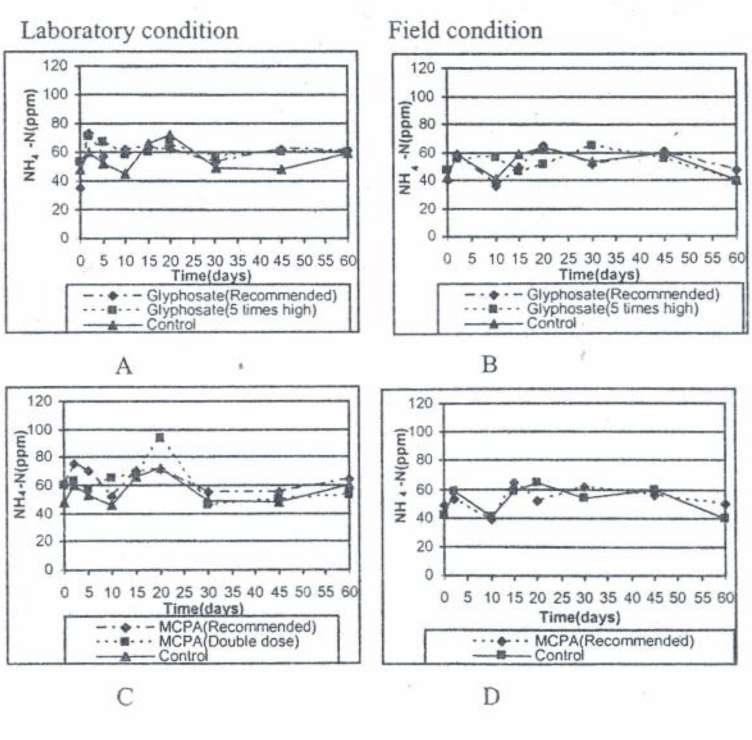
Effect of Herbicides on Nitrogen Mineralization

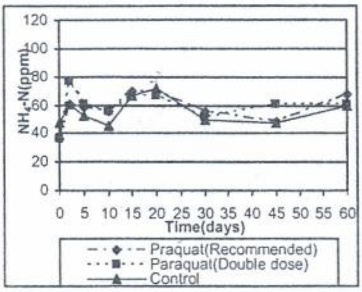
Ammonium-N: The NH_4^+-N content in the soils showed a significant difference among herbicide treatments. However, there was no significant difference in NH_4^+-N contents between the rates of herbicides tested. Under both field and laboratory experiments, there was a significant interaction between the rates of herbicides and time taken for sampling/incubation.

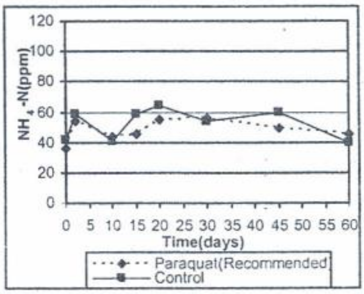
Addition of nitrogen into soil would result in immobilization and mineralization. The net mineralization is measured as NH_4^+-N. Under laboratory conditions, the highest NH_4^+-N was recorded in the Diuron treatment 2 DAT, followed by MCPA at 20 DAT (Figure 1G and 1C). Under field conditions, the differences in NH_4^+-N are not marked as under laboratory conditions. Application of Paraquat, Diuron and Oxyflurofen resulted in a low NH_4^+-N from 15-45 days compared to the control (Figure 1F, 1H and 1J). All the treated soils reached the initial values in 60 DAT.

Glyphosate, Diuron, Paraquat and MCPA consist of nitrogen molecules in their structure. Paraquat and Diuron have two nitrogen molecules while others have only one. Herbicides act as sources of carbon and nitrogen for the microbial biomass (Alexander, 1997). In addition MCPA acts as hormonal herbicide. Since Diuron is a substituted urea, it showed a quick mineralization at 2 DAT probably due to catalyzation of urea by urease enzyme found in the microbial biomass. In tea soils of Sri Lanka, the presence of autotropic nitrifying bacteria *Nitrosolobus* spp., *Nitrosospira* spp. and *Nitrosovibrio* spp. have been reported (Walker and Wickramasinghe, 1979). Under field conditions, leaching due to rain and uptake by plant roots could take place, thus recording a lower level of NH_4^+ -N when compared to laboratory conditions.

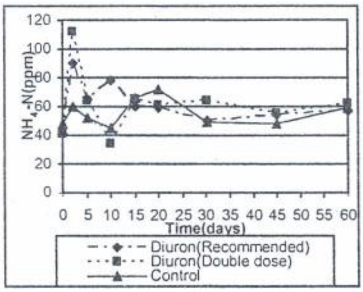
Nitrate-N: Similar to the observations made in NH_4^+-N, there were no significant differences in NO_3^--N between two rates of herbicides under laboratory and field conditions. Under laboratory condition, however, there were significant difference between herbicides and interaction between the rates and time of sampling/incubation. Under laboratory conditions at 10 DAT, the highest NO_3^- -N contents were observed in soils treated with recommended rates of Glyphosate, MCPA, and Oxyfluorfen, both rates of Paraquat, and the higher rate of Diuron (Figure 2). Under field conditions (Figure 2), however, there were no significant differences in NO_3^--N between treatments. The increase in levels of NO_3^--N may be due to the increase in microbial activity as a result of addition of carbon and nitrogen sources from the herbicides, and nitrification of already mineralized NH_4^+-N.

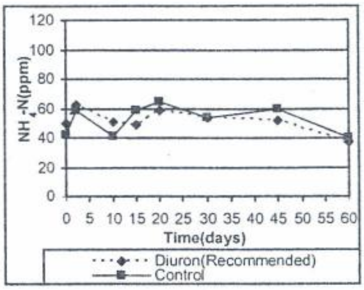




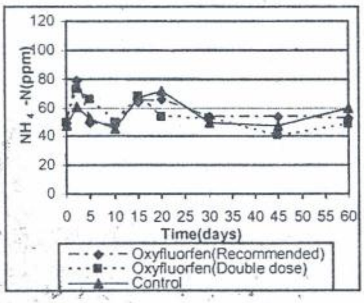


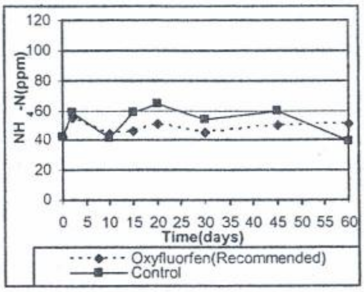
E   F





G   H

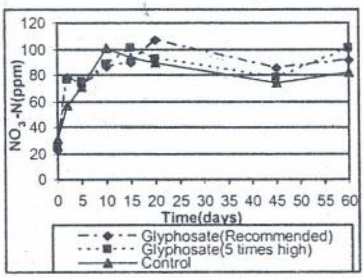


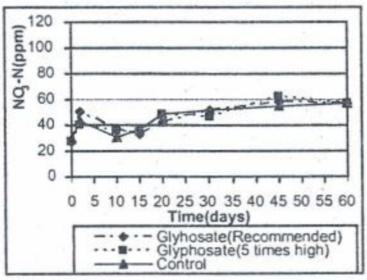


I   J

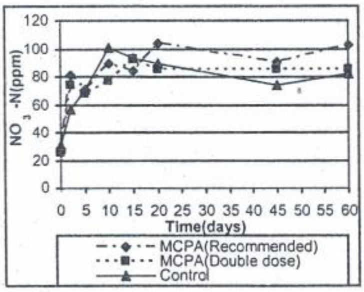
Figure 1. Changes of NH_4^+ -N in soil after different herbicide treatments

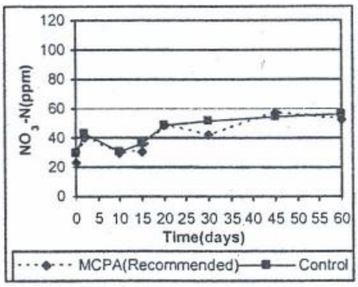
Laboratory condition   Field condition





A   B





C   D

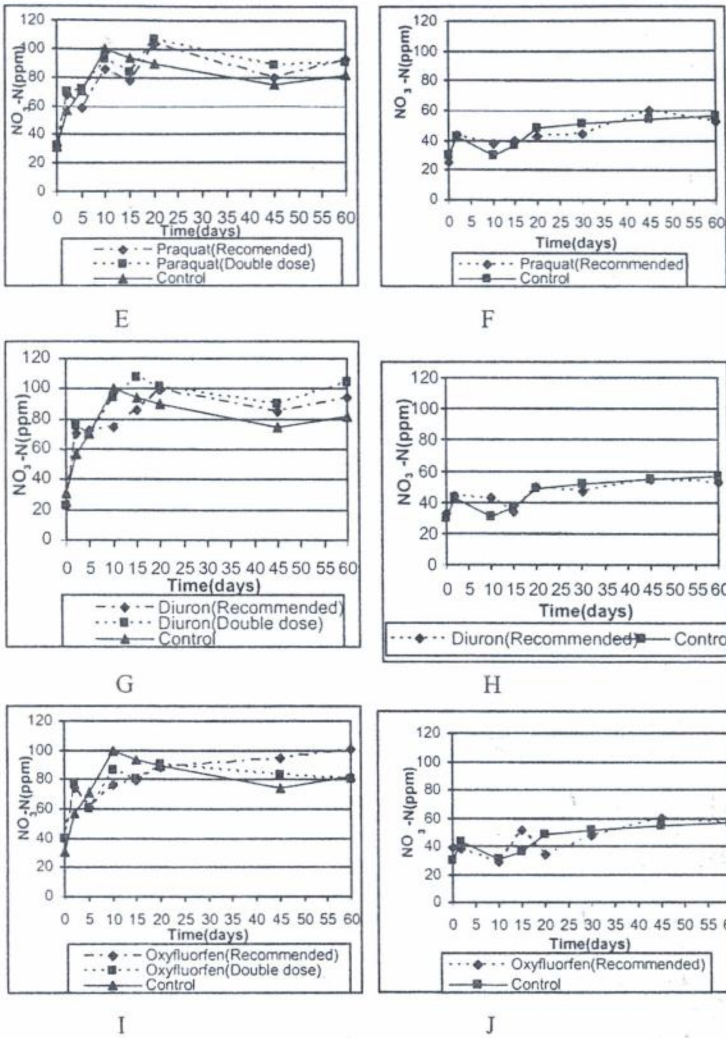


Figure 2. Changes of NO_3^--N in soil after different herbicide treatments

Microbial Biomass Carbon (MBC)

With increase in time after treatment, the soil microbial biomass carbon (MBC) showed a significant difference among herbicide treatments in both experiments. Soon after application of herbicides, there was sudden decline in soil MBC followed by an increase at 5 DAT (Figure 3). Thereafter, the soil MBC showed decreasing and increasing patterns over the experimental time period.

Soil microbial biomass is a dynamic property. The microbial biomass activity depends on several factors including substrate availability. The decrease in soil MBC observed in this study may be due to inadequate substrate availability. In all the cases the soil MBC reached the initial values after 60 DAT (Figure 3). Under field conditions, the soil MBC under Glyphosate (Round Up®, 36% a.i.; 6 l ha^{-1}) and Oxyfluorfen treatments was lower than the initial values (Figure 3B and 3J). However, Haney *et al.* (2000) reported that glyphosate stimulated soil microbial activity by C and N mineralization. In the present study we did not analyze the microbial species composition after application of the herbicides. Such analysis would have helped further elucidation of the impact of specific herbicides soil microbial populations.

Soil pH

There was no significant difference in soil pH among the herbicidal treatments (initial soil pH was 4.6). However the soil pH showed a decreasing trend with time of incubation/sampling (data not shown). The reduction in soil pH was less under field conditions when compared to the laboratory conditions, probably due to leaching of NO_3^--N and uptake by plant roots.

Soil Respiration

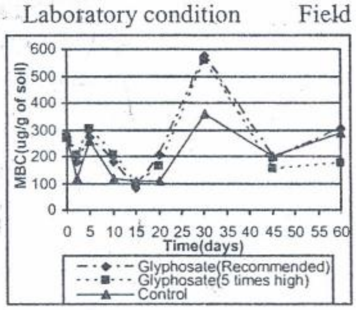
There were no significant differences in respiration (measured in terms of CO_2 liberation) in this study under the field condition (Table 1), although there were significant differences in soil MBC.

Table 1. CO_2 liberation under field condition

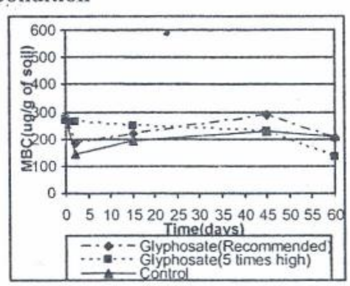
Treatment	Initial	15 DAT**	45 DAT
	(CO_2 kg ha^{-1} day^{-1})		
Glyphosate (R*)	32.6	41.9	37.5
Glyphosate (R* x 5)	32.6	32.66	28.8
MCPA (R*)	32.6	28.5	40.3
Paraquat (R*)	32.6	27.23	36.4
Diuron (R*)	32.6	26.23	30.6
Oxyfluorfen (R*)	32.6	27.73	35.6
Control	32.6	38.0	35.4

R* -Recommended rate ** DAT – days after treatment

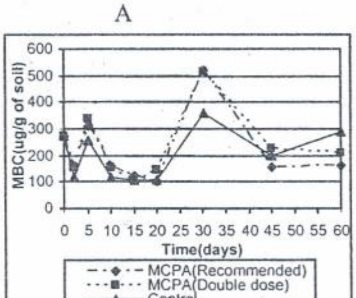
Laboratory condition Field condition



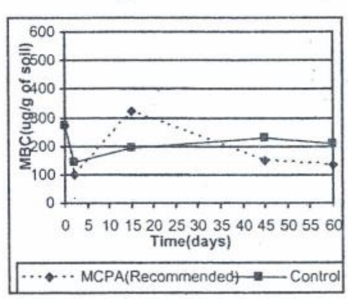
A



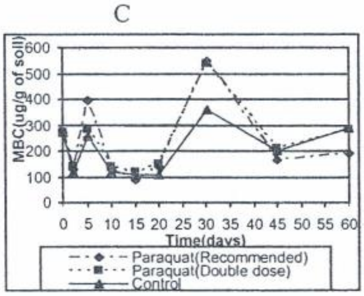
B

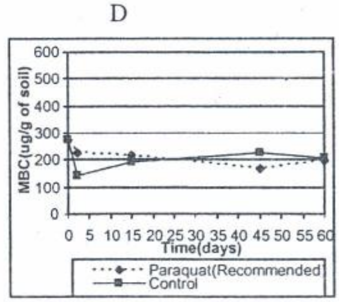


C



D





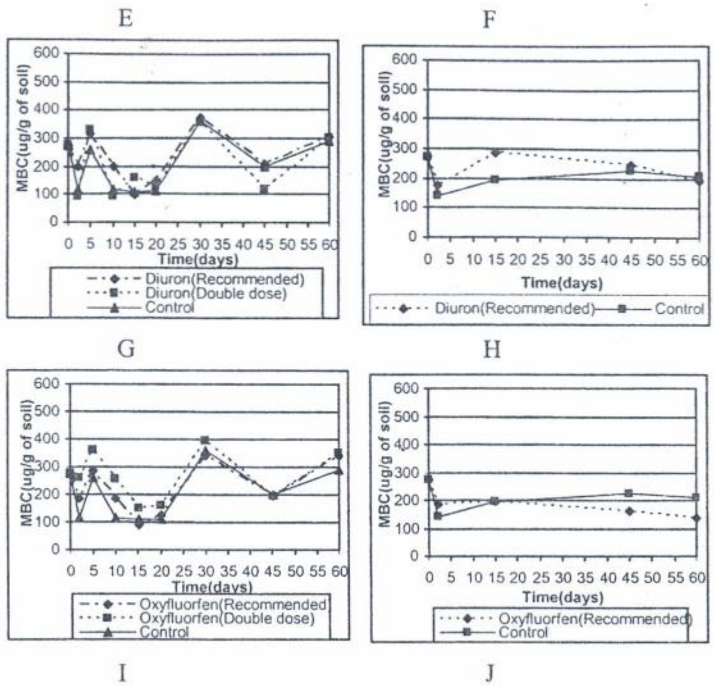


Figure 3. Changes of microbial biomass carbon under different herbicides

CONCLUSIONS

The results of the present study revealed that the soil microbial activity in high grown tea soils, measured in terms of microbial biomass carbon, decreased when Glyphosate was applied at 5-fold the recommended rate, and recommended rates of MCPA and Oxyfluorfen in high grown tea soils under the field condition. Application of recommended rates of Glyphosate, Paraquat and Diuron did not have any significant harmful effects on microbial activity

REFERENCES

Alexander, M.(1977). Microbial ecology introduction to soil microbiology. Introduction to Soil Microbiology (Ed M. Alexander.). pp 225. 2nd Edition, John Wiley & Sons, Inc., New York.

Anandacoomaraswamy, A., Lakshmie, M.S.D., Anandavijayan, S. and Kudagamage, S.N. (1987). Effect of pre emergent herbicides on N-mineralization and microbial population. Sri Lanka Journal of Tea Science 56:41-47.

Black, W. (1968). Aeration. pp 153-201. *In* 'Soil and plant relationship', John Wiley and Sons, Inc., New York.

Eden, T. (1940). Studies in the yield of tea IV. The effect of cultivation and weeds on crop. Empire J. Exp. Agric. 8: 269-279.

Gee, G. W. and Bauder J. W. (1986). Particle size Analysis. *In* 'Methods of Soil Analysis Part 1'. Chemical and Microbiological Properties (Ed. A. Klute) pp. 404-411. Agronomy Monograph No 9 (Part 1). Physical and Mineralogical Methods. American Society of Agronomy, Inc, Madision, Wisconsin, USA.

Phukan, I. and George, U. (1992). The effect of commonly used herbicides on activity of Microbes from a tea soil. Two and a Bud.39:34-37.

Killham, K. (1984). Soil Ecology. Cambridge University Press, Australia.

Kulasegaram, S. (1980). Technical development in tea production. Tea Quarterly 49: 157-183.

Rayment, G. E. and Higginson, F. R. (1992). Organic carbon. *In* Australian Laboratory Handbook of Soil and Water Chemical Methods'. (Eds. C. E. Rayment and F. R. Higginson.) pp. 29-31. Inkata Press, Melbourne.

Sparling, G. P., Felthans, C.W., Raynolds, J., West, A. W., and Singletan, P. (1990). Estimation of soil microbial carbon by fumigation, extraction method; Use on soils of high organic matter content and a reassessment of the K_{EC} factor. Soil Biology and Biochemistry 22:301-307.

Visser, T. (1961). Interplanting in tea.1- Effects of shade trees, weeds and bush crops. Tea Quarterly 32:69-87.

Walker, N., and Wickramasinghe, K.N. (1979). Nitrification and autotrophic nitrifying bacteria in acid tea soils. Soil Biology and Biochemistry 11:231-36.

Waidyanatha, U.P. DE S. (1966). Weeds effects on crop and yield of seedling tea at the low country station Rathnapura. Annual Report. Tea Research Institute of Sri Lanka, Talawakelle. pp 117.

Wettasinghe, D.T. and Watson, M. (1980). Effect of nitrogen, phosphorus, potassium and magnesium fertilizers on the leaf nutrient composition of low-grown tea in Sri Lanka. Tea Quarterly 49:44-52

Wimaladasa, G.D. and Wickramasinghe, K.N. (1986). Effect of herbicides on urea hydrolysis in tea soils. Sri Lanka Journal of Science. 55:22-27.

Utilization of Weeds

Nutritive value of non-cultivated grasses (Cyperaceae and Gramineae) in the Mekong Delta of Vietnam

Nguyen Nhut Xuan Dung[1], Luu Huu Manh[1] and Peter Uden[2]
[1]Department of Animal Sciences, Agricultural College, Cantho University, Vietnam.
nnxdung@ctu.edu.vn; lhmanh@ctu.edu.vn
[2]Department of Animal Nutrition and Management, Swedish University of Agricultural of Sciences, Box 7024, S-75007 Uppsala Sweden.
peter.uden@huv.slu.se

Abstract: A total of 25 green plant samples was collected from two families *Cyperaceae* (n=7) and *Gramineae* (n=18) and analysed for dry matter (DM), crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDF) acid detergent fibre (ADF), lignin, silica, Ca, P and *in vitro* true organic matter digestibility (IVOMD). All values were expressed as g kg^{-1} DM. The mean for CP of *Cyperaceae* and *Gramineae* were 120 (78-162) and 124 (60-207). The NDF mean was 526 (253-824) and 742 (619-824) and the IVOMD was 601 and 590 for *Cyperaceae* and *Gramineae*, respectively. The study indicated that these non-cultivated grasses are potentially feeding value for animal.

Key words: Composition, nutritive value, *in vitro* digestibility, tropical plants, Mekong delta.

