Pak. J. Weed Sci. Res., 18: 95-103, Special Issue, October, 2012

LONG TERM HERBICIDAL WEED MANAGEMENT INTEGRATED WITH NITROGEN NUTRIENT IN TRANSPLANTED RICE-RICE CROPPING SYSTEM OF TAMIL NADU, INDIA

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ABSTRACT

With a primary objective to evaluate the long-term herbicide application integrated with nitrogen management on weed shift, weed control efficiency, soil micro flora, herbicide residue and productivity of transplanted rice-rice cropping system, field experiments were conducted for ten years from 2000 to 2010. Field experiments with hand weeding (HW) twice, pre-emergence butachlor 0.75 or pretilachlor 0.75 kg/ha or in rotation + post emergence 2,4, D, 0.4 kg/ha along with inorganic and organic nitrogen(N) at 75 and 25 percent were conducted with four replications arranged in a randomized blocks design. Decreased grass weeds density from 53.0% with first rice crop during kharif 2000 to 42.1% with eighteenth rice in HW with 100% N as inorganics, was observed. Broad leaved weed (BLW) density was higher with HW in eighteenth and nineteenth rice crops compared to first rice crop. Ludwigia parviflora, Eclipta alba and Marselia quadrifoliata were BLWs in nineteenth and twentieth rice crops. Weed shift from Echinochloa crusgalli to Panicum distachyon was observed, which was more in rotational use of herbicides. BLW density was higher in HW with nineteenth and twentieth rice crops compared to first crop. Reduced weed density and dry weight were observed with herbicidal weed control and it was well pronounced under rotational use of herbicides (butachlor in kharif and pretilachlor in rabi with 2,4-D). Herbicides application recorded significantly higher yield in nineteenth and twentieth rice crops and the yield increase was higher with continuous and rotational use of herbicides. Residues of butachlor, pretilachlor and 2,4-D were below deductable level from 45 days after application in soil and crop. Improvement in soil actinomycetes, fungi and bacteria was observed with herbicides application.

Key words: Dry weight, herbicide residue, soil micro flora, transplanted rice, weed density, weed shift.

INTRODUCTION

Control of weeds at the early rice growth stage before they compete with crop is essential to restrict nutrient uptake by weeds and their availability to crop for higher yields. Manual weeding could

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be done only when the weed growth is to a size large enough for hand removal, by that time weeds would have competed with crop. Herbicide use for the control of weeds, especially in intensive rice-rice cropping system, is at higher rates as cost and demand for manual labour is increasing. Further, long term continuous use of selective herbicides in rice may cause a shift in weed flora, from annuals to perennials, which are difficult to control. Other crop management practices, especially nitrogen use (organic / inorganic / integrated nutrient management) is likely to change the crop-weed ecology as well as herbicide activity and herbicide residue in the soil. With these in view, a long term herbicide experiment on fixed plot basis has been initiated from *kharif* 2000 with the following objectives:

- To assess the effect of continuous use of herbicides on the shift in weed flora, control of weeds and yield of rice
- To estimate the fate of herbicides and level of herbicide residue in the soil and crop produce; and
- To study the impact of long term use of herbicides on the soil microbial population.

MATERIALS AND METHODS

Field experiment was initiated at the Wetlands of Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, is the southernmost State in the Indian Union. The experimental farm is located at 77 E 11°N latitude 426 metre above mean sea level, and the farm receives the normal total annual rainfall of 674.2 mm in 45.8 rainy days. Trial was conducted in soil with fine clay loam type of soil and belonging to *Typic chromusterts* soil group and *noyyal* soil series. This soil is medium in organic carbon content (0.64 per cent) and the available nutrient status is low in nitrogen, medium range of phosphorus and the potassium status is high with neutral to alkaline in soil reaction and soluble salt content is within the permissible limits.

The first crop of rice was planted during *kharif* season 2000 (sowing/planting from June to August months) and in rotation during *rabi* season (sowing / planting from September to November months) of every year. Field trials were carried out for ten years with twenty rice crops in rice-rice cropping system during *karif* and and *rabi* seasons up to 2009-10. Two sources of nitrogen (N) viz., organic (in situ green manuring with *Sesbania rostrata* to supply 25% of N) and inorganic (prilled urea with 46% N) were used as per the treatment schedule (Table-1). Weed management treatments include hand weeding, pre (PE) and post emergence (POE) herbicides in combination and pre emergence herbicides in rotation as detailed below.