INTRODUCTION

Non-cultivated plants play an important role in the livestock diet, particularly in the remote areas of the Mekong delta. Local plants supply protein, carbohydrate, vitamins and minerals to the animals. Livestock rearing is an integral part of the various farming systems, their diets based on high quantities of non cultivated grasses that mainly belonged to *Cyperaceae* and *Gramineae*. In the Mekong delta, the area used for cultivation of forage crops is restricted, while the sale of green folder such as Para grass (*Brachiaria mutica, Pannicum repens* or *P. coloratum)* for cattle keepers is a common practice. Animal raising is a means of supporting the earning capacity of landless and smallholder farmers. Therefore, non-cultivated grasses are major sources of grazing and fodder collection. The aim of this study therefore was to evaluate the chemical composition and nutritive value of common grasses found in the Mekong Delta that are used as feed for livestock.

METHODS AND MATERIALS

Study sites and sample collection

Plant samples of *Gramineae* and *Cyperaceae* were collected in the morning and immediately put into plastic bags to avoid water losses and brought to the laboratory the same day. A botanical identification was made using the "Illustrated Flora of South Vietnam" (Ho 1972-1999), "Flore du Cambodge de Laos et du Vietnam" (Tardieu 1969-1994) and "Flora Malesiana" (Van Steenis and de Wilde 1950-1995).

For the samples, tillers were taken with a stubble height of 5 to 10 cm, dead leaves were removed and samples taken of leaves young shoots and tillers. Growth stages were registered as "heading", "flowering" or "seeds developed". All the samples were first dried at 60°C and the weight changes recorded, then they were ground on a Cyclone mill to pass a 1 mm screen and stored at –18°C until analysed.

Chemical analysis

Chemical analysis was carried out at the Animal Nutrition laboratory of the Department of Animal Sciences, Agricultural College, Cantho University. Duplicate samples were analysed for dry matter (DM), crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin, cellulose, Si, Ca, P and *in vitro* "true" organic matter digestibility (IVOMD).

The DM content was determined by drying to constant weight at 105°C in a forced draught oven overnight. Nitrogen was measured by the Kjeldahl technique (Vapodest –20), with Cu as a catalyst and with boric acid used during distillation. The CP content was calculated as g kg^{-1} N x 6.25. EE was determined using anhydrous ethyl ether as a solvent in a Soxhlet apparatus. Ash was measured by incineration at 550° C for 3 hours.

NDF was prepared from 0.5 g samples according to Van Soest et al. (1991), but instead of refluxing for one hour the samples were incubated in an oven at 90°C overnight, according to Chai and Udén (1998), without sodium sulfite. Acid detergent fibre (ADF), permanganate lignin and silica were analysed according to Robertson and Van Soest (1981). Calcium and phosphorus were determined according to AOAC (1984) standard methods: CAS-7440-70-2 for calcium and CAS-7723-14-0 for phosphorus. The method of Goering and Van Soest (1970) as modified by Mbwile and Udén (1991) was used for determining IVOMD.

RESULTS AND DISCUSSION

Mean values are shown in Table 1. Samples with unusually low or high values are identified in the table as those with values greater or less than one standard deviation (SD) from the total mean. All values were expressed as g kg^{-1} DM

Dry matter

All species had high dry matter content (202, 91-275; Table 1), especially *Leersia hexandra* (275), *Sacciolepis indic* (257), *Brachiaria distachya* (241) and *Cynodon dactilon* (234), while the hydrophilic species had low dry matter such as *Eleocharis dulcis* (91).

Crude protein

The mean and ranges for CP was 123 (60-207; Table 1), with the lower values found in *Cyperaceae* (120; 78-162) as compared to in *Gramineae* (124; 60-207). There were no high CP contents in *Cyperaceae*, and low values were found in *Cyperus elatus* (78), *Cyperus iria* (101) and *Eleocharis geniculta* (104). As in *Cyperaceae*, there were no high values in the *Gramineae*, but there were some grass shoots with rather high CP contents, *e.g., Elesin indica* (180), *Panicum coloratum* (182) and *Phragmites karka* (207). The lowest values were found in *Axonopus compressus* (104), *Brachiaria distachya* (100), *Leptochloa chinensis* (99), sugar cane leaves (*Saccharum officinarum*; 75), *Sacciolepis indica* (60) and *Sacciolepis interrupta* (84).

Ether extract (EE)

Ether extract was low in most green plants (36; 25-67), especially in the *Gramineae* (35; 25-55) and *Cyperaceae* (40; 26-67).

Table 1. The composition and digestibility (g kg^{-1} DM) of green plants used as feed in the Mekong Delta[a]

No		n	Stage of maturity	DM	CP	Ash	EE	NDF	ADF	HC/CE	Lignin	Si	Ca	P	IVOMD
	Cyperaceae														
1	*Cyperus elatus*	6	M	217	78	89	29	**739**	379	**1.3**	112	39	3.3	1.8	445
2	*Cyperus iria*	5	M	160	101	122	26	**731**	**425**	1.0	114	14	4.5	2.3	529
3	*Cyperus tenuispica*	3	Y	169	146	126	48	659	334				8.2	2.1	821
4	*Eleocharis dulcis*	5	Y	91	162	140	67	626	361	0.8	49	25	5.5	2.8	764
5	*Eleocharis geniculata*	3	M	216	104	142	33	**728**	**415**	0.9	81	**50**			586
6	*Eleocharis ochrostarchys*	7	M	181	121	128	38	**714**	405	0.9	59	31	4.5	1.2	668
7	*Fimbristylis miliacea*	3	Y	146	130	145	39	**753**	404	**1.4**	**158**	18	10.4	2.7	396
	Gramineae														
1	*Axonopus compressus*	9	M	207	104	130	35	681	367	**1.2**	96	38	5.1	2.8	682
2	*Brachiaria mutica*	9	Y	182	133	99	46	671	392	0.9	69	19	4.2	2.6	705
3	*Brachiaria distachya*	5	M	**241**	100	124	33	**736**	401	1.1	100		4.0	3.6	529
4	*Cynodon dactilon*	10	Y	**234**	132	113	33	**718**	353	**1.2**	51	37	4.9	2.8	631
5	*Echinochloa Crus-galli*	4	Y	184	126	120	31	**716**	**430**	0.8	87	30	1.5	1.4	607
6	*Elesine indica*	1	Y	**233**	180	90	55	619	303				4.4	2.7	711
7	*Leersia hexandra*	5	M	**275**	117	139	32	**764**	**444**	0.9	80	**74**	2.3	1.8	534
8	*Leptochloa chinensis*	1	F	196	99	86	25	**795**	**436**	1.0	78	**43**			543
9	*Oryza sativa*	6	Y	**244**	135	150	33	**748**	**437**	0.9	79	**122**	4.4	4.3	514
10	*Pannicum coloratum*	1	Y	179	182	124	27						3.9	2.9	
11	*P. repens*	6	M	211	121	85	34	**764**	379	**1.3**	84	34	4.7	2.4	607
12	*Paspalum distichum*	8	Y	212	135	117	36	**716**	364				4.9	3.2	581
13	*Phragmites karka*	1	Y	226	207	94	45	**722**	357				2.7	1.8	517
14	*Saccaharum arundinaceum*	1	M	222	75	58	35	**824**	390	**1.6**	114				503
15	*Sacciolepis indica*	1	M(SD)	**257**	60	57	32						1.5	1.9	
16	*S. interrupta*	3	M	231	84	98	33	**810**	**437**	1.1	91	13	3.5	2.6	550
17	*S. myosuroides*	8	Y	163	117	110	31	**775**	411	1.1	75	40	3.5	2.8	638
18	*Setaria sphacelata*	2	M	175	124	114	36	**819**	406	1.0			3.9	4.1	
			Average	202	123	112	36	732	393	1.07	88	39	4.4	2.6	594
			Min	91	60	57	25	619	303	0.8	49	13	1.5	1.2	396
			Max	275	207	150	67	824	444	1.6	158	122	10.4	4.3	821
			SD	40	35	25	9	55	37	0.2	26	27	2.0	0.8	103

[a] DM = dry matter. CP = crude protein; EE = ether extract; NDF = neutral detergent fibre; ADF = acid detergent fibre; HC-CE = hemicellulose-cellulose ratio; L: lignin; IVOMD = in vitro organic matter digestibility. Values shown in bold are greater than 1 SD from mean, those underline are less than 1 SD from mean.

F = flowering

M = maturity

SD = seeds developed

Y = young

Neutral detergent fibre

The NDF mean was 732 (619-824; Table 1), and was highest in *Cyperaceae* (707; 626-753) and *Gramineae* (742; 619-824). There were no low values found in these families.

Hemicellulose - cellulose ratio (HC-CE)

The mean HC-CE ratio of all plants was 0.8 (0.1-1.6), with similar means for the Cypeaceae (1.1; 0.8-1.4) and *Gramineae* (1.1; 0.8-1.6).

Lignin

The total lignin average was slightly lower in *Gramineae* (84; 51-144). In the *Cyperaceae*, all plants except *Fimbristylis miliacea* were high in lignin (158), as shown in Table 1.

Silica

There was a large range in Si contents (13-122) with an overall mean of 24 (Table 1). The *Gramineae* (45; 13-122) was high in Si, whereas the *Cyperaceae* (30; 14-50).

Calcium and phosphorus

Gramineae were lower with 3.7 (1.5-5.1) for Ca and 2.7 (1.4-4.3) for P and in the *Cyperaceae* with 6.1 (3.3-10.4) for Ca and 2.2 (1.2-2.8) for P.

Digestibility

The mean of IVOMD was 594 (396-821), with lower values in *Cyperaceae* (601; 396-821) and in *Gramineae* (590; 503-711). There was no high IVOMD found in either *Cyperaceae* or *Gramineae*, but many low values were found *e.g* in *Cyperus elatus* (445), *C. iria* (529), *Firmbristylis miliacea* (396), *Brachiaria distachya* (529), *Leersia hexandra* (543), *Oriza sativa* (514) and *Saccharum arundinaceum* (503).

Factors affected the chemical composition of plants

The Mekong delta is in the tropical zone, with little change in day length, with high temperature and humidity and with long rainy and dry seasons. It is a flat area close to sea level with an interlaced river and canal network. Therefore, the vegetative system is diverse and grasses found here are used as livestock feeds (Dung 1996).

Forage composition is influenced by many factors, such as soil, climate, species, variety and presence of diseases and insects affecting consumption and digestibility (Blaser 1964). An increase in temperature stimulates development in grasses, reduces leaf/stem ratio resulting in a lower protein content and a lower digestibility (Buxton, 1996). High ambient temperature is usually associated with a high cell wall content, as seen in tropical and subtropical grasses in comparison with temperate grasses. (Deinum and Dirven 1975, 1976). The NDF of forages grown under higher temperatures is also less digestible than that of forages grown at lower temperature (Buxton and Fales 1994; Buxton 1996). The increase in NDF with increasing temperatures, however, is more rapid in temperate than tropical grasses (Mwbile and Udén 1997; Mero and Udén 1997 and 1998).

Non-ruminant herbivores are normally better at utilizing other fodder than grasses owing to their lower fibre content. It is also know that hemicellulose (HC) is normally better digested than cellulose (CE) by herbivores with hindgut fermentation, as a result of the susceptibility of hemicellulose to stomach acids preceding the hindgut fermentation (Udén and Van Soest 1982).

Silica is used by some plants as a structural element, complementing lignin to strengthen the cell walls, and the silica level in grasses is highly dependent on the soil (Van Soest 1994). Silica deposited in hairs on the plant surface and cuticular edges contributes to the defence mechanism of certain plants. Silica was high in *Graminaeae*, especially in rice (*Oryza sativa*) and *Leersia hexandra* and Si is also known to be an essential nutrient in the rice plant (Van Soest 1994). It has been shown that Si reduces cell wall digestibility (Hartley and Harris 1981; Shimojo and Goto 1989). Grasses and sedges characteristically contain high levels of biogenic silica

Promising plants

Cyperaceae were generally low in protein and nutritive value, but *Eleocharis dulcis* had a relatively high CP content (162) and is abundant in the saline areas during the rainy season. The rhizomes are also used for human consumption (Ogle et al. 2001), and are considered a good feedstuff for buffaloes in the wet season. *Graminaeae* were better in protein and nutritive value than *Cyperaceae. Brachiaria mutica,* can be compared with hybrid grasses such as *Paspalum atratum* and *Penisetum purpuerum* (Phuc 2004)

Non-cultivated grasses are widely used as feeds by farmers in the Mekong delta. Some of them have fairly good protein contents and high digestibility. The values of many indigenous plants used by farmers are still unknown and more studies in this area should be conducted.

ACKNOWLEDGEMENTS

The financial support of this study was provided by SAREC/SIDA. The authors would like to thank the Department of Animal Sciences, Agricultural College, Cantho University, Vietnam and the Department of Animal Nutrition and Management, Swedish Agricultural Sciences for the use of facilities. The authors also would like to thank Dr. Brian Ogle for kind advice and Mr.Börje Ericson for chemical analysis.

LITERATURE CITED

AOAC. 1984. Official Methods of Analysis. 12th edn. Association of Official Analytical Chemists, Washington DC.

Blaser R.E. 1964. Symposiums on Forage Utilization: Effects of fertility levels and stage of maturity on forage nutritive value. J. Anim. Sci., 23: 246-253.

Buxton D.R. and Fales S.L. 1994. Plant environment and quality. In Forage Quality, Evaluation and Utilization. Fahey, G. C. Jr. and M. Collins (Eds.). American Society of Agronomy, Madison, WI, pp. 155-199.

Buxton D.R. 1996. Quality-related characteristics of forage as influenced by plant environment and agronomic factors. Anim. Feed Sci. Technol., 59: 37-49.

Chai W. and Udén P. 1998. An alternative oven method combined with different detergent strengths in the analysis of neutral detergent fibre. Anim. Feed Sci. Technol., 74: 281-288.

Deinum B. and Dirven J.G.P. 1975. Climate, nitrogen and grass. 6. Comparison of yield and chemical composition of some temperate and tropical grass species grown at different temperatures. Neth. J. Agric. Sci., 23: 69-82.

Deinum B. and Dirven J.G.P. 1976. Climate, nitrogen and grass. 7. Comparison of production and chemical composition of *Brachiaria ruziziensis* and *Setaria sphacelata* grown at different temperatures. Neth. J. Agric. Sci., 24, 67-78.

Dung N.N.X. 1996. Identification and evaluation of noncultivated plants used for livestock feed in the Mekong delta of Vietnam. M.Sc. Thesis. Swedish University of Agricultural Sciences. Uppsala.

Goering H.K. and Van Soest P.Jr. 1970. Forage fibre analysis (apparatus, reagents, procedure and some applications). Agri. Handbook, 379: ARS/USDA, Washington D.C.

Hartley R.D. and Harris P.J. 1981. Phenolic constituents of the cell wall of dicotyledons. Biochem. Syst. Ecol., 9: 184-203.

Ho P.H. 1971-1972. Illustrated Flora of South Vietnam. Vol I and II. Lua Thieng Publisher.

Ho P. H. 1999. Illustrated Flora of Vietnam. Vol I, II and III. Ben Tre Publisher.

Mbwile R.P. and Udén P. 1991. Comparison of laboratory methods on precision and accuracy of predicting forage digestibility. Anim. Feed Sci. Technol., 32: 243-251.

Mbwile R.P. and Udén P. 1997. Effects of age and season on growth and nutritive value of Rhodes grass (*Chloris gayana* cv. Kunth). Anim. Feed Sci. Technol., 65: 87-98.

Mero R.N. and Udén P. 1997. Promising tropical grasses and *Leguminosae* as feed resources in central Tanzania I. Effect of different cutting patterns on production and nutritive value of six grasses and six *Leguminosae*. Tropical Grassl., 31: 549-555.

Mero R. N. and Udén P. 1998. Promising tropical grasses and *Leguminosae* as feed resources in Central Tanzania. III. Effect of feeding level on digestibility and voluntary intake of four grasses by sheep. Anim. Feed Sci. Technol., 70: 79-95.

Ogle B., Dung N.N.X., Do T.T. and Hambraeus L. 2001. The contribution of naturally occurring vegetables to micronutrient intakes among women; an example from the Mekong Delta, Vietnam. Eco. Food. Nutr., 40: 159-184.

Phuc D.H. 2004. Khảo sát đặc tính sinh trưởng và tính năng sản xuất của cỏ *Paspalum Atratum* và đậu *Macroptilium gracile*. Mimeograph report. Cantho Universtiy.

Robertson J.B. and Van Soest P.J. 1981. The detergent system of analysis and its application to human food. In The Analysis of Dietary Fibre in Food. James, W.P.T. and O. Theander (Eds.). Marcel Dekker, New York, pp. 123-158.

Shimojo M. and Goto I. 1989. The effect of sodium silicate on forage digestion with rumen fluid of goats or cellulase using culture adjusted for pH. Anim. Feed Sci. Technol., 24: 173-177.

Tardieu-Blot M.L. 1969-1994. Flore du Cambodge de Laos et du Vietnam. Aubréville, A. (Eds.), Vol 1-27. Museum Nat. Hist. Nat. Paris.

Uden P. and Van Soest P.J. 1982. Comparative digestion of timothy (*Phleum pratense*) fibre by ruminants, equines and rabbits. Brit. J. Nutr., 47: 267-272.

Van Soest P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University, New York.

Van Soest P.J., Robertson J.B. and Lewis B.A. 1991. Methods for dietary fibre, neutral detergent fibre and non-starch polysacharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.

Van Steenis and De Wilde, 1950-1995. Flora Malesiana. Kluwer Acedemic Pub., the Netherlands.

Effects of plant spacing and nitrogen levels on the growth, biomass production and nutritive values of tropical kudzu (*Pueraria phaseoloides*) *Macroptilium gracile* and cowpea (*Vigna unguiculata*) in the Mekong Delta, Vietnam

L. H. Manh[1] and N. N. X. Dung[1]

[1]Department of Animal Sciences, Agricultural College, Cantho University, Vietnam

lhmanh@ctu.edu.vn; nnxdung@ctu.edu.vn

Abstract: The aim of the study was to introduce some non-cultivated legumes for farming system in the Mekong delta as protein source for feeding animals. The study consisted of two experiments. The first experiment evaluated the effect of chemical fertilizer levels (30-50-70 kg N ha^{-1}) on plant height, growth rate in height, biomass production and nutritive values of *Macroptilium gracile* used as feed for livestock. The second experiment studied the effect of plant spacing (40*20; 40*30 and 40*40 cm) on growth rate, biomass yield, composition and nutritive values of three species of herbaceous legumes: cowpea (*Vigna unguiculata*), tropical kudzu (*Pueraria phaseoloides)* and *M. gracile,* which was planted according to a randomized complete block design with three replicates. No chemical fertilizer and water were applied to plants in the dry season. Results of the first experiment showed that the nitrogen levels did not affect the development and production of the plant. *Macroptilium* gave very high dry biomass (3.91-4.39 t cutting^{-1} ha^{-1}), high protein content (21.4-22.4%); high in vitro organic matter digestibility (75-77%), low fiber components, NDF (39%) and ADF (29-30%). Results of the second experiment showed that plant spacing did not affect plant height but biomass production tended to increase at plant spacing of 40*20 cm. Among the legumes, cowpea gave highest fresh biomass yield (11.04 t cutting^{-1} ha^{-1}), followed by tropical Kudzu (5.56) and *M. gracile* (2.95). The corresponding figures for protein biomass were 0.29, 0.029 and 0.051 t cutting^{-1} ha^{-1} for cowpea, tropical kudzu and *M. gracile*, respectively. Tropical kudzu was more drought tolerant than the others. The results indicated that the plants can be grown well with or without fertilizer and a plant spacing of 20*40 cm is suitable for planting herbaceous legumes.

Key words: Chemical fertilizer, composition, cowpea, growth, height, *Macroptilum gracile,* nutritive values, spacing, tropical kudzu.

INTRODUCTION

Tropical kudzu (*Pueararia phaseoloides L)* and *Macroptilum gracile* are considered as weeds in some aspects. However, during the last few years studies on local feed resources focused on local plants, which can give high yield, good quality, and protein for animals. The limitation of animal rearing in the Mekong Delta is the lack of protein in their diets, which is mainly based on low protein grasses and agricultural by-products like rice straw. Therefore, animal performance and productivity have been low. The availability of protein sources for animal feeding can be found from non-cultivated leguminous plants, which are adapted well to the soil conditions or weather. Although non-cultivated legumes have been used as feed for livestock, little is known on the growth characteristics, biomass yield and nutritive value of some promising species, which are very abundant in the field or homestead area.

The aims of the study were to use better local legumes, such as tropical kudzu and *M gracile,* investigate the growth rate, and biomass yield under farm condition, identify the nutritive values and compare with cowpea, a cultivated plant for livestock production in the Mekong delta.

MATERIALS AND METHODS

Study site

The first experiment was conducted during the dry season from November to March in a homestead area in Cantho City. The soil is very low in fertility and acidic; pH is 4-4.5 in the top soil. The second experiment was conducted during the dry season from November to March in Omon district, Cantho city. The soil has low fertility and acid, pH is 4.5-5.

Methods

Experiment 1. Effect of nitrogen levels on biomass production and nutritive value of M. gracile

M gracile was reared in the nursery. Twenty tons of cattle manure were applied in pits one week before planting. Seedlings were planted in a single row 40 cm apart and with 10 cm spacing within the row. Three levels of nitrogen (30; 50 and 70 kg ha^{-1}) were used in a randomized block design with three replicates. The plants were applied with water and weeding was done when needed.

Treatment 1. Applied 30 kg N ha^{-1}
Treatment 2. Applied 50 kg N ha^{-1}
Treatment 3. Applied 70 kg N ha^{-1}

Experiment 2. Effect of plant spacing on biomass production and nutritive value of M. gracile, tropical Kudzu and cowpea.

Seedlings of the three legumes were first raised for three weeks in the nursery then transplanted in the field. Fifteen tons of cattle manure were applied in pits one week before planting. The plants were not applied with chemical fertilizers and water. One time weeding was done two months after planting.

Treatment plots following with three different spaces 20*40; 30*40 and 40*40 cm were arranged in a complete block design with three replicates.

Measurements

Plant height and biomass production

Plant height was recorded weekly and the growth observations were recorded on 10 randomly selected sample plants. Green biomass was taken from each bed, using a 5*5 m sampling area. Samples were collected from the top end of the soft stem part with stubble height of 20 cm. considered as potential feed and allowed for re-growth of the plants.

Chemical analysis

The sub samples from the harvested fresh biomass were dried at 60°C, ground through a 1-mm screen using laboratory hammer mill and stored at 4°C until analysis. Analysis of plant samples was performed following the Association of Official Analytical Chemist (AOAC, 1990) in duplicate Dry matter (DM) was determined by drying air-dry samples at 105°C in an oven overnight. Crude protein (CP = N*6.25) was determined by the Kjeldahl method. Ash content was determined by combusting for 3 h at 550°C. Ether extract (EE) was extracted by anhydrous ether using a Soxhlet apparatus. Acid detergent fibre (ADF) was determined according to AOAC (1984). Neutral detergent fibre (NDF) was analyzed according to Van Soest et al. (1991) and modified by Chai and Udén (1998).

Statistical analysis

The data were analyzed statistically by a variance analysis using the General Linear Model (GLM) of Minitab Software version 13.2 (Ryan 2000). Treatment means showing significant differences at the probability level of P<0.05 were compared using Tukey's pair-wise comparison procedures. The following models were respectively used in the first and second experiments:

$Y_{ijk} = \mu + F_i + B_j + \varepsilon_{ij}$

$Y_{ijk} = \mu + S_i + L_z + B_j + S*L_{(iz)} + \varepsilon_{ij}$
where Y_{ij} is the dependent variable, μ is the overall mean; F_i is the effect of fertilizer levels; B_j is the effect of block; S_i is the effect of spacing; L_z is effect of plants; S*L is interaction of the plants and spacing; i = 1, 2, 3; j = 1,2,3; z = 1,2,3; ε_{ij} represents random error.

RESULTS AND DISCUSSION

Experiment 1

Plant height and growth rate in height

The plant height and growth rate (height) of *M. gracile* are presented in Table 1 and Figure 1. The plant grew fast (2.78-291 cm day^{-1}) and the re-growth rate was faster than before the first cutting (2.95-4.34 cm day^{-1}). However, the differences in nitrogen levels did not affect plant height and growth for the first (P=0.13) and second cutting (P=0.72). The plant height presents a capability to complete the first phase of the growth cycle. Normally for leguminous trees, the first cutting is after 120 days, when the plant reaches 0.7-0.9 cm. In the present study, the age of the first and second cutting was only 56 days and 42 days, because *Macroptilium gracile* is a herbaceous, soft-tissued angiosperm, therefore the cut part was almost edible. Compared with the report of Le et al. (2000), the first and second cutting of *Stylosanthes guianensis* should be at 120 days after sowing and 60 days of the re-growth. However, there is no report for *Macroptilium gracile*, which is a relatively new introduction to farmers.

Biomass production

The results presented in Table 2 show that there were no significant differences in nitrogen levels on biomass production among treatments and between two cutting times. *Macroptilium gracile* dry biomass of the second cutting (4.1-4.37) was slightly higher than the first (3.91-4.39). However, there is no report in the literature that compares the effect of nitrogen on biomass production of this plant.

Table 1. Effect of nitrogen levels on plant height (cm) and growth rate in height of *M. gracile*.

Days	First harvesting			P	Second harvesting			P
	30N	50N	70N		30N	50N	70N	
7	5.9	6.1	5.5		54.0	50.7	50.9	
14	11.6	12.7	11.7		74.8	72.0	70.0	
21	22.1	23.5	20.4		89.2	90.1	89.6	
28	32.5	37.2	30.0		117.3	122.4	118.9	
35	52.8	55.6	50.5		131.2	140.4	140.6	
42	79.8	82.4	76.2		157.2	154.1	158.5	
49	113.7	118.9	114.0					
56	136.1	142.6	140.1					
Growth rate (cm day^{-1})	2.78	2.91	2.86	0.13	4.34	2.95	3.07	0.7

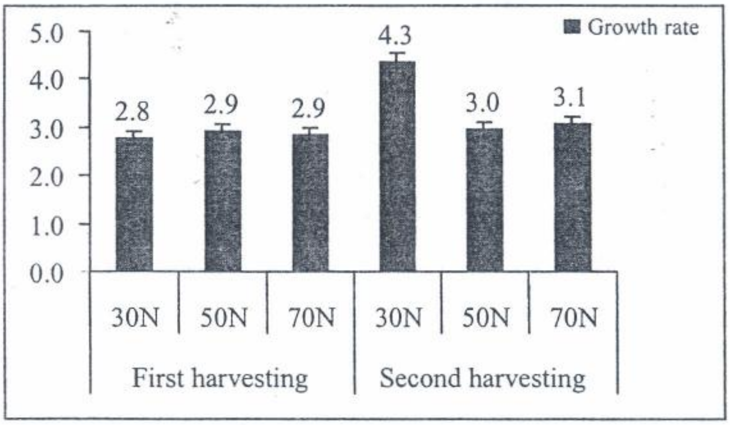


Figure 1. Effect of nitrogen levels on growth rate (cm) of *M. gracile.*

Nutrient composition

The data on nutrient composition in Table 3 show that nitrogen levels did not affect the composition and nutritive value of *Macroptilium*, which was very low in dry matter content as a result of fast growth and, hence, the plants absorbed much of water. *Macroptilium* was high in protein (21-22%) but low in NDF (39%) and ADF (29-31%) contents. These figures indicated that the plant is palatable to the animals. In vitro organic matter digestibility (IVOMD) was found rather high as compared to the other legumes such as *Stylosanthes* (68.6%), *Gliricidia* (71.1%), *Flemingia* (58.3%) and can be comparable with *Leucaena* (76.4%) (Le et al. 2000).

Table 2. Effect of nitrogen levels (kg N ha^{-1}) on fresh, dry and protein biomass of *M. gracile.*

Biomass (t ha^{-1})	First harvesting (56 days after planting)			P	Second harvesting (42 days)			P
	30N	50N	70N		30N	50N	70N	
Fresh	29.2	32.5	31		30.5	33.9	32.1	
Dry	3.91	4.39	4.21	0.26	4.1	4.51	4.37	0.5
Protein	0.87	0.94	0.91	0.58	0.92	0.96	0.94	0.2

Table 3. Effect of nitrogen levels on the nutrient composition and in vitro organic matter digestibility (IVOMD) of *M. gracile.*

	30N	50N	70N	P
Dry matter	13.48	13.32	13.59	0.75
Ash	10.08	11.34	10.74	0.87
Organic matter	89.92	88.66	89.26	0.88
Crude protein	22.36	21.37	21.63	0.65
Ether extracts	4.02	4.45	4.87	0.42
NDF	39.48	39.55	39.36	0.52
ADF	29.95	30.34	31.18	0.83
IVOMD	77.73	77.89	75.11	0.45

NDF: neutral detergent fibre; ADF: acid detergent fibre; IVOMD: in vitro organic matter digestibility

Experiment 2

Plant height and growth rate in height

The results presented in Table 4 and Figure 2 show that plant spacing had no effect on plant height and growth rate of the species. At the same time, plant height of cowpea was slightly higher than that of tropical Kudzu and *Macroptilium*. However, growth rate was not significantly different among species (P=0.10).

Table 4. Effect of plant spacing on plant height (cm) and growth rate (cm) in height of legumes.

Days	Cowpea			Tropical Kudzu			*Macroptilium gracile*			P
	40*20	40*30	40*40	40*20	40*30	40*40	40*20	40*30	40*40	
7	10.5	9.1	9.3	2.1	2.2	1.7	2.8	2.6	2.7	
14	13.5	12.0	12.4	4.3	4.0	2.9	4.2	4.0	4.2	
21	17.1	15.8	15.7	11.6	10.1	6.4	10.2	11.0	11.3	
28	25.7	23.9	23.2	19.4	18.0	14.0	13.0	13.0	13.8	
35	37.1	35.6	33.9	28.2	27.8	22.5	21.9	21.0	18.7	
42	58.9	56.8	47.1	41.4	39.6	36.9	31.9	29.0	28.5	
49				68.9	67.4	62.3	47.2	42.0	41.8	
56				117.9	114.3	106.4	60.5	55.0	54.8	
Growth rate (cm day^{-1})	1.38	1.36	1.08	2.76	2.67	2.49	1.37	1.3	1.24	0.1

Biomass production of legumes

Table 5 shows that plant spacing affected fresh, dry, and protein biomass production (P=0.01). Plant spacing of 40*20 cm had a significantly higher biomass production than that of spacing 40*30 and 40*40 cm. Among 3 species, at the same plant spacing of 40*20 cm, cowpea had the highest dry biomass (1.53 t cutting^{-1} ha^{-1}), followed by tropical kudzu (1.22 t cutting^{-1} ha^{-1}) and *Macroptilium* (0.47 t cutting^{-1} ha^{-1}). It was surprising to know that the dry biomass yield of *Macroptilium* in the first experiment (4.1-4.51 t cutting^{-1} ha^{-1}) was tenfold higher than that in the second experiment (0.23-0.47 t cutting^{-1} ha^{-1}). The biomass production depends highly on the soil fertility and water application during the dry season. In addition, many *Macroptilium* died or slowly developed due to drought, while cowpea and particularly tropical kudzu displayed a very good capacity for drought tolerance in the dry season

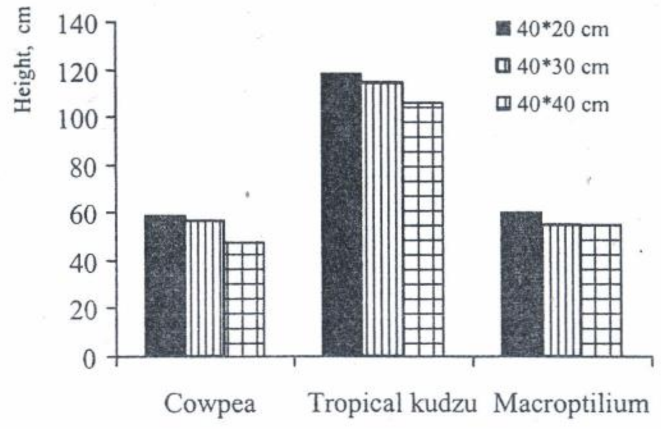


Figure 2. Effect of spacing on the plant height of legumes

Table 5. Effect of plant spacing on fresh, dry and crude protein biomass (t ha^{-1}) in one harvest of the legumes up to 56 days after planting.

Biomass	Cowpea			Tropical Kudzu			*Macroptilium gracile*			P
	40*20	40*30	40*40	40*20	40*30	40*40	40*20	40*30	40*40	
Fresh	11.03^{a}	8.50^{a}	7.90^{a}	5.60^{b}	4.30^{b}	2.90^{c}	2.94^{c}	2.12^{c}	1.52^{c}	0.01
Dry	1.53^{a}	1.16^{a}	1.07^{a}	1.22^{a}	0.95^{b}	0.64^{c}	0.47^{c}	0.33^{d}	0.23^{d}	0.01
Crude protein	0.268^{a}	0.205^{a}	0.191^{a}	0.156^{b}	0.117^{b}	0.083^{c}	0.069^{c}	0.048^{d}	0.033^{d}	0.01

^{ab} Means in the same row without common superscripts are different at P<0.05

Plant spacing did not affect the composition within species, however, there were high variations in composition among the legumes. DM content of tropical kudzu (21.1-22.1%) was higher than of cowpea (13.5-13.9%) and *Macroptilium* (15.3-15.6%) (Table 6). Cowpea had highest CP content (17%), followed by *Macroptilium* (14.5%) and tropical kudzu (12.8%). It is noted that the *Macroptilium* CP content in the first experiment (22%) was much higher than that in the second experiment (14%). Nitrogen application tended to increase protein content and biomass of *Macroptilium*. Nitrogen fertilizer is well known to increase CP and non protein nitrogen (NPN) contents in plans (Van Soest 1994), and the high CP value of *Macroptilium* found in the first experiment could have been influenced by this factor. It can be expected that benefit from nitrogen source will enhance protein content for the plants and also a means to supply non protein nitrogen for ruminants and also non-ruminant herbivores. As a legume, protein content of tropical kudzu was very low (12.8%), while 20% was reported by Gohl (1998). Dung et al. (2001) also reported that mean values of the CP content for tropical legumes ranged from 15-18%. According to Gohl (1998) tropical kudzu prefers fertile clay soils but may succeed on sandy loams, while the plant was planted in the acidic soil. Additionally, CP content of the legumes depend on the rhizobial inoculation of the roots during the first cutting of 56 days.

NDF and ADF of tropical kudzu were higher than that of cowpea and *Macroptilium* (Table 6). IVOMD of *Macroptilium* (72.1-735.%) was slightly higher than cowpea (67.8-69.5%; Figure 3). The lower IVOMD of tropical kudzu appeared to have higher NDF and ADF content than those of cowpea and *Maroptilium*

Table 6. Effects of plant spacing on chemical composition and nutritive of the legumes (as % of dry matter).

	Cowpea			Tropical Kudzu			*Macroptilium gracile*		
	40*20	40*30	40*40	40*20	40*30	40*40	40*20	40*30	40*40
Dry matter	13.9	13.7	13.5	21.8	22.1	22.1	16.0	16.0	15.3
Ash	9.3	9.9	9.8	7.6	7.4	7.4	7.1	7.2	7
Organic matter	90.7	90.1	90.2	92.4	92.6	92.6	92.9	92.8	93
Crude protein	17.5	17.6	17.9	12.8	12.3	12.9	14.6	14.6	14.4
Ether extracts	4.8	6.2	4.9	3	3.1	3.4	6.8	6.9	6.8
NDF	25.9	25.8	25.3	46.8	44.5	44.9	30.6	28.6	33.4
ADF	20.3	20.0	20.5	35.6	34.4	32.5	26.4	25	26
IVOMD	68.7	69.5	67.8	62.3	60.1	63.2	72.1	74	72.9

*Abbreviations see Table 3

Non-cultivated plants such as *Macroptilium* and tropical kudzu can be commonly found along the roadsides of the Mekong Delta. There are beneficial effects of the local legume species such as supplying more protein, thus enhance animal performance and productivity.

Planting herbaceous legumes, cowpea, kudzu and *Macroptilitum* in small areas of the backyard provides high quality leguminous forage for cut-and-carry feeding of household livestock.

Using non-cultivated plants as feeds, without applying herbicides, improve human and animal welfare.

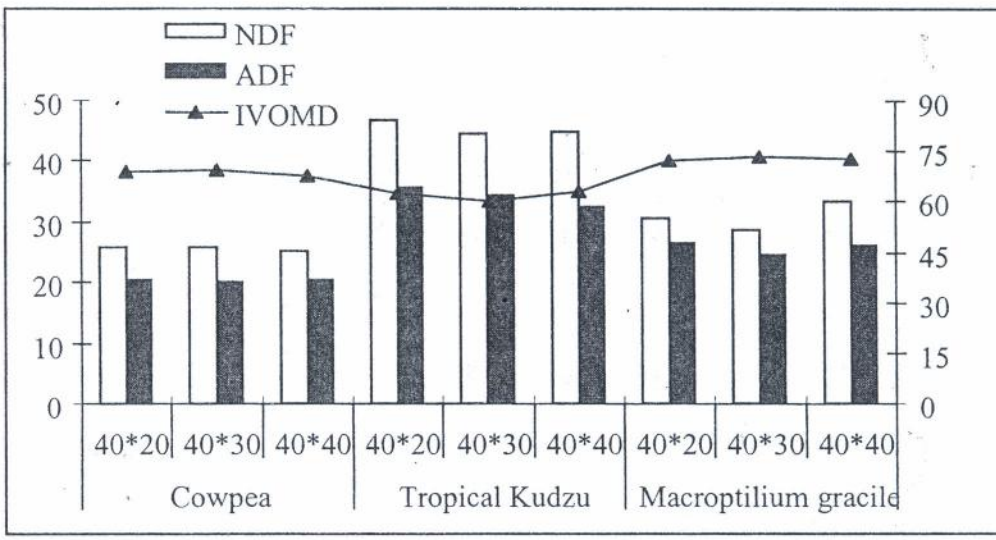


Figure 3. Variation of NDF, ADF content and in vitro organic matter digestibility (IVOMD) among legumes

LITERATURE CITED

AOAC 1990. Official Methods of Analysis. Association of Official Analytical Chemists. 15th edition (K Helrick ed). Arlington.

Chai W. and Udén P. 1998. An alternative oven method combined with different detergent strengths in the analysis of neutral detergent fibre. Anim. Feed Sci. Technol., 74: 281-288.

Dung N.N.X. and Udén P. 2001. Protein fractions in various feedstuffs from the Mekong Delta of Vietnam and their availabilities to monogastric animals. In Evaluation of green plants and by-products from the Mekong delta with emphasis on fibre utilization by pigs. PhD Thesis. Swedish University Agricultural Sciences.

Le K.H., Le V.A., Nguyen T.H.L, Dao T.P. and Ngo H.T. 2000. Leguminous forages as a protein source for livestock animals in upland farming systems. Workshop-seminar "Making better use of local feed resources" SAREC-UAF, January, 2000.

Ryan B., Joiner B.L. and Ryan Jr. 2000. Minitab statistical software release 13. Duxbury Press.

Van Soest P.J., Roberton J.B. and Lewis B.A. 1991. Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3579.

Van Soest P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University, New York.

Organic dye from leaves of *Lantana camara* – A noxious weed

A. Bansal, A. Sharma, A. Sood and S. Rani

[1] Department of Textiles and Apparel Designing, College of Home Science,
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur,
Himachal Pradesh, INDIA 176061.
ashab@hillagric.org

Abstract: *Lantana* is an introduced weed. It is now distributed throughout hilly places and has found its ways in the planes near the hills in the country. The plant is an aromatic straggling shrub with prickly stem and strong unpleasant smell. It blooms all year long and attracts butterflies in home gardens. It grows in almost any soil and is propagated by cuttings of softwood or by seeds. It is considered a pöisonous plant in nature but the leaves have useful application in traditional medicine. In the present investigation, leaves of *Lantana camara* were explored as a source of natural dye material. A vast range of shades and tints have been developed on wool and cotton using five mordants, viz., alum, stannous chloride, potassium dichromate, ferrous sulphate and copper sulphate with all the three mordanting methods, namely pre, simultaneous and post mordanting. The dyed samples were tested for colourfastness to various agencies, viz: washing, sunlight, crocking-wet and dry and perspiration-acidic and alkaline. *Lantana camara* produces fast colours by applying with various mordants or among itself in different shades of greens.

Key words: *Lantana camara*, noxious weed, organic dye.

INTRODUCTION

Dr. Hillebrand, a distinguished botanist of the Islands, introduced *Lantana camara* for ornamental purposes. This shrub subsequently became a noxious weed as it spread to the neighboring hills and pasturelands. Two birds, Chinese turtle dove and Indian myna, which feed on the fruits, rapidly carried the plants to the new land. *Lantana* is abundantly available in hilly and plain areas of Himachal Pradesh.

India's great tradition of vegetable dyeing was unequalled anywhere in the world. However the European development of synthetic dyes in the mid 19th century ended the export market for colourful textiles as well as the dyestuffs. The technical skills of vegetable dyeing were lost to all but a minority of textile craftsmen. However, today there is renewed interest in natural dyeing due to bans being imposed by European Governments, because of health risks from numerous synthetic dyes that they originally developed.

MATERIALS AND METHODS

Dye material

L. camara leaves were selected as dye material. The collected leaves were dried in shade and then powdered up to 0.5 mesh size to extract the dye.

Preparation of yarn for dyeing

Wool. Woolen yarn/fabric was scoured to remove natural oil, waxes and other impurities it contains. For this purpose, soap solution was prepared by dissolving neutral soap at the rate of 2 g L^{-1} in water taken as per MLR 1:50. The woolen yarn hanks were boiled in this solution for 45 minutes.

The hanks/fabric was rinsed under running water until it was free from traces of soap and dry flat in shade.

Cotton. Cotton fabric contains starch, dust, oil and other impurities that are to be removed by mild alkali and detergent. The detergent solution (2 g L^{-1}) was prepared by maintaining the material to liquor ratio of 1:40. The solution was made alkaline by adding sodium hydroxide (1 g L^{-1}). The yarn or fabric was boiled for 1 to 1.5 h with occasional stirring. The fabric was washed thoroughly, rinsed and dried in shade.