Table-1. Nitrogen and weed management treatments in transplanted rice-rice cropping system.

Weed control methods	Source of nitrogen	
	Inorganic	Organic
W1N1 - Hand weeding on 20 and 40 days after transplanting	100 %	-
W1N2 - Hand weeding on 20 and 40 days after transplanting	75%	25%
W2N1 - PE Butachlor 0.75 + POE 2,4-DEE 0.4 kg ha^{-1}	100%	-
W2N2 - PE Butachlor 0.75 + POE 2,4-DEE 0.4 kg ha^{-1}	75%	25%
W3N1 - PE Butachlor 0.75 + POE 2,4-DEE 0.4 kg ha^{-1} (*kharif*) PE Pretilachlor 0.75 + POE 2,4 DEE 0.4 kg ha^{-1} (*rabi*)	100%	-
W3N2 - PE Butachlor 0.75 + POE 2,4-DEE 0.4 kg ha^{-1} (*kharif*) PE Pretilachlor 0.75 + POE 2,4 DEE 0.4 kg ha^{-1} (*rabi*)	75%	25%

W1 & W2 : Same pre emergence herbicide for *kharif* & *rabi* rice crops;
W3 : Rotation of pre emergence herbicide for *kharif* and *rabi* rice crops;
Design : RBD;
Replications: Four.

Observations were made on predominant weed flora and weed density and dry weight, rice grain yield, herbicide residue in post harvest soil, grain and straw and post harvest soil microbial population (bacteria, fungi and actinomycetes) in every trial.

RESULTS AND DISCUSSION

Predominant weed flora of the experimental field

In thefirst rice crop (*kharif,* 2000) the general weed flora (Table-2) was *Echinochloa crusgalli* (41.1%), *Echinochloa colona* (8.1%) and *Leptochloa chinensis* (3.8%) among grasses (53.0%), while sedge (18.5%) mainly comprised of *Cyperus difformis* (15.7%) and *Cyperus iria* (2.8%). Broad leaf weeds observed were *Ludwigia parviflora* (12.3%), *Ammania baccifera* (9.4%), *Eclipta alba* (3.7%), *Marselia quadrifoliata* (1.9%) and others (1.2%). The absolute weed density was 41.7m^2 as observed in hand weeding twice applied with 100% N by inorganic source.

Analysis of Summed Dominance Ratio of weed species in the first and twentieth rice crop (60 days after transplanting -DAT) showed that the grass weed density decreased from 53.0% to 40.1 % (60 DAT), where hand weeding on 20 and 40 DAT method of weed control was practiced with 100% nitrogen nutrient as inorganics (Table-3). In all the treatments grass weeds density decreased from first rice crop to 20th rice crop. However the *Echinochloa colona* and *Leptochloa chinensis* which were present in first rice crop were completely absent in twentieth rice crop.

Table-2. Summed dominance ratio (SDR) of predominant weed species in first rice.

SDR of predominant weeds in first rice (*kharif* 2000)						
Treatments	**W1N1**	**W1N2**	**W2N1**	**W2N2**	**W3N1**	**W3N2**
Weed species						
Echinochloa crus-galli	41.1	38.6	33.8	33.3	38.9	34.0
Echinochloa colona	8.1	6.4	7.1	8.2	6.8	7.4
Leptochloa chinensis	3.8	2.2	2.5	4.1	3.7	2.9
Panicum distachyon	-	-	-	-	-	-
Total grasses	53.0	47.2	43.4	45.6	49.4	44.3
Cyperus difformis	15.7	14.6	14.1	14.8	15.3	15.0
Cyperus iria	2.8	2.7	1.5	1.6	2.1	1.2
Total sedges	18.5	17.3	15.6	16.4	17.4	16.2
Ludwigia parviflora	12.3	18.7	21.9	19.4	17.8	22.3
Ammania baccifera	9.4	10.1	8.9	10.4	7.3	8.4
Eclipta alba	3.7	3.4	4.7	4.2	3.6	4.3
Marselia quadrifoliata	1.9	2.3	3.1	2.2	2.1	2.7
Others	1.2	1.0	2.4	1.8	2.4	1.8
Total BLW	28.5	35.5	41.0	38.0	33.2	39.5
Absolute weed density m^{-2}	41.7	35.1	32.8	27.5	31.5	26.4