Pretreatment for cotton

For better dye fixation, cotton needs pretreatment of tannin. Myrobalan (*harda*), a natural mordant, was used for this purpose. The cotton hanks/ fabric of required quantity were weighed. The volume of water required for treatment was measured as per the material to liquor ratio of 1:20. The myrobalan solution was prepared by soaking 15 g of myrobalan for 100 g of yarn/fabric in water overnight, then the solution was strained. The fabric was soaked in the strained solution for 24 h then squeezed and dried under the sun for 3 h.

Mordants and Mordanting methods

Four mordants, viz., alum, potassium dichromate, ferrous sulphate copper sulphate and stannous chloride with mordant concentrations: 5, 10, 15 and 20 for alum.0.5, 1.0, 1.5 and 2.0% for chrome and copper sulphate and 0.5 ,1.0 ,1.5, 2.0 and 2.5% for ferrous sulphate and stannous were optimized. Three mordanting methods, namely, pre, simultaneous and post mordanting, were used for 30 minutes.

Optimizing dyeing variables

Medium of dye extraction. Litchi dye was extracted in aqueous, alkaline and acidic media and the best medium of dye extraction was determined on the basis of highest optical density.

Alkali concentration. The alkali concentration was optimized by taking five dye solutions containing 0.2, 0.4, 0.6, 0.8 and 1.0% alkali in five dye pots. The optimum concentration of alkali was determined on the basis of highest optical density.

Concentration of dye. The concentration of the dye material was optimized by taking seven concentrations prepared by boiling at 100^0C. Seven dye solutions of 2, 3, 4, 5, 6, 7 and 8 g of dye per 100 ml of water were prepared in seven dye cups, respectively, and boiled at 100^0C. The optical density was recorded after 30, 45, 60 and 75 minutes to optimize the dye extraction time.

Dyeing time. Percent dye absorption of the dye liquors was calculated after 30, 45, 60 and 75 minutes of dyeing. Optimum dyeing time for wool and cotton yarns was selected on the basis of highest percent dye absorption.

pH for dyeing cotton yarns. Seven dye solutions with pH ranging from 3.0 to 10.0 were taken and optimum pH for dyeing was selected on the basis of highest percent dye absorption.

Tests for colourfastness

The samples were subjected for colourfastness tests according to BIS standards.

- Colourfastness to washing – Test 2 (IS : 3361 – 1979)
- Colourfastness to rubbing – (IS : 766 – 1988)

- Colourfastness to sunlight – (IS – 686 – 1985)
- Colourfastness to Perspiration – (IS – 971 – 1983)

Colour fastness rating:
- Grey scale for evaluating change in the colour (IS: 768 –1982)
- Grey scale for evaluating staining (IS: 769 – 1982)

RESULTS AND DISCUSSION

The optimum proportions of different dyeing variables for wool and cotton are given in Tables 1 and 2, respectively. The alkaline medium was best among the three mediums of dye extraction with 1.0 alkali concentration. The optimum concentration of dye material was 2.0 g g^{-1} of yarn for wool and cotton on the basis of highest optical density. The optimum dye extraction time was 30 minutes. In case of cotton, *harda* is used as pre-treating agent and taken up to 10% for best results. The optimum pH for dyeing of wool was 4.0 and for cotton was 8. The optimum time for dyeing of wool yarns was 45 minutes and cotton yarns was 60 minutes on the basis of percent dye absorption.

Table 1. Optimum proportions of dyeing variables for dyeing of woolen yarns with Lantana leaves extract.

Sr. No.	Dyeing variables	Trial Proportions	Selected proportions
1.	Medium of dye extraction	Aqueous, alkaline, acidic	Alkaline
2.	Conc. of alkali	0.2, 0.4, 0.6, 0.8, 1.0 %	1.0 %
3.	Dye material conc.	0.5, 1.0. 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 g g^{-1} wool	2 g g^{-1} wool
4.	Dye extraction time	30, 45, 60, 75 min	30 min
5.	pH for dyeing	3, 4, 5, 6, 7	4
7.	Dyeing time	30, 45, 60, 75 min	45 min

Table 2. Optimum proportions of dyeing variables for dyeing of cotton yarns with Lantana leaves extract.

Sr. No.	Dyeing variables	Trial Proportions	Selected proportions
1.	Medium of dye extraction	Aqueous, alkaline, acidic	Alkaline
2.	Conc. of alkali	0.2, 0.4, 0.6, 0.8, 1.0 %	1.0 %
3.	Dye material conc.	0.5, 1.0. 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 g g^{-1} cotton	2 g g^{-1} cotton
4.	Dye extraction time	30, 45, 60, 75 min	30 min
5.	Conc. of harda	10, 20, 30, 40,50 %	10 %
6.	pH for dyeing	7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0	8
7.	Dyeing time	30, 45, 60, 75 min	60 min

Lantana leaf dye on woolen yarn

Table 3 depicts the best shades obtained from *Lantana*-dyed wool with various mordants. The 15% alum-dyed sample showed outstanding fastness grades for washing, crocking and perspiration, although increase in colour was also observed. Very good light fastness was seen with slight change in colour and the best shade obtained was Beechnut (PANTONE 14-0425 TPX) shade with simultaneous mordanting method. Straw (PANTONE 13-0822 TPX) shade was obtained with chrome 0.5% with outstanding fastness grades in post mordanting method. With copper sulphate (0.5%) all the samples depicted excellent fastness properties against all the fading agencies and the shade obtained was silver fern (PANTONE 15-0719 TPX). Ferrous sulphate (2.5%) post mordanted moon mist (PANTONE 18-4105) shade sample also showed outstanding fastness grades without any colour change and staining. With 1.5% stannous chloride, post-mordanting method obtained shade that depicted excellent results with very little change in colour in case of washing, light and perspiration. The shade obtained with stannous chloride was reed yellow (PANTONE 13-0915 TPX).

Table3. Fastness properties of best shades obtained on wool using Lantana leaf dye material .

Dye Percentage: 4% Dyeing Time: 45mins Dye Extraction Time: 30mins

Extraction Medium: Alkaline Mordanting Time: 30mins

Mordant Conc, g 100g^{-1} of silk	Mordan-ting method	Dye Absorption	Fastness properties														Best shades obtained
			Sun-light	Washing			Dry Crocking		Wet Crocking		Acidic Perspiration			Alkaline Perspiration			
				CC	CS		CC	CS	CC	CS	CC	CS		CC	CS		
					W	C						W	C		W	C	
Control		32.59	6	4	5	5	5	5	4/5	4/5	4/5	5	5	4/5	5	5	
Alum 15%	Simulta-neous	63.43	6	IC	5	5	5	5	5	4/5	5	5	5	IC	5	5	Beechnut (PANTONE 14-0425 TPX)
Chrome 0.5%	Post	58.24	7	5	5	5	5	5	5	4/5	5	5	5	5	5	5	Straw (PANTONE 13-0822 TPX)
$CuSO_4$ 0.5%	Post	58.11	7	4/5	5	5	5	5	5	4/5	4	5	5	4/5	5	5	Silver fern (PANTONE 15-0719 TPX)
$FeSO_4$ 2.5%	Post	30.05	8	5	5	5	5	5	5	5	5	5	5	5	5	5	Moon mist (PANTONE 18-4105 TPX)
$SnCl_2$ 1.5%	Post	21.32	7	4/5	5	5	5	5	5	5	4/5	5	5	5	5	5	Reed yellow (PANTONE 13-0915 TPX)

Note: CC-Colour change, CS-Colour staining, C-Cotton, S- Wool, IC-Increase colour

Lantana leaf dye on cotton yarns

Fastness grades of best shades obtained from dyeing cotton yarns in Lantana extract are shown in Table 4. Raffia (PANTONE 13-0725 TPX) was the best shade obtained with Alum 20% given excellent fastness grades in case of washing fastness where noticeable change in colour was seen. With 0.5% chrome, improvement in washing fastness was observed along with excellent crocking, light and perspiration fastness and the shade obtained was Pampas (PANTONE 14-0826 TPX). Cotton yarns dyed with Lantana using 1.5% copper sulphate showed outstanding results with negligible colour change and staining. Cotton samples mordanted with ferrous sulphate(0.5%) and stannous chloride (1.0%) depicted excellent fastness grades using post mordanting method. The best shades obtained with copper sulphate, ferrous sulphate and stannous chloride were dried moss (PANTONE 14-0686 TPX), goat (PANTONE 16-0806 TPX) and Chino green (PANTONE 13-0613 TPX) respectively. Post-mordanting method was the best method followed by pre-mordanting method.

- Colourfastness to su[...] shades obtained on cotton using Lantana leaf dye material
- Colourfastness to [...]g Time: 60mins Dye Extraction Time: 30mins

Colour fastness r[...] [...]danting Time: 30mins

- Grey scale f[...]
- Grey sca[...]

[...]rdanting method obtained
[...] of washing, light and
[...]PANTONE 13-0915

				Fastness properties													
				Washing			Dry Crocking		Wet Crocking		Acidic Perspiration			Alkaline Perspiration			Best shades obtained
				CC	CS W	CS C	CC	CS	CC	CS	CC	CS W	CS C	CC	CS W	CS C	
				2	5	5	5	5	4/5	5	4/5	5	5	4/5	5	5	
Alum 15%	[...]neous			2	5	5	5	5	5	4/5	4/5	5	5	4/5	5	5	Raffia (PANTONE 13-0725 TPX)
Chrome 0.5%	Pre	58.44	7	3/4	5	5	5	5	5	5	5	5	5	4/5	4/5	5	Pampas (PANTONE 14-0826 TPX)
$CuSO_4$ 0.5%	Post	60.06	7	3/4	5	5	5	5	5	5	5	5	5	5	5	5	Dried moss (PANTONE 14-0626 TPX)
$FeSO_4$ 2.5%	Post	43.82	7	3/4	5	5	5	5	5	5	5	5	5	5	5	5	Goat (PANTONE 16-0806 TPX)
$SnCl_2$ 1.5%	Post	19.16	7	3/4	5	5	5	5	5	5	4/5	5	5	5	5	5	Chino green (PANTONE 13-0613 TPX)

Note: CC-Colour change, CS-Colour staining, C-Cotton, S- Wool, IC-Increase colour

Lantana leaf dye on wool

Among three mordanting methods, post-mordanting method showed best results followed by pre method and simultaneous mordanting method.

The mordant percentages, which showed best results, were alum 15%, chrome 0.5%, copper sulphate 0.5%, ferrous sulphate 2.5% and stannous chloride 1.5%.

All the dyed woolen yarn samples showed excellent to outstanding fastness to all the four fastness agencies.

Lantana leaf dye on cotton

Very good to excellent light fastness was observed.

Washing, crocking and perspiration fastness was also found good with slight change in colour and staining.

The mordant percentages, which showed best results, were alum 20%, chrome 0.5%, copper sulphate 1.5%, ferrous sulphate 0.5%and stannous chloride 1.0%.

It is concluded that all shades obtained have excellent colourfastness properties. Post mordanting method came out as best mordanting method and all the three ratios showed equally good results. Dyeing of woolen and cotton yarns with Lantana camara leaf dye extract using combination of mordants is cost effective.

ACKNOWLEDGEMENT

We would like to thank the Indian Council of Agricultural Research for sponsoring this study.

LITERATURE CITED

AICRP-CT. 2004. Value Addition to Agro and Animal Based Fibres, Compiled annual report, AICRP-CT, 2003-2004.

Bansal A. and Sharma A. 2002. Value Addition to Agro and Animal Based Fibres, annual report, AICRP, Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University, Palampur.

Moses J.J. and Venkatachalam A. 2001. Natural Dyeing on Cellulosic and Protein Textile Materials. Book of Papers. Convention on Natural Dyes. IIT Delhi.17-18th Dec, 2001.

PANTONE. 2003. Western Hemisphere, Pantone Inc. New Jersey, USA. Pages 18, 20, 61,62, 63,64, 268.

The Wealth of India. 1990. Raw materials, CSIR, New Delhi.

Utilization of Himalayan weed flora for organic dyeing

Anjali Sood,[1] Anjali Sharma,[2] Asha Bansal[3]
[1]Assistant Professor, [2]Research Associate, [3]Head of Department
Department of Textiles and Apparel Designing, College of Home Science,
Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur,
Himachal Pradesh, INDIA176061. dr_rksood@rediffmail.com

Abstract: The term "Weed" has been traditionally taken to mean wild unwanted plant; recent efforts to utilize this bioresource have transformed the meaning into a useful asset. These wild plants can be used as source material for organic dyeing of wool, silk cotton fiber. We tested *Eupatorium adenophorum* leaves for dye properties. Fresh leaves of Eupatorium were leaves taken and the shade dried and grinded up to 2.00mm mesh size. Various concentrations of dye extract were tried to yield maximum dye on the basis of percent dye absorption. Trials were done using various mordants (dye fixing agents) i.e alum, copper sulphate, ferrous sulphate within eco-friendly limits. All the three mordanting methods viz. pre, simultaneous and post mordanting were tried. The dyed samples were tested for their color fastness to various agencies viz. Sunlight, washing, perspiration and crocking Excellent to very good washing and light fastness was observed, in case of dry and wet crocking outstanding fastness with no color change and color staining was observed. For alkaline and acidic perspiration, dyed samples showed excellent fastness ranging from 5 to 4/5 grades.

With the increased awareness of the hazards of synthetic dyes, certified organically dyed hand-woven products represent a niche market with less competition. In this scenario of globalization and industrialization, Herbal Technology has immense implications for the Himalayan region, being rich in biodiversity. This presently unutilized weed has potential to provide value addition and economically viable livelihoods in this Himalayan belt. Value addition making strategic use of technology to help strengthen existing mountain livelihoods or create new ones based upon sustainable utilization and conservation of local biodiversity. This will further help in the revival of tradition of weaving, help conserve culture and traditional motifs, empower the rural communities and promote stable ecology.

Key words: Eupatorium, Organic dyeing, Himalayan ecology, Livelihoods

INTRODUCTION

The term "Weed" has been traditionally taken to mean wild unwanted plant; recent efforts to utilize this bioresource have transformed the meaning into a useful asset. These wild plants can be used as source material for organic dyeing of wool, silk, and cotton fiber.

Eupatorium adenophorum is a disagreeably smelling shrub or perennial herb & an important alien invasive plant species. Rampant growth of a toxic grass (*eupatorium adenophorum*) is devastating tens of thousands of hectares of grasslands. Once rooted, eupatorium adenophorum can cover 100 percent of a hectare of grassland within two years. Each hectare of grassland invaded by this toxic species produces no more than 1 kilogram of grass but 78,000 kilograms of eupatorium adenophorum. This grass has a unique odor and toxin that makes it unattractive to cattle and sheep. However, a multitude of livestock have already died after eating this poisonous grass by mistake. Utilization of the plant products for organic dyeing could be way to control this weed profitably. Natural dye collection, processing, extraction and dyeing if promoted as agro based rural cottage industry will open immense possibilities for livelihood and promote rural economy.

MATERIAL AND METHODS OF ORGANIC DYEING

Dye material: *Eupatorium adenophrum* leaves were selected as dye material. The collected leaves were dried in shade and then powdered to extract the dye.

Yarn used for dyeing: Locally available wool and Cotton and silk yarns were used. Scouring of wool was done by boiling the wool in solution containing 2 gm per litre neutral soap for 45 minutes in 1:50 material liquor ratio. Then it was rinsed in cold running water to remove all the traces of soap, and dried in shade. Cotton yarn was desized to remove starch, dust, oil and other impurities. One gm sodium hydroxide and 2 gm detergent were taken per liter of water in the material liquor ratio 1:40. The yarns were boiled for 1½ hour in the soap solution with occasional stirring. Then the yarns were washed thoroughly in water until any trace of soap remained and then dried in shade. The raw silk yarn was degummed by taking it in the form of hank and weighted. The value of water to be taken was calculated as per the material to liquor ratio of 1:50.The detergent solution was then prepared by dissolving nonionic detergent at the ratio of 2gram per liter of water. The yarn was boiled in the detergent solution for 45 minutes. The yarn was then thoroughly rinsed to remove traces of detergent and dried in shade.

Mordants and Mordanting methods: Different mordants yield different colors in the same dye bath; while vegetable dyes yield warm, subtle colors, their density and colour fastness are determined by varying concentrations and skilful manipulation of the mordants The matter used for dyes and for mordants *is* the most crucial aspect *in* determining the colour as well as the effects on health and the environment. Consciousness about the environment and health has led to an evaluation of the matter used for dyeing and for mordants. The mordant is also derived from natural mineral sources. These are used to precipitate the active principal of the dye and to fix the colour, to make it insoluble in water or neutral, and play a major part in determining the luster and performance of natural dyes.

Three mordants viz. Alum, Ferrous Sulphate and Copper Sulphate with all the three mordanting methods namely pre, simultaneous and post mordanting were used for 30 minutes. The percent of mordant used was 5-30%/100gm of yarn for alum and 1-6%/ 100gm of yarn for Ferrous Sulphate and Copper Sulphate

Dyeing variables:

Following dyeing variables were optimized for dye extraction from *Eupatorium adenophorum:*

Medium of dye extraction: The *Eupatorium adenophrum* dye was extracted in aqueous, alkaline and acidic mediums and the best medium of dye extraction was determined on the basis of highest optical density.

Alkali concentration: The concentration of alkali was optimized by taking 5 dye solutions containing 0.2 percent, 0.4 percent, 0.6 percent, 0.8 percent and 1.0 percent alkali in 5 dye pots respectively. The optimum concentration of alkali was determined on the basis of highest optical density.

Myrobalan concentration: For the dyeing of cotton, myrobalan (harada) was used as the pre-treating agent. Myrobalan solution was prepared in 5 tubs containing 10 gm, 20 gm, 30 gm, 40 gm, 50 gm of myrobalan respectively per 100 gm yarn with material liquor ratio 1:20. The yarns were treated in myrobalan solution for 24 hours at room temperature. The treated yarns were exposed to sunlight for 3 hours without washing. The optimum concentration of myrobalan was determined on the basis of per cent dye absorption.

Concentration of dye: The concentration of dye material was optimized by taking seven concentrations prepared by boiling at 100^0C. Seven dye solutions of 2, 3, 4, 5, 6, 7 and 8 gm of dye per 100 ml of water were prepared in seven dye cups respectively and boiled at 100^{0}C. The optical density was recorded after 30 minutes, 45 minutes, 60 minutes and 75 minutes to optimize the dye extraction time.

Dyeing time: Percent dye absorption of the dye liquors was calculated after 30 minutes, 45 minutes, 60 minutes and 75 minutes of dyeing. Optimum dyeing time for wool, silk and cotton yarns was selected on the basis of highest percent dye absorption.

pH for dyeing of yarns: Eight dye solutions of pH ranging from 3.0 to 10.0 were taken and optimum pH for dyeing was selected on the basis of highest percent dye absorption.

Colour fastness test: The dyed woolen, silken and cotton yarn samples were assessed for their colour fastness with four agencies viz. colour fastness to washing, perspiration, sunlight and rubbing. These tests were rated according to following standard test procedures.

Washing fastness test	IS:	3361-1979
Perspiration fastness test	IS:	971-1983
Light fastness test	IS:	686-1985
Rubbing fastness test	IS:	766-1988

RESULTS AND DISCUSSIONS

Table 1: Optimum proportions of dyeing variables for dyeing of woollen, cotton and silken yarns with Eupatorium dye material

Sr. No	Dyeing variables	Trial proportions	Selected proportion WOOL	Selected proportion COTTON	Selected proportion SILK
1	Medium of dye extraction	Aqueous, alkaline, acidic	Alkaline	Alkaline	Alkaline
2	Concentration of alkali	0.2%, 0.4 %, 0.6%, 0.8%, 1.0 %	1.0%	1.0%	1.0%
3	Dye material concentration	0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 gm	1.5 gm	3.0 gm	3.0 gm
4	Dye extraction time	30, 45, 60 and 75 minutes	45 min	45 min	45 min
5	Concentration of myrobalan	10%, 20%, 30%, 40% and 50%	Not Applicable	30%	Not Applicable
6	pH for dyeing	7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0	4.0	7.0	4.0
7	Dyeing time	30, 45, 60 and 75 minutes	45 min	45 min	45 min

The optimum proportions of different dyeing variables for wool, cotton and silk are presented in table 1. The alkaline medium is best medium of dye extraction with 1.0 percent alkali concentration. The optimum concentration of dye material is 1.5gm/gm of wool and 3.0gm/gm of cotton and silk on the basis of highest optical density. The optimum dye extraction time is 45 minutes. In case of cotton, myrobalan is used as pre-treating agent and taken up to 30 percent for best results. The optimum pH for dyeing of wool and silk is 4.0 and 7.0 for cotton. The optimum time for dyeing of wool, cotton and silk is 45 minutes on the basis f percent dye absorption.

Table 2: Best shades obtained on wool with Eupatorium dye material

	Mordant	Mordant % age	Mordanting method	Shade obtained
1.	Alum	15%	Post	Greenish yellow ochre
2.	$CuSO_4$	4%	Post	Yellow brown
3.	$FeSO_4$	4%	Post	Light umber

Table 2 depicts the best shades obtained after dyeing of woollen yarns with *Eupatorium adenophorum* dye material. The best shades obtained are greenish yellow ochre, yellow brown and light umber obtained with alum, copper sulphate and ferrous sulphate respectively.

Table 3: Best shades obtained on cotton with Eupatorium dye material

	Mordant	Mordant % age	Mordanting method	Shade obtained
1	Alum	5%	Pre	Greenish raw umber
2	CuSO4	2%	Post	Light greenish raw umber
3	FeSO4	4%	Post	Olive green

Table 3 presents best shades obtained from dyeing of cotton yarns with eupatorium. The shades obtained were greenish raw umber, light greenish raw umber and olive green after mordanting with alum, copper sulphate and ferrous sulphate respectively.

Table 4: Best shades obtained on silk with Eupatorium dye material

	Mordant	Mordant % age	Mordanting method	Shade obtained
1.	Alum	10%	Post	Yellowish green
2.	$CuSO_4$	4%	Post	Light army green
3.	$FeSO_4$	4%	Post	Dark army green

The best shades obtained from dyeing with eupatorium and mordanting with alum, copper sulphate and ferrous sulphate are yellowish green, light army green and dark army green respectively on silken yarns.

The dyed woollen, cotton and silken yarns were tested for colour fastness to various colour fastness agencies. The dyed yarns showed high degree of fading Fastness to sunlight ranging from 6 to 8 in fading scale (blue wool standard) of 1-8 for light fastness & Grade 3-5 in fading and staining grey scale of 1-5 for washing, rubbing and perspiration.

IMPLICATIONS & PROSPECTS

Hazards of Synthetic Dyes: The use of chemical dyes has been a cause for concern, for ecological and health reasons. The weavers use VAT and napthol for chemical dyeing of the yarn. These two methods have already been discarded internationally because they use caustic, hydrose, nitric acid and acetic acid for mordanting. Moreover, the chemicals used for the dyes are not Azo-free. The workers who are engaged in dyeing are exposed to various health hazards. They use their hands to mix the chemicals, e.g. mixing acid and napthol in cold water as a result of which they develop boils. The waste-water gives off a bad smell and pollutes the surroundings. The trees and plants get burnt and die gradually. Even as a user of clothes dyed with chemicals, one is at risk of getting skin cancer

Value Addition Possibilities With Natural Dyes: The Shivalik belt of Himalayas is not only a region rich in biodiversity of flora with plentiful source material of natural dyes, but also supports wool producing animals and traditional livelihoods based on weaving. Natural dye cultivation/ collection, processing, extraction and dyeing if promoted as agro based rural cottage industry will open immense possibilities for livelihood and promote rural economy.

In the globalization scenario, traditional weaving industry in this hill state of north India is facing a stiff competition from power loom industry of neighboring industrial centers. Industries are capable of mass production at low costs to capture the market. These industries usually use traditional means of production, which is labor intensive and cannot be produced on a large scale. So, to retain the market share and survive in the increasing globalized scenario, weavers need to innovate and respond in a befitting manner. Naturally dyed hand-woven products represent a niche market with less competition. A study by the World Bank and University of Georgetown USA, in Himachal Pradesh, India -Cottage Industry Global Market, revealed that there is an immense potential for naturally dyed hand-woven products.

Commercialization of natural dyes can be done by scientific approach to their extraction, dyeing and use. Optimization of the extraction and dyeing process is essential to avoid discrepancy in shade quality. Natural plant resources such as local weeds, shedded leaves of fruit trees, rinds, roots and barks of trees alone and in combinations when used with different mordants in varying concentrations can yield a rich variety of shades, which are fast to various agencies of colour fastness.

CONCLUSIONS

The above discussion reveals that obnoxious weeds like *Eupatorium adenophorum* can be utilised for obtaining eco friendly products like natural dyes which represent a niche market with high profits to the producers.

ACKNOWLEDGMENT

The present study was sponsored by Indian Council of Agricultural Research, New Delhi, India.

LITERATURE CITED

Bansal, A., Sood A. (2001), Development of vegetable dye on wool from Eupatorium leaves. Textile Magazine, Chennai, India, Vol.42, No. 3, pp 41-44.

Bansal, A., Sood A. (2001), Development of vegetable dye on cotton from Eupatorium leaves. Textile Magazine, Chennai, India, Vol.42, No. 8, pp 81-84.

Sood, A. et.al, (2004), Dyeing of woollen and cotton yarns with Eupatorium leaves. Asian Textile Journal, Mumbai, India, October, pp 91-94.

Vijayakumar, A. V. et.al, (1999), Colours from common weeds. Pro. Of Convention on Natural Dyes, Department of textile Technology, IIT, New Delhi, India, pp 47-49.

Education and Technology Transfer

Enhancing weed management skills by resource-poor farmers

P.A.C. Ooi[1] and M.C. Casimero[2]
[1]Food and Agriculture Organization, Regional Office for Asia and Pacific, Maliwan Mansion, 39 Phra Atit Road, 10200 Bangkok, Thailand
[2]Chief Science Research Specialist, Philippine Rice Research Institute, Maligaya, Science City of Munoz, 3119 Nueva Ecija, Philippines
Peter.Ooi@fao.org; mcasimero@philrice.gov.ph

Abstract: In recent years, weed management has become synonymous with weed control and the most common recommendation is the use of chemical herbicides. Weeds were considered as nuisance at best or a competitor to economic production at worse and therefore should be eradicated. However, this approach has been known to cause environmental degradation, health hazards, plant succession and in some cases, herbicide resistance. Such developments have their parallel in the field of insect pest management. To address the complexity associated with managing insect pests, FAO pioneered and established participatory farmer education in rice, vegetables and cotton. This is implemented in Integrated Pest Management (IPM) Farmer Field Schools where farmers learn skills in carrying out experiments, generating knowledge, learning to manage and organize themselves to work in groups. This has resulted in empowered farmers who are capable of making "science-informed" decisions. As with insect management, weed management should start by helping farmers understand weed ecology. It has been traditional for farmers to use weeds as food, medicine, animal feed and mulching material. As herbicides became the main control strategy for weeds, the traditional uses of these plants have been minimized. Building on the experiences in Cotton IPM, some rice farmers in the Philippines who had been educated on IPM underwent an FFS on integrated weed management. This activity resulted in the familiarization of weeds associated with rice including their competitive abilities and enhanced their capacity to develop and implement sustainable weed management strategies.

Key words: Cotton, farmer field school, resource poor farmers, rice, weed management skills

INTRODUCTION

Current farmers' practices and the recommended weed control practices, that are largely herbicide based, are most often very costly and unsustainable. In developed countries, herbicide resistant weeds have emerged with long term and continuous application of the same type of herbicides. The prolonged practice of eradicating weeds by intensive herbicide application may result in the same grim scenario seen with insects and insecticides, as is being observed happening in direct seeded rice and the weeds associated with this crop. The prolonged application of butachlor-based herbicides that target the *Echinochloa* species had successfully reduced the population of this species but favored the shift to *Leptochloa chinensis* as major weed in direct seeded rice (Casimero and Kawana 2000). This weed, which is controlled by using Acetyl co-enzyme A carboxylase enzyme inhibitor herbicides, has developed resistance after 8 years of continuous application in a farmer's field in Thailand (Maneechote et al. 2003).

Traditionally, the weeds taken out from the field are either used as food, medicine and fed to livestock or used as mulch for the growing vegetable. Weeds likewise serve as habitat for beneficial insects and other organisms, thereby maintaining balance in the ecosystem. This role of weeds as refuge of beneficial insects has been recognized in insect pest management and thus, the importance of conserving them.

With farmers' traditional knowledge on weed utilization, weed management can be viewed from another perspective. Rather than viewing weeds as "pests that need to be removed as it is bad for the crop", management strategies can be developed based on the concept of weeds as useful to farmers. It is therefore important to consider weeds as pests only when they cause significant yield reduction at the vulnerable stage of the crop. The knowledge on weed ecology need to be introduced to farmers so that they know how the weeds grow together with the crop and when do they compete with the crop for nutrients, water and light.

Weed ecology provides a basic understanding of the distribution and abundance of weeds in natural ecosystems and the impact of weed infestation in managed ecosystems. Understanding weed ecology and competition allows farmers to identify the weeds in the field and separate those that are likely to reduce their crop yield from the useful or minor weeds, assess/estimate weed population from the seed bank and current vegetation, and understand when and how it affects their crop. These parameters are important in the development of weed management strategies that promotes efficiency by putting emphasis on sound ecology, weed utilization, timeliness of implementation and savings on costs.

The farmer field school (FFS) has illustrated the importance and success of participatory approach in honing skills and decision making capability of farmers to manage insect pests (Kenmore 1996, Ooi 1998; Pontius et al. 2002, Ooi et al. 2004). Though IPM has been largely equated to insect pest management, the acquired skills of farmers in understanding the crop agro-ecosystem and making learned management decisions provide an important springboard to integrating weed management into the broader IPM perspective. Learning about weed ecology is a knowledge intensive process and the indigenous knowledge and experience of farmers is an essential entry point to build up farmer confidence to learn more.

METHODOLOGY

1. Lessons from training on enhancing facilitation skills of IPM facilitators

Recognizing the need to integrate weeds into the broader IPM perspective, the EU funded and FAO-UN implemented IPM Programme for Cotton in Asia (1999-2004), initially conducted the International Course on Weed Ecology for Cotton IPM. This is a week-long intensive training course participated by cotton IPM facilitators from Bangladesh, Pakistan, India, Philippines, China, and Vietnam. Three international experts served as resource persons on basic topics about weeds, weed ecology, and crop-weed competition. Field exercises, led by the local resource person, on weed identification, quantitative and qualitative weed population assessment and seed bank estimation were conducted to familiarize the participants on some exercises that can be done to "concretize" the concepts learned from the lectures and discussions. Participants developed a design of field exercises that can be conducted to introduce the science of weeds to farmers.

A follow up training to enhance the facilitation skills of cotton IPM facilitators was conducted in Cebu City, Philippines and in Vietnam in 2003. In this training, more focus was done in facilitation skill improvement to enable the facilitators to become more adept at conducting the season-long training on cotton IPM. The trainees were again familiarized on the uses of upland weeds and quantitative assessment of weed population in the field. A field trial (composed of two set ups for the weed-free and weedy treatments) on critical period of competition (CPC) was established to enhance the capacity of facilitators to explain crop-weed competition to farmers. The following treatments were imposed in field plots measuring 16 m^2: Set up 1 Weed free for first 20 days (T1); first 30 days (T2); first 40 days (T3); first 50 days (T4); first 60 days (T5) and weed free throughout the season (T6). Except for T6, all the plots were unweeded for the rest of the cropping season. Set up 2 Weedy for the first 20 days (T1); first 30 days (T2); first 40 days (T3); first 50 days (T4); first 60 days (T5) and weedy throughout the cropping (T6). In the first five treatments, the weeds were removed after the weedy periods and remained weed free until harvest. Participants also conducted an interview to cotton farmers about their current weed management practices and weed utilization. Lessons learned from this activity are discussed.

2. Facilitating Weed Management Skills of Farmers

A season-long training on weed ecology participated by IPM-FFS graduates was conducted in the Philippines in 2004. In this training, farmers were familiarized about the major weeds associated with rice, conducted field exercises on weed density quantification and assessment , critical period of competition similar to the above mentioned set up, and a participatory technology demonstration on integrated weed management. In the PRD, the treatments involved were T1- Agro-ecosystem analysis (AESA) based weed management; T2- Farmers practice {pretilachlor followed by 2,4-D + handweeding (HW) at 30 days after seeding}; T3- Post-emergence herbicide fenoxaprop-p-ethyl + HW); and T4- pre-emergence herbicide (pretilachlor at 1 li ha^{-1} at 3 DAS + HW). Thirty farmers participated in the training that was facilitated by the trained local government extension officers. Resource persons were invited to discuss relevant concepts and issues related to weed ecology and integrated weed management.

RESULTS AND DISCUSSION

Lessons from teaching weed ecology to IPM Facilitators

In the first field exercise, it was learned that farmers have various uses for their weeds (Ooi and Casimero 2004). Hence, weeds can be viewed from another perspective such that weeds need to be managed well so farmers can fully use them as beneficial farm resources. To reinforce the need for better and timely weed management, the critical period of competition was recommended and developed as an entry point in studying weeds and weed ecology. One output generated from the training is a protocol of a field exercise on crop weed competition.

Two season-long training of specialists/facilitators (ToS/ToF) served as the testing ground for the CPC field trial which was initially implemented in the Philippines and Vietnam. Farmers in the practice farmer field school (FFS) were interviewed about their concept on weeds, especially those weeds associated with the cotton crop, their management methods and uses of weeds as a complementary activity to the CPC trial. From these interviews, it was learned that farmers had many uses for these plants. As has been learned from the interviews done in Cebu, Philippines, farmers use the weeds for food, medicine, fodder and mulching material. In many instances, weed usage was very much similar in Negros Oriental and Cebu which was expected as farmers belong to the same culture (Table 1).

In Vietnam, most of the weeds associated with cotton especially the grasses and sedges are used as feed for animals (Ooi and Casimero 2004). Farmers in the Philippines similarly save the grasses as feeds for cattle, goat and carabao. As these weeds are of moderate to high level of occurrence in the field, this information is very important in terms of proper timing of management. These weeds can then be allowed to grow with the crop for a certain period then removed to be used as food, medicine or feed for livestock when it has reached the stage that it can cause yield loss. A few weeds like *Centella asiatica, Eclipta alba, Ageratum conyzoides* and *Achyranthes aspera* are used for medicine. *C. asiatica, O. repens* and *Amaranthus panicudatus* are used for food. It is interesting to note that there are common weeds like *C. asiatica* and *Amaranthus spp.* used as medicine and food in both countries.

Table 1. Weeds associated with cotton and their uses. Bayawan ToS, Bayawan City. Philippines, 2003/4 (adapted from Ooi and Casimero 2004).

Weed Name	Uses	Part of Weed	How is it Used
Euphorbia heterophylla	medicine for wound	leaves	extract juice and apply on open wound
Chromolaena odorata	medicine for wound	leaves	extract juice and apply on open wound
..hia hirta	medicine for dengue	leaves, roots	boil, when cool drink concoction
Corchoruindicum	medicine for body pains	roots and leaves	soak in water for 2 hours, drink
Amaranthus spp.	..d, animal and food,	leaves and shoot	ingredient for sinigang, fed fresh to pigs and fish
Rottboellia cochin chinensis	animal feed	young leaves	as vegetable
		seed	pound and apply to allergic skin
		young leaves	as vegetable
Cynodon dactylon	animal feed	stem	fed fresh
Eleusine indica	animal feed	stem and leaves	fed fresh
Portulaca oleracea	animal feed	leaves	fed fresh
	medicine for post partum trauma	whole plant	dry and burn ... ing
Cyperus rotundus	medicine for tooth ache and animal wound	leaves	pound and apply to wound or aching tooth

Learning about the critical period of competition (CPC)

The field exercise on crop weed competition in cotton illustrated the impact of various durations of exposure of cotton to weeds. The parameters measured and used as indicators of competition wer weed weight, weed population, plant height, boll count plant^{-1} and crop yield. In the CPC set up i Vietnam, the graph between the duration of weed competition and crop yield clearly illustrates tha weeds need to be removed from the field from 30 to 50 days after planting to avoid substantial yiel reduction (Ooi and Casimero 2004). This period then corresponds to the CPC and the weed free period is about 50 days after planting.

2. Facilitating skills on weed management by farmers

In another activity, a follow-up FFS on integrated weed management in direct seeded rice was initiated among rice farmers that had undergone IPM-FFS in rice. Some of the activities conducted include weed survey, identification and utilization, CPC study and a participatory technology demonstration (PTD) on weed management for direct seeded rice. Weed utilization of farmers in Aklan was similar to those in Cebu and Negros Oriental (data not shown). Most grass weeds were fed to livestock or used as mulch for vegetables. *Portulaca oleracea* and *Ipomoea triloba* were used for food. Farmers were able to establish that the CPC in direct seeded rice occurs during the first 45 days (Figure 1), hence it is in this period that weed management strategies have to be imposed to prevent significant yield reductions. In another field study, they established a PTD on weed management using a combination of single herbicide and handweeding (if necessary) during the first 45 days compared to their current practice of two herbicide applications. Farmers observed that sedges were more dominant than grasses and broadleaved weeds. With their knowledge about weeds, farmers increased their rice yield by 0.5 t ha^{-1} compared to the traditional practice of applying two herbicides (Table 2). With the AESA done weekly, farmers observed a low weed density at 30 DAS composed mostly of secondary sedges, thus a decision was made to eliminate the second application of a post-emergence herbicide or handweeding. It was also observed that reducing herbicide application by 50% did not reduce their yields as indicated by the higher yields observed with the single application of either a pre-emergence or a post-emergence herbicide (Table 2). Hence, farmers understood that better weed management strategies can be made if they have sufficient knowledge of what the weeds are, the competitive ability of such weeds and density at the critical period of competition. The learning by doing approach during the FFS equipped farmers with the knowledge that weeds need to be managed at the right time to prevent yield loss, reduce weed control costs and allow them to use the weeds in their farming systems.

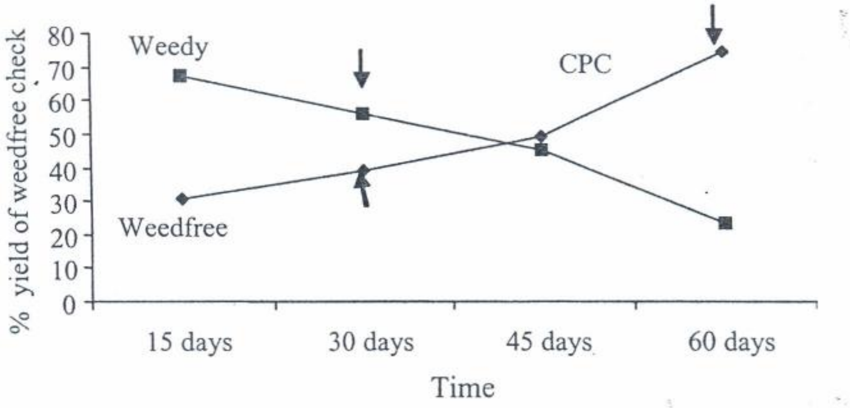


Figure 1. Percent yield of weed free and weed infested plots as compared to completely weed free yield for rice exposed to different durations of weed competition at the FFS in Malinao, Aklan, Philippines, 2005.

Integrated weed management involves bringing back ownership of weed management to farmers. It may start up as a best mix of strategies, direct or indirect, that is cost effective, environmentally sound and socially acceptable to the farmers. As in insect pest management, it will evolve into a deliberate selection, integration and implementation of effective weed management strategies by farmers with due consideration to the economic, ecological and sociological consequences, not unlike the goals proposed by Buchanan (1976). Such strategies aim at not only reducing the weed population and preventing yield loss but recognizing that the weeds may be useful resources to farmers. Over and above the goal of reducing weed population, management strategies developed should have a positive impact on the lives of farmers and protect the environment and its biodiversity. As with insect pest management, learning from the farmers first and educating both facilitators and farmers on the application of weed ecology using a participatory approach in the development of integrated weed management is indispensable. The success of the participatory approach in IPM has empowered farmers to make "science based" decisions to manage insect pests. The first FFS on weed ecology in the Philippines has shown that it is likewise an effective approach to empower farmers in making the necessary "science-based" decisions in developing weed management strategies for their crops.

Lessons learned from implementing IPM over the last 10 years in Asia have shown that IPM is effectively practiced by farmers only when it is developed by them (ter Weel and van der Wulp 1999; Pontius et al. 2002). To help farmers tackle complex issues in extension, such as pest management, the farmer field school approach appears to be the most practical (Schmidt et al. 1997). Despite evidence from case studies and impact assessments, the success of farmer education through farmer field schools continues to be challenged by complaints of costs, poor quality of teaching, lengthy "schooling" period and low staying powers by farmers who have been taught. The FFS approach continues to evolve in response to these challenges. For example, improvements were innovated to look at reducing costs, provide independent proofs of social and economic impact improve quality of farmer education and promote sustainable farmer groups to continue generation of new knowledge. In the latter case, the need for follow up activities like farmer field research is encouraged (Ooi 1998).

Table 2. Grain yield of rice as influenced by the different weed management practices. FFS-Malinao, Aklan, Philippines, 2004-2005 DS.

Treatment	Grain Yield ($t\ ha^{-1}$)	Weed Control Cost (Php)
AESA* based weed management (fenoxaprop-p-ethyl at 0.5 L ha^{-1} fb HW when needed)	4.7	1,150
Farmer's practice (pretilachlor fb 2,4-D at 1 L ha^{-1} each)	4.2	1,670
Post-emergence herbicide (fenoxaprop-p-ethyl at 0.5 L ha^{-1})	5.4	1,150
Pre-emergence herbicide (pretilachlor+fenclorim at 1 L ha^{-1})	4.8	990

AESA - Agro-ecosystems analysis based weed management refers to the management decision arrived at by farmers during the weekly observation of weed density and intensity of crop-weed competition in the field.

Attempts to include weed management into regular IPM activities are part of the effort to improve quality of farmer education to improve efficiency in production. However, as in insect pest management, initial reactions to an ecological approach in weed management face an uphill struggle. Experiences in 2002 and 2003 suggest that this ecological approach towards weed management met with much initial resistance and indeed, many IPM Facilitators find it difficult to adapt towards the concept that weeds can be important resources for farmers. Many complained that the exercises are too complicated to implement. Indeed, there were many failures in the planning and execution of the protocols developed in two international workshops. Despite these failures, it is necessary to continue to incorporate implementation of weed ecology into the Training of Facilitators (ToF) curriculum. The ToF should provide an opportunity for potential Facilitators to practice implementation of Critical Period of Weed Competition. This should be complemented with facilitation skills to learn from farmers about their understanding of weeds as well as develop baseline information about location specific weed management by farmers.