Increase in total sedge weed density was observed in all the treatments when compared to the first rice crop except in the case of rotational use of pre emergence herbicides with butachlor for *kharif* rice and pretilachlor for *rabi* rice (W_3) and hand weeding for both seasons rice in rice-rice cropping system. Broad leaved weed density was higher in hand weeding treatments of twentieth rice crop (60 DAT) compared to first rice crop. *Ludwigia parviflora*, *Eclipta alba* and *Marselia quadrifoliata* were the predominant broad leaved weeds present in the twentieth rice crop at both stages.

An increase in total broad leaved weed density was observed at 60 DAT in twentieth rice crop. Among the grasses, *Echinochloa colona* and *Leptochloa chinensis* and *Cyperus iria* among the sedges recorded in the first rcie crop were absent in twentieth rice crop.

Weed density and dry weight

During 60 DAT increase in grass weed density when compared to the first rice crop was observed in the plots which received herbicidal weed management treatments (Table-4). The same trend was observed during harvest stage also. Treatments which received 100% inorganic nitrogen recorded higher grass weed density. The total sedge density was more in all the treatments when compared to the first rice crop. Broad weed density was more in the treatments which received hand weeding and also higher in the 100 % inorganic nitrogen applied plots.

Table-3. Long-term weed control methods and source of N on weed flora of transplanted rice-rice cropping system.

Treatments	Summed Dominance Ratio(SDR) of weed species–60 DAT											
	First crop (*kharif*, 2000)						Twentith rice crop (*rabi*, 2009-10)					
	W1N1	W1N2	W2N1	W2N2	W3N1	W3N2	W1N1	W1N2	W2N1	W2N2	W3N1	W3N2
Echinochloa crus-galli	41.1	38.6	33.8	33.3	38.9	34.0	29.5	24.6	16.1	6.8	10.9	12.2
Echinochloa colona	8.1	6.4	7.1	8.2	6.8	7.4	-	-	-	-	-	-
Leptochloa chinensis	3.8	2.2	2.5	4.1	3.7	2.9	-	-	-	-	-	-
Panicum distachyon	-	-	-	-	-	-	13.3	15.5	15.5	24.7	16.6	14.4
Total grasses	53.0	47.2	43.4	45.6	49.4	44.3	42.8	40.1	31.6	31.5	27.5	26.6
Cyperus difformis	15.7	14.6	14.1	14.8	15.3	15.0	28.6	18.1	12.4	25.1	6.1	9.7
Cyperus iria	2.8	2.7	1.5	1.6	2.1	1.2	-	-	-	-	-	-
Total sedges	18.5	17.3	15.6	16.4	17.4	16.2	28.6	18.1	12.4	25.1	6.1	9.7
Ludwigia parviflora	12.3	18.7	21.9	19.4	17.8	22.3	40.1	11.7	11.7	15.6	20.9	-
Ammania baccifera	9.4	10.1	8.9	10.4	7.3	8.4	14.5	19.1	19.1	0.0	19.1	28.2
Eclipta alba	3.7	3.4	4.7	4.2	3.6	4.3	-	-	-	-	-	-
Marselia quadrifoliata	1.9	2.3	3.1	2.2	2.1	2.7	12.1	16.3	22.2	25.1	12.1	12.1
Others	1.2	1.0	2.4	1.8	2.4	1.8	-	-	-	-	-	-
Total BLW	28.5	35.5	41.0	38.0	33.2	39.5	66.7	47.1	53.0	40.7	52.1	40.3

In both rice crops, hand weeding treatments recorded significantly higher weed dry weight than in chemical treatments. Treatments with rotational application of herbicides (butachlor + 2,4-D (*kharif*) and pretilachlor + 2,4-D (*rabi*) and integration of organic and inorganic source of nitrogen nutrient recorded significantly lesser weed dry weight at 60 DAT and harvest stage in both the first and twentieth rice crops.