It is recommended that the FFS curriculum should include exercises on recording farmers' traditional knowledge about weeds and their management. Helping farmers to identify the "good" and "bad" weeds will encourage further questions and develop curiosity among farmers to learn more about weeds. A natural development to this understanding is the ability to manage "bad" weeds. CPC experiments are good follow up activities by groups of farmers who have graduated from FFS. It is not recommended to include CPC experiments in FFS curriculum as the purpose of FFS is to develop farmer confidence to ask questions and develop skills to find answers to these questions. Generating knowledge in pest management helps farmers to develop IPM, making them more efficient in their agriculture activities resulting in reduction of input costs, increase profits, reduce health risks from using poisons, protect the environment and maintain biodiversity and sustainable agricultural development.

ACKNOWLEDGEMENTS

The authors are grateful to the National IPM Programmes in the six participating countries of the FAO-EU IPM Programme for Cotton in Asia, especially the Philippines and Vietnam. Our grateful thanks to Dr. J. S. Binamira and Mr. C. Galvan for their support in ensuring the implementation of CPC studies in ToS/ToF of their respective countries. Our thanks to the IPM Facilitators, participants and farmers involved in these ToS/ToF. To the rice farmers who willingly undertook the follow up FFS on IWM in rice in Aklan, Philippines and to the facilitators especially Mr. Pat I.

Rebuelta, we are very grateful. To Dr. Labrada, Dr. Quintanilla and other resource persons, our appreciation for your contribution to make weed science an integral part of IPM.

LITERATURE CITED

Buchanan GA. 1976. Weeds and weed management in cotton. Proceedings Beltwide Cotton Production Research Conference. pp. 166-168.

Casimero MC and Y Kawana. 2000. Control of grass weeds in wet-direct seeded rice. JICA PhilRice Collaborative Project Report. 25 pp.

Kenmore PE. 1996. Integrated pest management in rice. In: Biotechnology and integrated pest management, (ed). GJ Persley. CAB International, pp. 214-232.

Ooi PAC. 1998. Beyond the farmer field school: IPM and empowerment in Indonesia. Gatekeeper Series No. 78. International Institute for Environment and Development. 16 pp.

Ooi PAC., G. Walter-Echols, Dai WD., AL, Morales-Abubakar, Lim, GS, P. Pachagounder, MH, Soomro, C. Galvan, F. Mancini, R. Petersen and K. Kamp 2004. Environmental Education for Poor Farmers FAO-EU IPM Programme for Cotton in Asia. FAO Regional Office for Asia and Pasific. Bangkok 62 pp.

Ooi P.A.C. and MC Casimero. 2005. Facilitating skills in weed management by resource poor farmers. Proc. Pest Management Council of the Philippines. Pp. 35-48.

Pontius J., Dilts R. and Bartlett A. (Editors) 2002. From farmer field school to community IPM. Ten years of IPM training in Asia. FAO, Bangkok, Thailand, 106 pp.

Schmidt P., Stiefel J.and M. Hürlimann M. 1997. Extension of Complex Issues. Success Factors in Integrated Pest Management. Publication of Swiss Center for Agricultural Extension, Lindau, Switzerland 100 pp.

ter Weel P. and van der Wulp H. 1999 Participatory Integrated Pest Management. Policy and Best Practice Document No. 3. Netherlands Ministry of Foreign Affairs, Development Cooperation, The Hague. 67 pp.

Technology transfer for improving weed management on small holdings in isolated communities in New Zealand

T.K. James[1], A. Rahman[1], H Kerckhoffs[2]
[1]AgResearch, Ruakura Research Centre, Hamilton, New Zealand
[2]Crop and Food Research, Lawn Rd, Hastings, New Zealand
trevor.james@agresearch.co.nz

Abstract: A multidisciplinary programme was recently initiated to lead positive change in distant rural communities by developing and implementing technological innovations appropriate to their needs. It aims to increase employment and income opportunities through transition from low labour, extensive pastoral agriculture to high margin, high labour intensive organic vegetable production. A reciprocal learning network was established to provide scientific, educational and extension services to develop and implement best organic vegetable growing practices, covering various topics from crop selection to market, in collaboration with local farmers. Soil health and weed management, amongst others, were identified as constraints that needed to be confronted. This paper documents the programme that has been designed to give the growers more skills and information on weed management. Reciprocal learning immediately identified some problems with the traditional approach to technology transfer. Large, 1 or 2 day workshops were not well attended. Also, 1 – 2 hour seminar-type presentations of information did not work despite a varied programme and capable presenters. The most effective communication was found to be with very small groups (5 – 10 people) centred around the communal meeting house and for presentations to be limited to 15 – 20 min with a high practical content. We found important knowledge areas to cover: awareness and timing of weed control, early identification, ability to separate annual weeds from perennial species and apply relevant management strategies, predicting weed emergence, climate recording and crop selection. To achieve good results in some of these areas new tools such as site specific identification keys were developed. Ongoing education is mostly by field days and field walks where actual problems are identified and addressed. Sustained and reciprocal interactions between growers and scientists on a one to one basis appear to be the key element for successful knowledge transfer.

Key words: Predicting weed emergence, reciprocal learning network, technology transfer, weed identification, weed management

INTRODUCTION

In addition to comprising around 18.4% of the population of New Zealand (King 2003), the Maori community exercise joint ownership over a considerable proportion of this country's productive land. The Maori Trust Office manages over 2,200 leases covering some 26,000 ha and Maori also independently manage a significant area of land. Sustainable and profitable management of Maori land is, therefore, clearly a significant factor in sustaining our rural communities and productive land.

Much of the Maori land with farming potential has typically been used for extensive agriculture or has remained uncultivated. This has not always served our Maori or rural communities well because it has not generated the capital or labour requirement to stimulate economic growth or employment. Many of these communities want to move from this low input agriculture to a high input crop production system. Such a move, however, requires access to a much greater level of skills and knowledge than is presently available. A research programme was established to lead a positive change in the capacity of rural agricultural communities to develop and implement technological innovations in crop production systems that are more resilient, profitable and environmentally benign. Much of the experimental work was planned and conducted in close co-operation with active end-user groups, to test the hypothesis that such an approach will ensure that relevant problems are addressed in a practical way with rapid and effective technology transfer. The outcome, it was hoped, would be that researchers became the agents for change, rather than just being technical specialists.

Development of the educational framework

The user group associated with this objective is the East Coast Organic Producers (ECOP) Trust. This trust aims to overcome the lack of economic growth or employment by promoting self-initiated Maori development based upon organic production. Its development strategy is broad based and comprises detailed plans to enable its members to farm organically, process raw organic produce locally, and market goods locally, nationally and internationally. Traditional Maori values provided the foundation for ECOP Trust's development strategy and an ethical orientation that assisted in decision making.

East Coast Maori and rural communities working through the ECOP Trust chose organic vegetable production as a way to improve their social and economic environment. They identified the need for a combination of science education and new research to achieve their goal. The task for the researchers involved in this project was to assist the Trust by providing scientific, education and extension services for development of best organic vegetable farming practices. Good organic farming methods, establishment and maintenance of healthy soils and attending to all plant protection needs in the organic production system were the main focus-areas of research and technology transfer. An independent extension specialist and social scientist were included in the project team, along with the specialist scientists, to deliver all the aims of the project and document the changes in the rural communities.

The overall efforts of the project team fell into three main areas

(1) The Knowledge Pathway – transferring existing knowledge and skills through workshops, field days and visits to successful growers. A meeting of all interested stakeholders at the start of the project identified the key topics to be covered and a schedule of workshops.

(2) The Research Pathway – acquiring new knowledge through experiments designed with the ECOP Trust members. The research areas to be covered include; (i) successions of crops (both the ecological and economic sequence) to ease the transition to intensive organic production, (ii) improving and maintaining soil fertility, keeping in mind the financial constraints, and (iii) developing relevant plant protection strategies to reduce weed, disease and pest loads in the succession of crops.

(3) The Community sharing – spreading the benefits of this project and the experiences gained with ECOP Trust to other rural communities. Success here will potentially encourage other rural groups as well as scientists to undertake research and develop solutions in partnership.

Practice and refinement of the technology transfer process

As the educational needs of the ECOP members were determined by the members themselves, it was thought that this would provide sufficient motivation for them to pursue their own education. As in similar instances in other countries, weeds were identified as one of the major constraints to good crop production (De Datta 2003). With this in mind, large multi-day workshops on aspects of weed ecology and identification were organised to match the educational needs of the group.

Important considerations in planning the workshops and achieving the technology transfer included: concentrate on the basics with simple learning outcomes, practical with a hands-on approach, organised into modules of about 20 minutes with several breaks and time for discussion, availability of tutors for one-on-one support if required. Despite all this, the first workshop was a dismal failure, not because of the teaching methods but because less than 2% of the ECOP members attended. A critical review conducted with the senior members of ECOP Trust identified that in our all-inclusive attempt at education we had failed to motivate individuals or even small groups to attend. An alternate approach was therefore postulated. This involved focussing on smaller units within the ECOP Trust and organising workshops for each small community or cluster, centred around their own cultural centre or meeting house. This placed the responsibility for workshop attendance back onto the community leaders. In practice this worked very well. Attendance numbers improved dramatically and often included entire families.

Among the first workshop topics were basics of soil fertility and structure, and weed identification. These workshops were very applied and practical, with substantial hands-on participation. In the weed identification workshop, for example, the participants worked with common weeds of the region using plants grown in the greenhouse. With the grass weeds the learning exercise was to identify such parts as the ligule and auricles and to assess features like hairiness, emerging leaf shape, etc. The participants were then given a simple key to work with, which separated the 10 most common grass weeds of the region (Figure 1). For broadleaf weeds the focus was on cotyledon and leaf shapes. A chart was produced which separated most broadleaf weeds according to the shape of the cotyledon and then the shape of the first leaf (Figure 2).

Other projects were designed to capture and hold participants' interest over a greater period of time. Certain farms close to the meeting venues were used as 'field laboratories' to test and evaluate important agronomy principles. Soil samples (to 10 cm depth) were collected from the fields and assessed for soil nutrients and weed seeds. These data were shared and discussed with the participants and predictions were made about the impacts or consequences of this information. For example, the soil weed seedbank data for each field were presented along with the predicted weed problems during the next growing season (Table 1) and the best methods for their control (James et al 2002; Rahman et al 2001, 2003 and 2004). In an organic environment weed management options are sometimes limited, so factors such as crop selection and planting time can be more critical than in a situation where pesticides can be used. Also taken into account were soil factors like poor soil fertility, soil moisture, water holding capacity etc, which can have a major impact on both weed emergence and crop production.

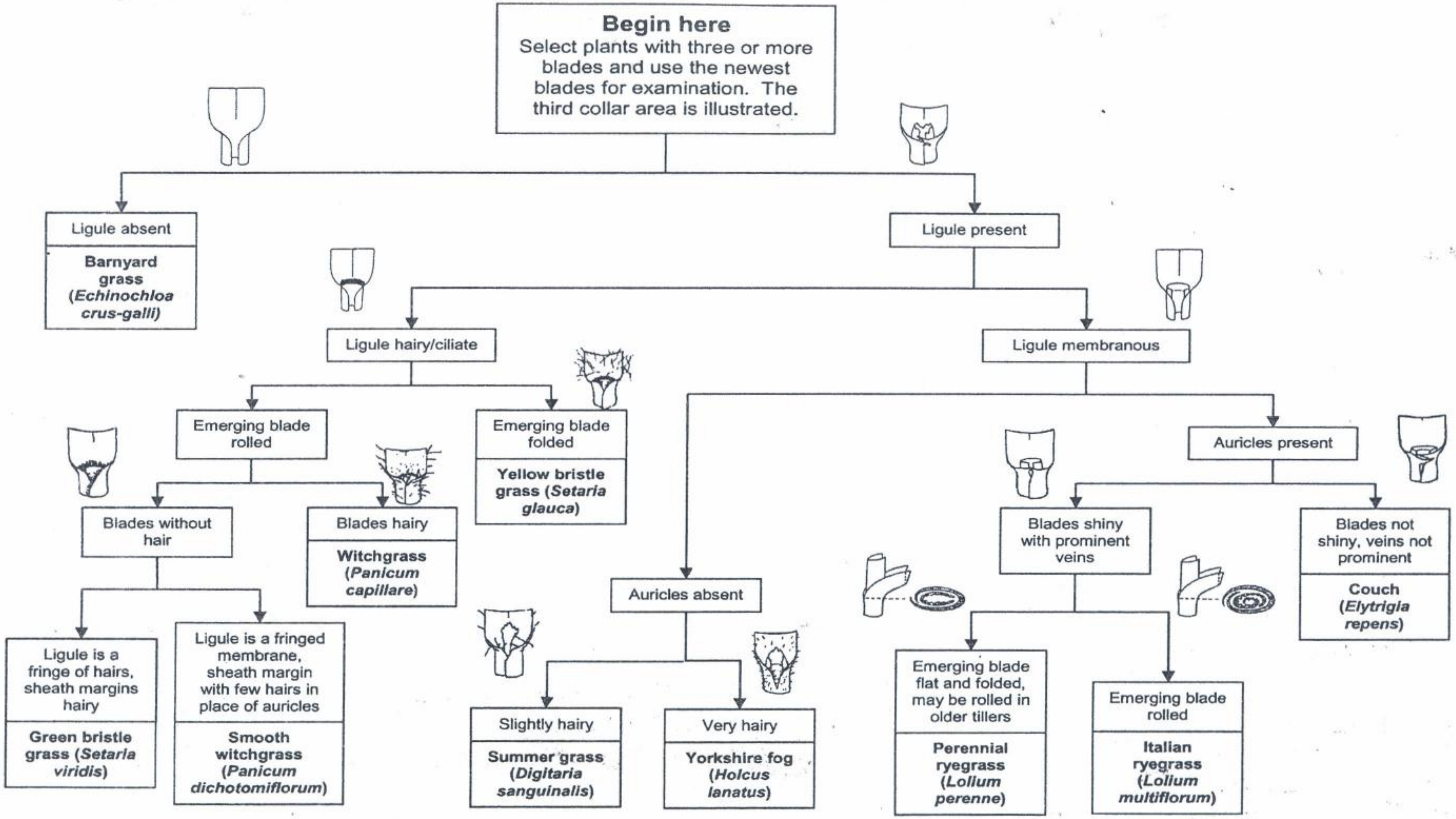


Figure 1. A simple key for separating the main grass weeds of the target region.

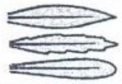
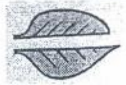
	Leaf Shape	Needle-shaped	Lanceolate	Oval, entire or toothed
Cotyledon shape				
Needle-like		*Spergula arvensis*		
Lanceolate			*Plantago lanceolata*	
Ovate pointed				*Solanum nigrum* *Stellaria media* *Anagallis arvensis*

Figure 2. Part of the chart used for identification of broadleaf weed seedlings. The chart had notes on the reverse side explaining how to separate species when there were more than one species in a box.

Table 1. Example of weed seedbank information, from a single field, given to land owners and workshop participants along with its interpretation.

Species	Weed type	No. of seed	Expected emergence (m^{-2})
Spergula arvensis	annual broadleaf	42	1680
Lotus sp.	perennial broadleaf	36	144
Agrostis capillaris	perennial grass	14	420
Trifolium repens	perennial broadleaf	5	20
Polygonum persicaria	annual broadleaf	4	120
Trifolium dubium	annual broadleaf	4	16
Plantago lanceolata	perennial broadleaf	3	60
Trifolium glomeratum	annual broadleaf	3	12
Rubus sp.	perennial broadleaf	2	8
Stachys arvensis	annual broadleaf	2	60
Echinochloa crus-galli	annual grass	1	50
Potentilla sp	perennial broadleaf	1	4

Interpretation

The weed seed bank at this site is dominated by perennial species with the exception of a large number of *Spergula arvensis* and some *Stachys arvensis* which are both winter annuals. The implications of this are that if you plant too early in the spring the *Spergula arvensis* and *Stachys arvensis* could come with a late germination and smother the crop. However, if you plant later this would probably be avoided. The perennial weeds could germinate at any time although many of them also prefer autumn for optimum germination. As weeds, however, they should be dealt with before they get too large. The reason for this is as perennial plants they will be much more difficult to control when large and also they might start producing rhizomes and stolons for vegetative reproduction and these are very difficult to manage in an organic environment.

Another (and unanticipated) result of the move to smaller, culturally centred workshops was that the participants, particularly the elderly, were more willing to share their traditional knowledge of the local soils, crops and growing conditions. Traditional knowledge tends to be a series of work procedures and dates that through practice were found to work, but little was known about why they worked. In the light of modern understanding, much knowledge can be gained from these traditional practices and people were excited to learn that traditional customs contained many sound scientific principles.

Integrating research with technology transfer is not a new concept. Casimero et al (2003) used this method to effectively communicate the principles of integrated weed management to small communities. Similar to their findings, a hands-on approach was demonstrated to be an effective method of technology transfer. However, small communities, even when close together, can be insular in their outlook and it was imperative for good communication to address each community individually.

ACKNOWLEDGEMENTS

This research was supported through funding from the New Zealand Foundation for Research and Technology. We also wish to thank the ECOP Trust and individual members for support and provision of trial sites along with Dan Bloomer and Moana Puha for liaison with the communities.

LITERATURE CITED

Casimero M.C., Capistrano A.O.V., Canete S., Dasalla N., Corales R.G., Juliano L.M. and Baltazar A.M. 2003. Village level integration of integrated weed management strategies in rice-onion systems. Proceedings of the Asian-Pacific Weed Science Society Conference, 19: 867-874.

De Datta S.K. 2003. Globalizing weed science and IPM research, education and technology transfer. Proceedings of the Asian-Pacific Weed Science Society Conference, 19: 1-15.

James T.K., Rahman A., Webster, T. and Waller, J. 2002. Emergence of weeds as affected by vertical seed distribution in arable soils. New Zealand Plant Protection, 55: 213-217.

King M. 2003. The Penguin history of New Zealand. Penguin Books, Auckland, New Zealand. 563 pp.

Rahman A., James T.K. and Grbavac N. 2001. Potential of weed seedbanks for managing weeds. A Review of Recent New Zealand Research. Weed Biology and Management, 1: 89-95.

Rahman A., James T.K., Mellsop J.M. and Grbavac, N. 2003. Relationship between soil seedbank and field populations of grass weeds in maize. New Zealand Plant Protection, 56:215-219.

Rahman A., James T. K., Mellsop J. M. and Grbavac, N. 2004. Predicting broadleaf weed populations in maize from the soil seedbank. New Zealand Plant Protection, 57: 281-285.

No-tillage culture - weed management, economics and extension participation

N. C. Thanh
Ph.D. Scholar, Division of Agricultural Extension
Indian Agricultural Research Institute - PUSA Campus, New Delhi 110012, India
nguyencongthanhct@yahoo.com

Abstract: Rice-wheat cropping system is the major production system in agriculture in India. The main problems in this system are the decline in productivity due to herbicide resistant weed and cost of production. Zero-tillage technology has emerged a successful practice in wheat cultivation after rice in India, resulting in many benefits such as reduction in tillage cost, early sowing, decrease in dominant weed population of *Phalaris minor,* reduction in the use of herbicides, saving in water, gaining high grain yield of wheat due to more number of days the crop gets from sowing to harvesting, less population of *Phalaris minor*, offering competitive advantage to that crop and efficient use of inputs, improvement in soil properties, temperature moderation, and improved ecological environment. This paper tries to review the new mode of agricultural production - no-tillage - which has recently emerged in India and some parts of the world in the context of integrated weed management. This paper deals with the concept of no-tillage cultivation, adaptation process in India and other countries, economic benefits, weed control of the technique, and extension participation. This technique can be introduced into other countries growing rice having condition to rotate with wheat or other crop like maize, soybean, etc. for reducing cost of production, effective weed control, reduced herbicide application, and protecting the environment.

Key words: Integrated weed management, *Phalaris minor*, rice-wheat system, tillage system.

INTRODUCTION

Weeds still represent an important constraint to crop production in the world. Agricultural practice has demonstrated that the same philosophy of integrated management used for insect control also needs to be adopted for weed control. Because of the vast number of serious weed problems in all regions of the world, one method alone can no longer be relied on. Moreover, agriculture has promoted new methods, which also directly or indirectly affect weed control. These methods are original *per se* and demand a new approach for weed control. For example, organic agriculture does not permit the use of chemical herbicides. Therefore, cultural and biological controls are the only possible means left to cope with weeds (Stockin 2004).

Weed management today emphasizes on integrated weed management. This is the new concept of weed management for sustainable agriculture. The Rice-Wheat Consortium (2003) had given the concept of integrated weed management thus: "The use of herbicides in rice-wheat cropping system was not accompanied by improved tillage, crop diversification, herbicide rotation, herbicide application techniques, and training of users. A proper combination of all such practices could be the key ingredients of a sustainable weed management system. Perfecting sowing techniques that allow integration of mechanical methods with herbicides or cultural methods will reduce the frequency of herbicide use which would, in turn, delay the onset of herbicide resistance."

Integrated weed management project in India led to the evolution of zero tillage. Initially the difficulties which scientists and extension agencies thought on the acceptance of zero tillage was much harder than they thought on its application in the rice-wheat cropping system. In South Asia's Indo-Gangetic Plains, wheat is grown on nearly 13.5 million ha in rotation with rice. Since the late 1980s, the rate of yield increase has slowed down partly due to increasing incidence of weeds. The herbicide isoproturon was widely used in the northwestern states of India to control little seed canary grass (*Phalaris minor*) - the most common weed in wheat. Over the years, this weed has developed resistance to this herbicide and increased in menacing proportions. Repeated use of a single isoproturon herbicide has been the main cause for the weed to develop resistance (Rice-Wheat Consortium 2003). Rice-Wheat Consortium has further pointed out the evidence of herbicide resistance in India from many experiments conducted in the rice-wheat sequence zone and indicated that burning of straw was a reason for the increase in density of little seed canary grass. Demonstrations (with burning straw plots) for confirming resistance were, therefore, conducted in fields where straw was not burnt. Grain yield of wheat in these demonstration plots declined over time due to poor efficacy of isoproturon. The resistance factor was also found to increase if the use of this herbicide continued.

Therefore, non-disturbance of the soil surface to prevent weed seeds germination, no burning the straw and using the straw for covering crops were the major contributions of zero tillage which led to reduction of weed population, increased productivity of wheat and reduced cost of production. Milik et al. (2002) has remarked that evolution of zero tillage was therefore, a notable achievement of work done for the management of herbicide resistant weed in wheat in rice-wheat cropping system.

WHAT IS NO-TILLAGE?

No-tillage is a tillage system where no disturbance of the soil occurs prior to planting, except for the injection of liquid manure or anhydrous ammonia. In addition, the entire residue from the previous crop remains on the soil surface to protect it from erosion. No-till often is used to achieve soil conservation requirements on highly erodable land, but it is becoming a more popular management practice among Iowa producers, for the advantages it offers, and because of emerging technologies that address its limitations (Mahdi 2000).

Another definition by Sharma et al. (2004): Zero-tillage is the seeding of a crop without going for any ploughing for field preparation. In case of wheat the crop is sown directly in the field immediately after rice harvest using a specially designed seed-cum-fertilizer drill.

To describe the benefits of zero-tillage and distinguish between zero-tillage and conservation agriculture, Labrada (2003) stated that the so-called conservation agriculture is gaining a lot of recognition among farmers all over the world. Grain crops like wheat, barley, maize, rice and soybean are grown in some parts of the world under this system, which consists of the judicious use of crop rotation with minimum or zero tillage, including the use of green manures and cover crops. This approach is beneficial to effectively protect and increase soil fertility. It is wrong to identify conservation agriculture as the practice of zero or minimum tillage. In fact, these procedures are part of the system, but if they are implemented in areas of monocropping then this cannot be considered conservation agriculture.

The switch over to zero tillage or direct seeding practices concerns many producers when it comes to weed control. The non-use of tillage as a method of weed control means that producers must adjust crop rotations, herbicide use, and other cultural practices to compensate. Perennial weeds may become a serious problem to overcome, and there is a need to implement additional cultural methods, such as the use of covers. Some annual weeds, such as wild oat and volunteer canola, also grow well under zero-till conditions.

NO-TILLAGE ADVANTAGES AND DISADVANTAGES

According to Mahdi et al. (2000), no-tillage culture had some advantages as well as disadvantages.

Many producers found that no tillage crop production systems helped them save time, conserve moisture and reduce erosion. Depending on their current tillage system, eliminating tillage could offer significant cost savings on labor, fuel, and other machinery operating costs. They also considered the impact of reduced insurance, interests, and depreciation costs resulting from converting to a no-till system.

Other advantages of no-tillage might have an impact on timely planting. Because with no-till they get in and out of the field faster, they could cover more acres and finish within narrow planting windows that offered optimum yield potential.

Three potential disadvantages of no-till are as follows. First, using burn-down herbicides instead of tillage to eliminate competition from early-season weeds is relatively expensive, thus raising production costs. Second, the crop residue left on the soil in no-till systems might hinder soil warming and drying, making planting more difficult and germination conditions less than ideal. Third, no-till poses many new management challenges for the new no-till producer. For example, in no-till soybean an increase in residues on the soil surface led to an increase in soil moisture that in turn could increase the potential for soybean root diseases.

NO-TILLAGE IN THE WORLD

Edenfield (1999) reported that reduced tillage crop production is becoming more widely accepted by growers in the southeastern U.S. There are several advantages with no-tillage production systems including reduced soil erosion, lower fuel requirements, greater flexibility in planting, reduced labor requirements, and adaptability to most crops, reduced equipment requirements, and improved water retention.

He further emphasized that the common belief that no-till requires much greater use of herbicides than in most conventional systems is not true, if good no-till practices are followed. No-till is more dependent on crop rotations, competition and sanitation to control weed pressure than conventional till. Herbicide use per dollar of product output is often only slightly greater, and in many cases is much less than with tillage. Good no-tillers use herbicides to augment other weed control methods. Most conventional tillage systems use tillage and herbicides as a replacement for other weed control methods. One of the problems with early no-till farming methods is the belief that herbicides would replace tillage. In reality, good management and proper rotations replace tillage in successful no-till programs; herbicides are only one tool in this scheme.

Crop rotation is one of the most important factors in planning an effective weed control program. Rotations that contain plants of the same type with similar growth patterns (seeding and harvest dates) will develop weed problems (whether tillage is used or not) from weed species with similar growth habits (www.infohavest.ab.ca/pcd).

No-tillage cultivation in USA showed that annual medics and red clover planted after wheat harvest reduced density and dry weight of winter annual weeds before planting no-till corn. Similarly, annual medics and red clover reduced summer annual weed dry weight; however, weed density was only occasionally reduced. The suppressive effect of annual medic residue on summer annual weed density and dry weight was consistent across all sites and years. Berseem clover had no effect, whereas the effect of red clover was not consistent. Dry weight of perennial weeds before corn planting was consistently reduced by both annual legumes and red clover; however, density was unaffected. The annual medics suppressed perennial weeds 45 to 60 days after chemical kill, but this effect was not as strong as the effect observed before corn planting. Residue of all legumes reduced both density and dry weight of perennial weeds. This study indicated an excellent potential of annual medics to reduce weed density and growth in no-till corn grain systems. Further research is needed to quantify if chemical control can be reduced or eliminated by the use of annual legume cover crops (Fisk et al. 2001)

Preton Sullivan's study (2003) showed that some crops were especially useful because they had the ability to suppress other plants that attempted to grow around them. *Allelopathy* refers to a plant's ability to chemically inhibit the growth of other plants. Rye was one of the most useful allelopathic cover crops because it was winter-hardy and could be grown almost anywhere. Rye residue contained generous amounts of allelopathic chemicals. When left undisturbed on the soil surface, these chemicals leached out and prevented germination of small-seeded weeds. Weed suppression was effective for about 30 to 60 days. If the rye was tilled into the soil, the effect was lost.

Another research article available on website www.ctic.purdue.edu.com (2004) on weed control strategies said that in most no-till systems, a mixture of a burn-down herbicide plus one or more residual herbicides was normally used for weed control. The burn-down herbicide killed existing vegetation before or after planting. Residuals were normally applied before or after planting to control weeds germinating from seed. To complete the weed control system, one or more post-emergence herbicides may be needed later for broadleaved weeds or grasses or both.

The website article mentions this general scenario to give an idea of the products involved, not to outline any sort of normally followed pattern. Certain "routines" can cost a lot more money than we need to spend. Any weed control program should be based on sound scouting, not overkill. For instance, it is not unusual for some no-till soybean growers in the Midwest to use only a burn-down herbicide-no residual or post-emergence herbicide at all. Their success is due to fields with a history of low weed pressure, timely and frequent scouting, and narrow row systems. Narrow-rows allow the crop canopy to close early and shade out emerging weeds.

Post-emergence applications of nicosulfuron and primisulfuron were compared to pre-plant glyphosate and atrazine plus simazine for quackgrass control in reduced tillage and no-till corn. The level of quackgrass control was reduced by no-till practices. At six weeks after planting, glyphosate and atrazine plus simazine were most effective in controlling quackgrass. Quackgrass biomass 12 weeks after planting indicated that the performance of the herbicides were generally similar, although primisulfuron was less effective in no-till. One year after corn planting, levels of quackgrass control in the tilled plots were the same or better than in the no-till treatments. Atrazine plus simazine was the most effective herbicide treatment over tillage systems, while primisulfuron was the least effective (William et al. 1994).

ADOPTION OF NO-TILLAGE IN INDIA

ACIAR Research Programme in India introduced zero-till technologies around 1980 but there was little farmer adoption until the mid-1990s, when *Phalaris minor* became an unmanageable problem with traditional technologies. This project showed that zero-tillage was a key to *Phalaris* management and helped to stimulate the uptake, with zero-till wheat areas in Haryana going from nil in 1997-98 to 20,000 acres in 1999-2000 and 100,000 acres in 2000-2001, whilst in Punjab the area grew to 10,000 ha in 2000. Increased farmer interest and demand promoted considerable development of local manufacture of zero-till seeders between 1996 and 2001 (ACIAR Research Programme 2003).

The results of a study conducted by Singh et al. (2004) to assess the knowledge, attitude and constraints in adoption of zero-tillage indicated that about 92% of the farmers had positive attitude towards this technology. Among the constraints in the adoption of zero-tillage technique were lack of local manufactures, lack of adequate manpower from state extension agencies, no subsidy on zero-tillage machines and technical, extension and financial constraints, respectively.

The National Agriculture Magazine (2004) remarked that in India, zero tillage farming has been found to save field preparation expense by a minimum of Rs. 2,000 per hectare. Moreover, it has also been found to save at least three weeks time required to clear the field. Buoyed by the success during the last three years, the Centre has said it would extend zero tillage farming to 1.5 million hectare of land under wheat this year (2005).

Peter et al. (2000) wrote that zero tillage and sowing of wheat in standing rice stubble using a seed drill, locally manufactured in India and Pakistan, was a key technology for farmers with access to tractors. This drill, a modified version of the local rabi drill, costs US$400. Resource poor farmers were able to rent them. In a variant of zero tillage (reduced or minimum tillage) a rotovator stirred a thin layer of soil in a strip ahead of the seed drill. Although it delayed planting by 4-5 days compared to zero tillage, reduced tillage may be the preferred system for areas with post-rice harvest weed problems. There was also a "strip-till" version that cultivated only the area where the seed was placed and not the entire area. Both 2-wheel and 4-wheel versions were available for these reduced tillage systems. Such technologies opened the door to improvements in resource efficiency leading to timely sowing, water savings, and higher fertilizer efficiency, reduced weed germination, less herbicide use, reduced residue burning, lower fossil fuel use, decreased air pollution – and higher yields.

EXTENSION PARTICIPATION

In any program, if we get the full participation of farmers it would be successful. In the campaign regarding herbicide resistance management in some rice – wheat system regions of India, the campaign has led to the evolution of zero tillage and it was also successful based on the farmer's participation.

Problems related to the lack of effective linkages between research and extension in weed management programmes in the developing world are examined. These programmes (designed for general use) were often not accepted by farmers, because they did not allow local adaptations or the farmers' perceptions in decision making. A participatory-oriented method of agricultural extension, supported by research, is needed (using the farmers as experimenters and their farms as field laboratories). Coupled with a farmer-to-farmer extension approach, this could provide a conducive atmosphere to encourage sustainable learning and facilitate the adoption of integrated weed management (Ho et al. 1996).

Zero tillage was considered impractical to the point of impossibility because it was not researched for introduction in conjunction with farmers. After working closely at farmer's field during 1996 to 1999, it was observed that farmers have spotted an opening in zero tillage system of wheat growing; farmers thought that the zero tillage was promising because it was just as good as cheaper than conventional tillage. Encouraged by the surprise success of zero tillage, the Department of Agriculture, Haryana supported the case for extension efforts by extension agencies in the state (Malik et al. 2002).

The responsibility for farmer's knowledge on weed management practices is of the main role of extension, as indicated in the study of Singh & Lall (2001). They found that majority of farmers (44%) under rice–wheat cropping system had some knowledge, more than 50% on modern weed management practices in rice and more than 75% had knowledge on modern weed management practice in wheat. Farmers under rice crop reported maximum gap (54%) against herbicide application methods through broadcasting by mixing with urea/sand and minimum gap (3%) against stage of herbicides application recommendation adopting integrated weed management.

Their study also found that in weed crops, none of the farmers did not only use manual weeding alone for controlling weeds. Chemical or integrated weed management was also adopted. Overall average gap in weed management practices in rice crop was 25 per cent. Maximum average technological gap of 31.4 per cent in wheat crop was found in case of chemical weeding followed by integrated weed management (20.3 percent). Overall gap in weed management practices in wheat crop was 25.8 per cent.

In the case of farmers' attitude in the adoption of new technology of weed management, Malik et al. (2002) found in survey of 100 farmers that their responses to questions related to attitude were uniformly positive. Such positive response could be because of following factors:

i). farmers are financially conservative; they dislike debt and watch their money,
ii). farmers generally have keen eye on opportunities,
iii). they are motivated by pragmatic self-interest, and
iv). they value profits and believe in handing over as big an inheritance as possible to their children.

An important reason for the success story on herbicide resistance management to the evolution of zero tillage was that farmers demanded more returns over unit investment. To make such returns, zero tillage emerged as best opportunity to cut cost. Returns were further boosted by an improvement in wheat yields especially under timely sown wheat (Malik et al. 2002).

BENEFITS OF ZERO-TILLAGE TECHNOLOGY IN WHEAT

Effect of zero-tillage on weed management

An important benefit from zero-tillage technique is the reduction in the population of herbicide resistant *P. minor*. The study of Purina and Malik (2004) showed that infestation of wheat crop with little seed canary grass (*P. minor*) and decline in soil productivity were two major constraints in the decline of productivity of rice-wheat cropping system in India. New herbicides recommended to control resistant *P. minor* were very costly. Moreover, it was possible that continuous use of these herbicides might develop cross-resistance in time. Under such a situation, sowing of wheat with zero-tillage technique has proved most beneficial to farmers as it reduced the density of *P. minor* and the cost of cultivation without affecting the crop yield, as well as advanced the planting time of wheat.

Effect of weed control of zero tillage, especially on the dominant weed *P. minor* was very significant. Sharma et al. (2004) had reported that the lower *P. minor* population and dry weight was recorded under zero-tillage and the higher under conventional tillage system of wheat cultivation. The less weed population under zero tillage might be due to less soil disturbance helping in keeping the weed seeds at depth from where it could not germinate.

So, no-tillage practice helped to prevent the germination of the weed seed that was very large in quantity in the cultivated soil. Preton Sullivan (2003) stated that weed seed distribution and density in agricultural soils are influenced by cropping history and the management of adjacent landscapes, and may be highly variable. A study of Western Nebraska cropland found 140 seeds per pound of surface soil, equivalent to 200 million seeds per acre.

Malik et al. (2002) emphasized that puddling in rice distributed seeds in different layers and zero-tillage in wheat was not likely to make big difference in the composition of species except that the factor of early sowing due to zero tillage might allow some broad leaved weeds and *wild oat* to dominate in the long run. The possibility of presence of less seed bank in the surface soil after puddling of rice field has also been hypothetically depicted in pictures.

Effect of zero-tillage on wheat productivity

The project of integrated weed management/zero tillage demonstrated increased economic efficiency of wheat crop production. It was mainly due to factors such as increased productivity, reduction of cost, water saving, reduction in herbicides investment, etc.

Success in the reduction of weed population led to the improvement in the yields of the zero-tillage crops (wheat). The study conducted in different locations in India during 2002-03 (Punia & Malik 2004) showed that the yield of wheat at different locations under zero tillage condition was higher than under conventional tillage. Average yield (kg/ha) from seven locations was 5089 for zero tillage compared to 4927 for conventional tillage.

Another result from the research of Malik et al. (2002) was the positive impact of zero tillage on the grain yield of wheat, which became quite clear from the outputs of last five years. Yield advantages of zero tillage were more in early sown than in late sown wheat. During 1996-97, 1997-98, 1998-99 and 1999-2000, the average yields under zero tillage were 4.2, 4.5, 4.9 and 5.41 tones per ha, respectively. In the conventional tillage with isoproturon in 1996-97 and 1997-98 and with alternate herbicide used in 1998-99 and 1999-2000, the average yields were 2.2, 2.9, 4.75, and 5.25 t ha^{-1}, respectively.

Effect of zero-tillage on cost reduction in wheat production

Zero tillage has given valuable contributions in the reduction of herbicide investment, as well as savings in fuel, and water. Gangwar and Tomar (2004) stated that tillage is necessary for getting optimum soil tilth for proper placement of seeds, germination and establishment of different crops. In agriculture, a major portion (25-30%) of energy was utilized for field preparation and crop establishment. The age-old practice of excessive tillage not only deteriorates soil structure but also involves high amount of energy (fuel and draft animal). In the reduction of cost, zero tillage technology used 22-31% less energy (Punia and Malik 2004)

Impact of zero tillage on the reduction of investment on herbicides was obvious. When the weed population was declining, the investment on herbicide was also reducing significantly. For the effectiveness in the saving of herbicide from zero tillage technologies as compared to conventional tillage, Malik et al. (2002) reported that farmers in different districts who adopted zero tillage in 4 years had less investment on herbicides in the fourth year. Control of weeds that emerged before seeding, at least in high population situations of *Phalaris,* was done with glyphosate, glufosinate or paraquat, and more rotation of herbicides. Therefore, alternative of herbicide rotation would prevent resistant development.

Punia and Malik (2004) found that zero tillage saves time by 30 to 40% and quantity of first irrigation compared to conventionally sown wheat. Farmers directly sow wheat after harvesting paddy without undertaking any ploughing operation. All activities were performed on the field which was irrigated for the standing paddy crop a few days before harvesting.

Time saving was also important, because it contributed to high yields and cost reduction. Time of sowing wheat after rice in rice-wheat cropping system was one of two major constrains in the decline of rice and wheat productivity. Singh et al. (2002) remarked that since rice (*Oryza sativa*) and wheat (*Triticum aestivum*) are the most important cereal crops in the Indian subcontinent, their sustainability are of prime concern as the productivity of these two crops was declining or stagnating over the years. Several constraints have been identified for this decline. The two major constraints were late sowing and increased cost of production due to excess tillage and weed infestation. To address these constraints, zero till ferti -seed drill and other strip till drills were widely adopted by farmers.

Saving in the sowing time has contributed to the increase in wheat productivity. Punia and Malik (2004) found that the number of days the wheat crop got from sowing to harvesting, the contributed to grain yield for each day of advance sowing reflected the overall improvement in the productivity of wheat.

Effect of zero-tillage on the soil properties and environment

Improvement in soil properties was the other success of the project. Punia and Malik (2004) emphasized that long standing stubbles of rice after harvest without burning not only added residues in the soil to improve its fertility and structure but also prevented environmental pollution.

The emission of greenhouse gases CO_2, CH_4 and N_2O in rice-wheat system in particular and other environmental concerns associated with food grain production in general has become a great concern. The significant contribution of zero tillage in wheat in rice-wheat system was reduction in greenhouse gases. Peter et al. (2003) found positive changes in agronomic practices like tillage, manuring and irrigation can help reduce greatly the release of greenhouse gases into the atmosphere. Adoption of zero tillage and controlled irrigation can drastically reduce the evolution of CO_2 and N_2O. Reduction in burning of crop residues reduced the generation of CO_2, N_2O and CH_4 to a significant extent. Saving on diesel by reduced tillage and judicious use of water pumps can have a major role to play. He further emphasized that changing to zero tillage would save 98 liters diesel per hectare. With each litter of diesel generating 2.6 kg, about 3.2 Mt CO_2/annum could be reduced by zero tillage in the 12 million ha under rice-wheat system in the Indo-Gangetic Plains alone.

CONCLUSION

The rice–wheat sequences are prevalent in Indo-Gangetic plains covering vast areas in Uttar Pradesh, Bihar, Punjab, Madhya Pradesh, Haryana, parts of West Bengal, Rajasthan, Assam, Gujarat and Maharashtra. Therefore, the benefits of zero-tillage had significant contribution to the production of the region and the country.

Punia and Malik (2004) said that zero-tillage was a big boost to resource-poor farmers and technology was so simple that farmers in India have adopted it on a large scale covering approximately 8 lakh (800,000) acres in Haryana, Punjab, Uttar Pradesh, Uttaranchal and Bihar. It seemed that they were heading for second green revolution, which would be sustainable and farmers friendly, arresting not only the further decline in soil productivity but eventually reversing the long-term damage to soil health.

Zero tillage evolution from integrated weed management programme in India was consequently a notable achievement of work done for management of herbicide resistant weed in wheat in rice wheat cropping system. The benefits could be gained from the innovation such as: Reduction in tillage cost, early sowing, reduction in *P. minor* population, saving in water, high grain yield of wheat, improvement in soil properties, temperature moderation, and improved environment. This new technology of weed management has brought economic, social and environmental efficiency for agricultural and rural development in India.