Rice grain yield

Rice grain yield was not significantly influenced by the interaction of source of N and hand weeding method of weed management in first as well as twentieth rice crops (Table-4). The effect of weeding methods on grain yield was more pronounced during *rabi*, 2009-10 compared to *kharif,* 2000. Manual weeding recorded higher grain yield in the first crop. Whereas, treatments involving pre emergence and post emergence herbicides recorded

significantly higher yield in twentieth rice crop. Among the herbicidal weed management treatments which received rotational use of pre emergence herbicides recorded higher grain yield than single herbicide of butachlor for both *kharif* and *rabi* seasons rice.

Table-4. Weed density and dry weight and rice grain yield as influenced by long-term herbicide application and sources of N in transplanted rice-rice cropping system.

Treat-ments	Weed density 60 DAT (m^{-2})		Weed dry weight 60 DAT (g m^{-2})		Rice grain yield (kg ha^{-1})	
	I rice crop	XX rice crop	I rice crop	XX rice crop	I rice crop	XX rice crop
W1N1	41.7	46.7	18.4	48.3	5784	4937
W1N2	35.1	37.3	13.9	38.6	5542	5300
W2N1	32.8	29.8	20.9	30.5	5626	5225
W2N2	27.5	30.0	16.3	29.4	5426	5000
W3N1	31.5	25.9	21.0	27.1	5676	5362
W3N2	26.4	33.6	15.8	32.5	5570	5700
CD (P=0.05)	7.9	5.6	3.4	4.9	136	315

Table-5. Persistence and residues of pre emergence herbicide butachlor in transplanted rice-rice cropping system.

Treatments	Days after herbicide application					
	1	7	15	30	45	At Harvest
First rice (*kharif*, 2000)						
W2N1	0.301	0.212	0.116	0.025	0.002	0
W2N2	0.289	0.174	0.101	0.022	0.0011	0
W3N1	0.312	0.194	0.112	0.0106	0.001	0
W3N2	0.278	0.186	0.106	0.012	0.008	0
Twentieth rice (*rabi*, 2009-10)						
W2N1	0.526	0.324	0.201	0.087	0.054	BDL
W2N2	0.451	0.285	0.169	0.065	0.025	BDL
W3N1	0.421	0.265	0.197	0.085	0.025	BDL
W3N2	0.358	0.218	0.19	0.078	0.031	BDL

Continuous application of butachlor + 2,4-DEE herbicide mixtures in every season or rotational application of butachlor + 2,4-DEE during *kharif* and pretilachlor + 2,4-DEE during *rabi* seasons did not show build up of these herbicides in the post harvest soil or grain and straw of the first (*kharif,* 2000) and twentieth (*rabi,*2009-10) rice crops as observed in hand weeding treatment in all the twenty rice crops in rice-rice cropping system (Tables 5 and 6).

Soil microbial population

The soil microflora was not quantitatively affected as far as the bacterial and fungal populations are concerned. The normal range of

population of bacterial and fungi in a flooded soil was present throughout without any alarming changes. The actinomycetes population was very low during the entire duration of crop growth, but a slight increase was observed after harvest of the crop (Table-7).

Table-6. Persistence and residues of post emergence herbicide 2,4-D in transplanted rice-rice cropping system.

Treatments	Days after herbicide application				
	1	15	30	45	At Harvest
First rice (*kharif*, 2000)					
W2N1	0.94	0.061	0.003	0	
W2N2	0.083	0.068	0.004	0	0
W3N1	0.079	0.059	0.003	0	0
W3N2	0.075	0.067	0.003	0	0
Twentieth rice (*rabi*, 2009-10)					
W2N1	0.214	0.125	0.054	BDL	BDL
W2N2	0.215	0.108	0.048	BDL	BDL
W3N1	0.21	0.124	0.048	BDL	BDL
W3N2	0.15	0.115	0.04	BDL	BDL

The microbial population among different treatments varied during *kharif* 2000 and *rabi* 2009-10 seasons experiments. Higher bacterial population was recorded with rotational pre emergence herbicidal weed management integrated with organic source of N in twentieth rice (*rabi,* 2009-10) which was comparable with first rice crop (*kharif*, 2000) with rotational herbicidal and hand weeding weed management. Whereas, fungi population was consistently higher with hand weeding combined with inorganic N and integrated N management in both the rice crops. Similarly, actinomycetes population was also higher in hand weeding integrated with either the sources of N (organic and inorganic) management in twentieth rice crop (*rabi*, 2009-10).