The review of zero tillage technology reveals that it offers many advantages in the spheres of economic efficiency, effective weed management and resistance management. The merits outweigh the demerits. Thus it forms an important component in integrated weed management to ensure profit, productivity and environmental sustainability. So the success of this technique can be introduced into other countries growing rice having condition to rotation with wheat or other crop like maize, soybean etc., to reduce cost of production, effective weed control and reduce herbicide application to protect the environment.

LITERATURE CITED

ACIAR Research Program, conducted in the duration of 1998 to 2003. Herbicide-resistant weeds of wheat in India and Australia. Integrated Management. Available at: http://www.aciar.gov.au/

Edenfield M.W., Gallaher R.N., Brecke B.J. and Tredaway J.A. 1999. Weed management programs in no-till cotton, peanut, and soybean. GA. 6-8 July 1999. Georgia Agriculture Experiment Station Special Publication 95. Athens, GA.

Fisk J.W., Hesterman O.B., Shrestha A., Kells J.J., Harwood R.R., Squire J.M. and Sheaffer C.C. 2001. Weed suppression by annual legume cover crops in no-tillage corn. Agronomy Journal, 93: 319-325.

Curran W.S., Werner E.L. and Hartwig N.L. 1994. Effectiveness of herbicides and tillage on quackgrass (*Elytrigia repens*) control in corn (*Zea mays*). Weed Technol., 2:324-330.

Gangwar K.S. and Tomar O. K. 2004. Tillage requirement of different systems. Indian Farming, Indian Council for Agricultural Research. Vol. 54, No. 2. Page 6.

Ho N., Ho N.K., Brown H., Cussans G.W., Devine M.D., Duke S.O., Fernandez Q.C., Helweg A., Labrada R.E., Landes M., Kudsk P. and Streibig J.C. 1996. Proceedings of the second international weed control congress, Copenhagen, Denmark, 25-28 June 1996: Vol. 1-4. Pages 675-684.

Hobbs P.R., Gupta R., Ladha J.K. and Harrington L. 2000. Sustaining the green revolution by resource conserving technologies. The Rice-Wheat Consortium's Example. 8 Ileana Newsletter •

Labrada R. 2003. Present Trends in Weed Management. The FAO Technical Paper, 2003. Website: http://www.weedscience.org/in.asp, last update: 29/10/04.

Mahdi A.K., Hanna M. and Tidman M. 2000. Tillage in 2001: No-Till. http://www. agron.iastate.edu

Milik R.K., Yadav A., Singh S., Malik R.S., Balyan R.S., Banga R. S., Sardana P.K., Jaipal S., Hobbs P.R., Gill G., Singh S., Gupta R.K. and Bellinder R. 2002. Herbicide Resistance Management and Evolution of Zero Tillage – A Success Story. CCS Haryana Agricultural University HISAR – 125 004 (India). Pages 6-18.

Sullivan P. 2003. Principles of Sustainable Weed Management for Croplands Agronomy Systems Guide. ATTRA - National Sustainable Agriculture Information Services. http:/www.attra.ncat.org/attra-pub/PDF/weed.pdf.

Punia S. S. and Malik R. K. 2004. Zero-tillage sowing of wheat for sustainability of rice-wheat cropping system. Indian Farming – ICAR. Vol. 54, April 2004, No. 1. Pages 19-23.

Rice-Wheat Consortium for Indo-Gangetic Plains, 2003. Conserving Center CIMMYT. Addressing Resource Conservation Issues in Rice-Wheat Systems of South Asia – A Resource Book. Herbicide Resistance in Littleseed Canary Grass. P.276, 278.

Sharma R. K., Chhokar R. S. and Chauhan D. S. 2004. Zero-tillage technology in rice – wheat system: retrospect and prospects. Indian Farming, 54(4): 12-15.

Singh A.K., Surender K., Singh S. P. and Saurabh S. 2004. Knowledge, attitude and constraints in adoption of zero-tillage technology in wheat under rice-wheat system. Indian Farming, 54(2).

Singh G., Bhardwaj A.K., Singh Y., Singh R. K., Kumar Abnish, Singh S. P. and Saxena Amal. 2002. Seed rate requirement of wheat sown by different conservation tillage methods in rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system. Extended Summaries Vol 1: 2nd International Agronomy Congress. Nov. 26-30, 2002, New Delhi, India. pp. 82.

Singh Sanjay and Lall A.C. 2001. Study on technology gaps and constraints in adoption of weed management practices for rice-wheat cropping system. Indian Journal of Weed Sciences, 33(3 & 4): 116.

Stockin M. 2004. Land Management for Sustainable Development: Parmer Participation. http: www. google.com.

The National Agriculture Magazine. Agriculture Today, Vol. December 2004. Zero tillage enhances crop yield: Study. p 6.

www. ctic.purdue.edu.com, 2004. Weed Management – Weed Control Strategy and Traditional Tools.

www. infohavest.ab.ca/pcd. No-till Guidelines for the Arid and Semi-Arid Prairies (pdf format).

Other Paper

Leptochloa chinensis - A host of *Bipolaris oryzae* in the Mekong Delta, Vietnam

T. T. T. Thuy[1], E. de Neegaard[2], and H. J. L. Jorgensen[2]
[1]Department of Plant Protection, Can Tho University, Cantho, Vietnam
thuytran@ctu.edu.vn
[2]Department of Plant Biology, the Royal Veterinary and Agricultural University, Denmark

Abstract: *Leptochloa chinensis* is an important grass species in the rice fields of the Mekong Delta. An experiment was conducted under screen house and laboratory conditions of Can Tho University in 2003 and 2004 to determine whether this weed potentially serves as a host of *Bipolaris oryzae*, the pathogen causes brown spot disease of rice. The fungus *B. oryzae* was collected from *L. chinensis* in Cantho Province and isolated on rice extract agar medium. Pathogenicity tests were made on 15 rice cultivars following the Koch's postulate. The fifth leafs of each cultivar were inoculated with the pathogen at the concentration of 20,000 spores ml^{-1}. Sporulation of the fungus on different rice cultivars was measured in a square centimeter of the leaf surface at 9 days after inoculation. Results showed that the fungus from grass can attack and proliferate on rice cultivars tested. Furthermore, the putative role of *L. chinensis* as a source of inoculum is demonstrated. The largest spore production was reported on cultivar MTL 233. This finding indicated the potential survival and transmission of *B. oryzae* in the rice field of the Mekong delta of Vietnam.

Key words: *Bipolaris oryzae*, host, *Leptochloa chinensis*, sporulation.

INTRODUCTION

Bipolaris oryzae (Breda de Haan) Shoemaker (syns. *Dreschlera oryzae* (Breda de Haan) Subramanian & P. C. Jain and *Helminthosporium oryzae* Breda de Haan), teleomorph *Cochliobolus miyabeanus* (Ito & Kuribayashi) Drechs. ex Dastur syn. *Ophiobolus miyabeanus*) is a pathogen of brown spot disease of rice in the Mekong Delta of Vietnam (Thuy 2002). The fungus is also considered an important seedborne pathogen in the region (Thach 1998). *B. oryzae* is known as a parasite on many species of grasses and sedges, many of which are common weeds in rice fields (Ou 1985). *Leersia hexandra* (Ou 1985) and *Chikusichloa aquatica* (Ureyama & Tsuda 1977) were reported as alternative hosts. Wild rice (*Zizania aquatica* or *Zizania palustris*) was reported to be infected under natural conditions (Bean & Schwartz 1961; Percich et al. 1997). A concern in this respect is whether inoculum from weeds can infect rice and *vice versa*. Cross inoculation studies could indicate this. For example, Nisikado & Miyake (1922) inoculated isolates of *B. oryzae* on various grasses and found that infection took place in many cases e.g. on *Agropyrum semicostatum*, *Cynodon dactylon*, *Eleusine indica*, *Panicum acranthum* and *Setaria itarica*. Nisikado & Miyake (1922) did not indicate from which host species the isolates of *B. oryzae* came but probably it was from rice. Apparently there are not many studies whether isolates of *B. oryzae* from species other than rice can infect rice. *Leptochloa chinensis* was recorded as very common weeds in rice fields of the Mekong Delta (Thuy & Thanh 1995) and is not known as a host of *B. oryzae*. This grass species is also known as resistant to the post-emergence herbicides presently used in the Mekong Delta and the best method for controlling this weed is to use pre-emergence herbicides combined with hand weeding later in the growth season. *L. chinensis* produces large quantities of small, fine seeds which are easily transferred to other places by wind. However, farmers do not pay attention to controlling weeds later in the growth season or of weeds around the fields. Thus, there is a risk that this weed may serve as a host for *B. oryzae*. The study was undertaken under screen house and laboratory conditions of the Department of Plant Protection in 2003 and 2004 to determine whether an isolate of *Bipolaris* from the grass species *L. chinensis* is *B. oryzae* and to determine this fungus can infect rice cultivars.

MATERIALS AND METHODS

For the identification of the species of *Bipolaris*, the fungus isolated from infected leaves of *L. chinensis* were inoculated to healthy leaves and re-isolated following Koch's postulate. The biological characteristics of this fungus were examined.

The pathogenicity and sporulation of this pathogen was observed on rice cultivars. The experiment was carried out following a completely randomized design with three replications. Fifteen rice cultivars and a grass species *L. chinensis* were grown in square plastic pots (10x10 cm), 12 plants per pot containing sun-dried garden soil. Nitrogen was applied 12 days after sowing at a rate equivalent to 115 kg N ha^{-1} (0.25 g pot^{-1} of urea containing 46% N, Norsk Hydro A/S, Indonesian) to determine the pathogenicity and sporulation of the pathogen. The fungus *B. oryzae* was isolated on *L. chinensis* and rice collected in the rice fields of Cantho City and cultured on rice extract agar (RE: 200 g rice leaves, 10 g sucrose, 15 g agar and 1,000 ml distilled water). The cultures were incubated for 7 to10 days with alternating cycles of 12 h under near-UV light (Philips TLD 36W/08) and 12 h darkness at 25°C until sporulation. At 25 days after sowing, the rice and grass leaves were fixed in a horizontal position on bent plastic plates, abaxial side upwards, using unbleached cotton strings (Jørgensen et al. 1996). Conidia were harvested by adding distilled water to the cultures and carefully scraping their surface with a scalpel. The spore concentration was determined using a haemacytometer, the inoculum concentration adjusted to 20.000 conidia ml^{-1} and spraying onto the fixed leaves with a glass hand sprayer until run-off and immediately the plants were sealed in plastic bags. Plants were kept in darkness 24 h until the plastic bags were removed. The symptoms of disease were observed and scored at 9 days after inoculation (dai) by a scale modified from Aluko 1975 (Thuy 2002). The sporulation of *B. oryzae* on rice was harvested in 50 cm^2 of affected leaf area and counted under light microscopy by using a haemacytometer. After counting, the number of spores was calculated in a square centimeter of affected leaf area (cm^2).

To observe the infection biology of *B. oryzae* collected from *L. chinensis* in rice, leaf segments (4 to 5 cm long) were cut 4, 8, 12, 24, 48, 72 and 96 h after inoculation (hai) with *B. oryzae*. Chlorophyll was extracted from the leaf segments by carefully placing them in boxes on top of three layers of filter paper saturated with a solution of absolute ethanol and glacial acetic acid (3:1) (Carver et al. 1991). After clearing, the leaves were stored on filter paper saturated with lactoglycerol (lactic acid: glycerol: distilled water, 1:1:1) until examination. The cleared leaves were stained with Evans Blue, 0.1 % in lactoglycerol, and examined by normal light microscopy and epifluorescence light microscopy (excitation 400-440 nm, dicroitic mirror DM 455, barrier filter > 475). Four leaves from each of two pots at each sampling time were observed the germination of spore, cellular response and hyphal growth in rice leaves.

RESULTS AND DISCUSSION

Colonies of the fungus were dark brown when cultured on RE medium. Conidia and conidiophores had the same characteristics of *B. oryzae* as described by Lee et al. (1984) and Thuy (2002). Conidia were brown, curved, comprised with many cells, geminated from one or both sides and formed germ tubes. At the end of germ tubes, there were various shapes of appressoria produced. The formation of appressoria was found at 4 hai. Under artificial inoculation, the grass species *L. chinensis* gave the symptom at 5 dai when inoculation with *B. oryzae* isolated from its host.

The pathogenicity of 15 rice cultivars inoculated with *Bipolaris oryzae* had shown the symptoms like brown spot disease as described by Thuy (2002) and disease score ranged from 2 to 4 (Table 1). The sporulation of fungus was high on MTL 233 (505.2 spores sq cm^{-1}) and IR64 (395.8 spores sq cm^{-1}) rice cultivars, the least was on MTL265 (5.2 spores sq cm^{-1}) (Table 1). Sporulation of fungus used to measure the virulent of *Bipolaris* species has been reported by Touhami et al. (2000). The proliferation of the fungus on rice cultivars indicated the invasion and colonization of the pathogen in the hosts. The infection and sporulation of *B. oryzae* in rice also plays an important role in transmission of this pathogen from weed to rice and the study can partly explain the outbreak of brown spot disease in some areas of the Mekong delta presently. A cross inoculation an isolate from rice to *L. chinensis* also caused disease (data not shown).

Table 1. Reactions of 15 rice cultivars to *B. oryzae* isolated from *Leptochloa chinensis* and its sporulation.

TT	Rice cultivars	Disease score	Spores sq cm^{-1}
1	MTL119	2	12.8 ef
2	MTL189	2	47.9 de
3	MTL198	2	89.9 c
4	MTL231	3	57.6 d
5	MTL232	3	54.5 d
6	MTL233	3	505.2 a
7	MTL265	3	5.2 f
8	MTL340	3	21.9 def
9	OM 269	4	38.6 def
10	OM 1490	2	31.3 def
11	OM 3556	3	21.2 def
12	OMCS 2000	3	45.9 de
13	IR 64	4	395.8 b
14	IR 50404	2	35.8 def
15	ST3	3	13.5 ef

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Results also showed that there was a cellular response of rice to infection of *B. oryzae* at 12 and 24 hai. The hyphal infection was found at 12 hai.

ACKNOWLEDGEMENTS

This work was financed by the Royal Danish Ministry of Foreign Affairs through the DANIDA-ENRECA-project "Systemic Acquired Resistance - an Ecofriendly Strategy for Managing Diseases in Rice and Pearl Millet".

LITERATURE CITED

Aluko M.O. 1975. Crop losses caused by the brown leaf spot disease of rice in Nigeria. Plant Disease Reporter, 59: 609-613.

Bean G.A. and Schwartz R. 1961. A severe epidemic of *Helminthosporium* brown spot disease on cultivated wild rice in northern Minnesota. Plant Disease Reporter, 45: 901.

Carver T. L.W., Robbins M.P. and Zeyen R.J. 1991. Effects of two PAL inhibitors on the susceptibility and localized autofluorescent host cell responses of oat leaves attacked by *Erysiphe graminis* DC. Physiological and Molecular Plant Pathology, 39: 269-287.

Jørgensen H.J.L., Andresen H. and Smedegaard-Petersen V. 1996. Control of *Drechslera teres* and other barley pathogens by preinoculation with *Bipolaris maydis* and *Septoria nodorum*. Phytopathology, 86: 602-607.

Lee C.H., Hou H.H. and Jong S.C. 1984. Cytology of *Helminthosporium oryzae*. Mycopathologia, 87: 23-27.

Nisikado Y. and Miyake C. 1922. Studies on the helminthosporiose of the rice-plant. Berichte des Ōhara Instituts für landwirtschsftliche Forschungen 2: 133-195 + plate III - IX.

Ou S.H. 1985. Rice Diseases. 2nd ed. Commonwealth Mycological Institute, Kew, UK. 201-221.

Percich J.A., Nyvall R.F. and Malvick D.K. 1997. Interaction of temperature and moisture on infection of wild rice by *Bipolaris oryzae* in the growth chamber. Plant Disease, 81: 1193-1195.

Thach N. D. 1998. Preliminary study on grain discoloration of rice (*Oryza sat*iva L.) and its affect on grain quality, Autumn – winter crop 1997 at Long an province. MS Thesis. The national university of Ho Chi Minh. 111 pages.

Thuy T.T.T. and Thanh D.N. 1995. Preliminary results on survey of weed population in the rice fields. Selected Research Papers, Can Tho University, Vietnam, 238-243 (in Vietnamese).

Thuy T.T.T. 2002. Infection Biology of *Bipolaris oryzae* in Rice and its Pathogenic Variation in the Mekong Delta, Vietnam. Ph.D. Thesis. The Royal Veterinary and Agricultural University, Department of Plant Biology, Plant Pathology Section, Copenhagen, Denmark.

Touhami A. O., Ennaffah, B., El Yachioui, M. and Douira, A. (2000). Pathogénie comparée de 4 espèces d' *Helminthosporium* obtenues a partir des plantes malades du riz au Maroc. Journal of Phytopathology, 148: 221-226.

Ueyama A. and Tsuda, M. 1977. Leaf-spot disease fungus of *Chikusichloa aquatica*, a new host plant of *Cochliobolus miyabeanus* (imperfect state: *Helminthosporium oryzae*). Transactions of the Mycological society of Japan, 18: 245-250.

PROCEEDINGS

The 20th Asian - Pacific Weed Science Society Conference

Responsibility of publication

NGUYEN CAO DOANH

Design, draft : **NGUYEN PHUNG THOAI**

Cover : **LE ANH VU - KHANH HA**

AGRICULTURE PUBLISHING HOUSE

167/6 - Phuong Mai - Dong Da - Ha Noi

Tel: (04) 8523887 - 5760656 - 8521940

Fax: (04) 5760748.

E.mail: nxbnn@hn.vnn.vn

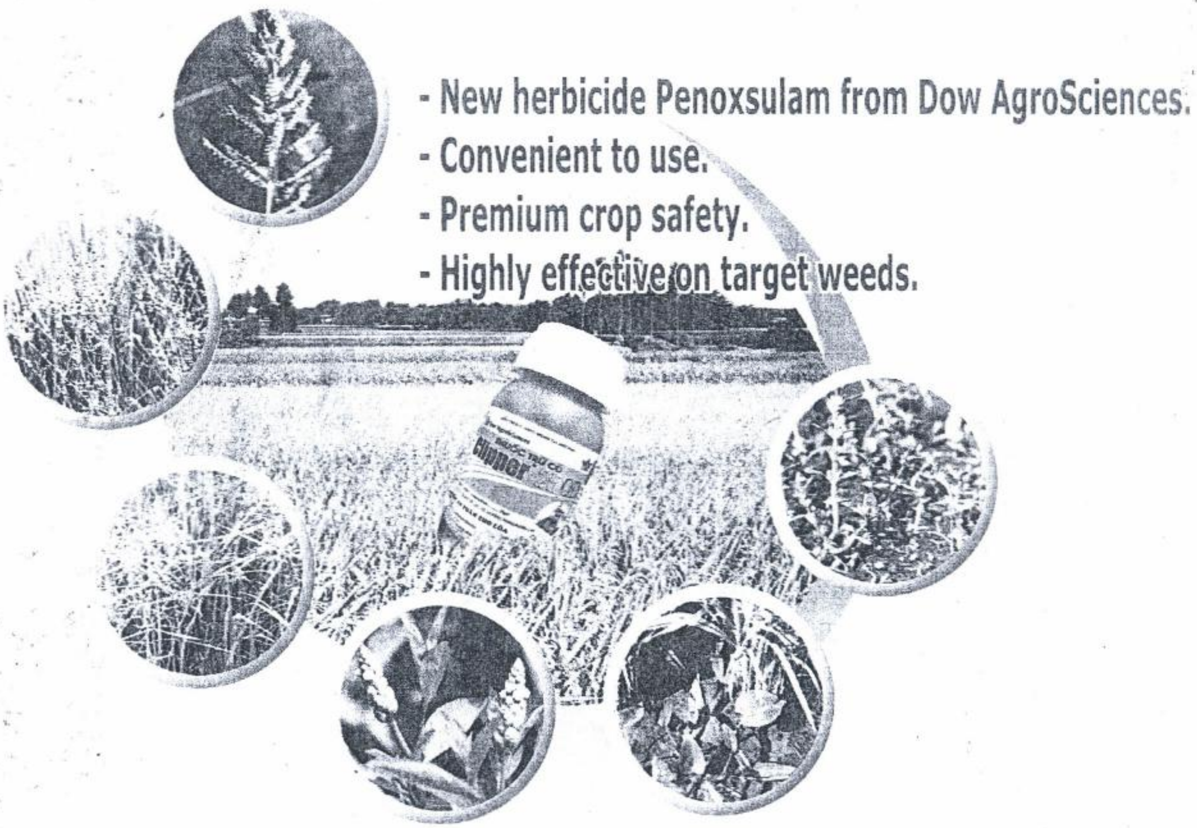
BRANCH OF AGRICULTURE PUBLISHING HOUSE

58 Nguyen Binh Khiem, Distric 1, Hochiminh City

Tel: (08) 8297157 - 8299521

Fax: (08) 9101036

Printed 265 copies, dimension 20,8 x 29 at Im - Export Package Printing House
Permit N^{O} 990/XB-QLXB dated 23/06/2005. Copyright deposit in quarter IV/2005


- New herbicide Penoxsulam from Dow AgroSciences.
- Convenient to use.
- Premium crop safety.
- Highly effective on target weeds.