Table-7. Soil microbial population at post harvest stage in transplanted rice-rice cropping system.

Treat-ments	First rice crop (*kharif,* 2000)			Twentieth rice crop (*rabi*, 2009-10)		
	Bacteria x 10^6/g ODS	Fungi x 10^3/g ODS	Actinomycetes x 10^3/g ODS	Bacteria x 10^6/g ODS	Fungi x 10^3/g ODS	Actinomycetes X 10^3/g ODS
W1N1	37.15	52.99	17.17	32.46	56.32	18.45
W1N2	58.33	53.80	19.79	50.35	48.62	25.92
W2N1	43.05	23.06	4.86	39.45	28.54	3.56
W2N2	36.81	27.51	6.25	41.56	32.92	7.03
W3N1	56.04	40.45	7.64	61.34	45.31	8.94
W3N2	22.57	32.76	9.38	45.37	42.54	14.58

g ODS: gram of oven dry soil

DISCUSSION

Rotational application of pre emergence herbicides (butachlor + 2,4-D (*kharif*) and pretilachlor + 2,4-D (*rabi*) and integration of nitrogen nutrient with inorganic and organic sources recorded significantly lesser weed density and weed dry weight at 60 DAT in both first and twentieth rice crops. In general weed dry matter accumulation was significantly lower under combined use of organic and inorganic sources of nutrients as compared to inorganic alone irrespective of the method of weed management as earlier observed by Rajkhowa *et al*. (2001). Rotational use of selective pre emergence herbicide might have helped in broad spectrum weed control avoiding chances of herbicide resistant weed biotypes while using a single herbicide for a longer period.

Normally herbicide applied treatments observed with lesser weed density and dry weight compared to hand weeding treatments. According to Jacob *et al*. (2005) who had reported that pre-emergence application of anilofos + 2,4-D EE supplemented with 2,4-D sodium drastically reduced the weed density and dry weight when compared to anilofos + 2,4- D EE supplemented with hand weeding. Integration of weed control by butachlor + 2,4-DEE followed by pretilachlor 0.75 + 2,4-DEE 0.4 kg ha^{-1} with 100% inorganic nitrogen recorded maximum yield in twentieth rice crop and the application of butachlor + 2,4-DEE during both the seasons recorded maximum yield in twentieth rice crop. Similar increase in grain yield of tenth rice grown in succession was reported by Kandasamy and Chinnusamy (2005) with rotational use of pre emergence herbicide integrated with organic and inorganic source of N in transplanted rice. Rice grain yield increase in effective weed management methods involving rotational pre emergence herbicides usage integrated basal application of organic source on N and split application of inorganic source of N in rice could be attributed to lesser weed density and dry weight recorded consistently with all the twenty rice crops in transplanted rice-rice cropping system. These results corroborate with the findings of Singh *et al*. (2003) who had observed similar increase in rice grain yield with split application of nutrients along with effective weed management increased the crop yield due to lower density, dry matter accumulation in weeds which helped in providing favorable growing environment resulting into better expression of potential yield.

Mean half life of the butachlor and 2, 4-DEE during *kharif* was found to be 9 and 7 days respectively and 13 days during *rabi* for both the molecules. Comparing pooled data of 2000-05 with 2005-2010, butachlor build up was 31 per cent high irrespective of continuous or rotational application and was also influenced by the N

sources. 2,4-DEE persistence and build up was influenced by the N sources was in the range of 14 to 19 percent. However at harvest the residues were not detected in grain, straw or in soil. These results are in line with the findings of Shanmughasundaram *et al.* (2005) and Janaki *et al*. (2010) who had reported below deductable levels of butachlor, pretilachlor and 2,4-DEE applied in rotation integrated with organic and inorganic source of N in transplanted rice-rice system.

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