Pak. J. Weed Sci. Res., 18: 469-475, Special Issue, October, 2012

IMPACT OF PRE- AND POST- PLANTING HERBICIDES ON GROWTH PERFORMANCE AND YIELD OF ORYZA GENOTYPES IN SRI LANKA

W.J. Nimanthika[1] and S.R. Weerakoon

ABSTRACT

Herbicide application is one of the most effective methods of weed control in agricultural crops. However, herbicides can cause adverse effects on crops including rice (Oryza species). A preliminary greenhouse study was conducted to evaluate the herbicide tolerance in rice using five improved (BG-360, BG-352, BG-359, AT-306, AT-308), three traditional ("Machel", "Kuruluthuda", "Madathawaru") varieties of O. sativa and five wild rice spp. (O. nivara, O. rufipogon, O. eichingeri, O. rhizomatis, O. granulata). Broad spectrum pre-planting (glyphosate; 360g/l Count-up®) and post-planting (Fenoxaprop-p-ethyl; 69g/l RiceStar®) herbicides were used in single (0.5 g/l, 5.0 g/l) and double dose (1.0 g/l, 10.0 g/l) concentrations respectively with control and eight treatment combinations. Seedling emergence time, plant height after two weeks and one month, whole plant biomass at maturity and productive yield were measured. Results indicated that herbicide treatments have caused a significant ($p \geq 0.05$) impact on the growth and yield of all rice genotypes at single and double doses. After treating with herbicides, traditional and wild genotypes showed comparatively a shorter germination time and better growth compared to improved varieties. Single and double doses of both herbicides indicated a significant yield loss as well as reduced biomass. Compared to AT- and BG-varieties, traditional varieties showed significantly a higher tolerance to both herbicides. The tolerance was even higher in wild genotypes. There were no comprehensive studies carried out so far on effects of pre- and post-planting herbicides on rice genotypes available in Sri Lanka. The results revealed the significance of evaluating herbicide tolerance in terms of their concentrations among cultivated rice varieties to minimize the crop and yield damage due to herbicide application.

Keywords: *Oryza* spp., pre- and post- planting herbicides, Sri Lanka.

INTRODUCTION

Weeds are a source of biotic stress in crop systems that decrease the yield, increase production costs, and contribute to income risk. Therefore, weed control is an essential component of profitable crop production. Weeds can be controlled mechanically (by cultivation or hoeing), chemically (with herbicides) or culturally (crop rotation). Most farmers rely on an amalgamation of these methods. In general, a

[1] Department of Botany, The Open University, Nawala, Nugegoda, Sri Lanka
Corresponding author's email: shyamaweerakoon@gmail.com

combined approach including herbicides is more economical, and often more effective, than reliance solely on mechanical or cultural control practices (Tu *et al*., 2001).

The discovery of herbicide resistant weeds in the early 1970s generated an interest in mimicking this unintentional development for use in crop breeding. Herbicide resistant crops (HRCs) have been grown commercially since 1984, when the first triazine-resistant oilseed rape cultivar (OAC Triton) was introduced on the Canadian market (Hall *et al*., 1996).

Out of the 20 wild rice species spread throughout the world, five are found in Sri Lanka, i.e. *Oryza nivara*, *O. rufipogon*, *O. eichingeri*, *O. granulata* and *O. rhizomatis*. Studies have shown that many wild rice species exhibit herbicide tolerance (HT) (Hager *et al*., 2003). However, the HT in Sri Lankan wild rice species as well as traditionally cultivated *O*. *sativa* varieties has so far not been evaluated. Similarly the HR in developed *O. sativa* varieties has also not been evaluated so far. Evaluation of HT for broad spectrum herbicides among the Sri Lankan rice species is vital to identify the genes conferring HR. Therefore, it is worthwhile screening the Sri Lankan rice gene pool for their HR for possible incorporation in rice breeding programs.

Sri Lanka's paddy cultivation is threatened by rice weeds and these weeds have already damaged nearly 20 % of the harvest (Abeysekara *et al*., 2010). Application of herbicides is damaging when the cost and evolution of herbicide resistance in weed population is considered. On the other hand if the application of herbicide has negative effects on the rice such as growth retardation and yield loss, this problem will be more detrimental over controlling rice weeds to minimize the rice-yield loss. So far no comprehensive studies carried out to screen the effect of herbicides on rice in Sri Lanka. Since rice is the staple food for more than half of the world’s population as well as in Sri Lanka, it is vital to carry out such studies because farmers are continuously applying a massive amount of herbicides on rice crops to reduce the effects of weed populations on the growth performance of rice. The present study was carried out to evaluate the effect of pre- and post- planting herbicides on growth performance and yield of Sri Lankan rice genotypes and to identify any herbicide tolerant rice varieties.

MATERIALS AND METHODS

A greenhouse experiment was carried out to screen the effect of herbicide application on 13 Sri Lankan rice genotypes, i.e. *Oryza sativa* – developed varieties (BG-360, BG-352, BG-359, AT-306, AT-308), traditional varieties (“Machel”, “Kurulutuda”, “Madathawaru”), and wild species (*O. nivara*, *O. rufipogon*, *O. eichingeri*, *O. rhizomatis*, *O. granulata*). All rice varieties showed over 85% germination under normal conditions. The soil used for the study was collected from a rice field in Kalutara District where rice is regularly cultivated. The soil composition is; sand -21.3%, silt – 23.0%, clay – 55.6% and pH – 5.4. Count-up® (360 g/l glyphosate)-pre-planting and RiceStar® (69 g/l fenoxaprop-p-ethyl)-post-planting herbicides were used in this study. Single and double dose concentrations of 0.5 g/l, 1.0 g/l of Count-up® and 5.0 g/l, 10.0 g/l of RiceStar® were used. There were nine different combinations of herbicide treatments as follows, subjecting 50 plants per treatment: T1 (control), T2 (No pre-:5.0 g/l post-), T3 (No pre-:10.0 g/l), T4 (0.5 g/l pre-:No Post-), T5 (0.5 g/l Pre-:5.0 g/l Post-), T6 (0.5 g/l Pre-:10.0 g/l Post-), T7 (1.0 g/l Pre-:No Post-), T8 (1.0 g/l Pre-:5/0 g/l Post-) and T9 (1.0 g/l Pre-:10.0 g/l Post-). Black polythene bags (height of 60cm and a diameter of 45cm) were used as the pots to grow the plants and the amount of soil in each bag was at the same weight. Complete Randomized Block Design (RCBD) was used in the experiment and there were ten replicates and five blocks in each treatment combination. The recommended time line of application of the herbicides specified by the herbicide manufacturers were followed in the study, i.e. pre-planting herbicide (Count-up®) should be applied seven days prior to planting/sowing and post-planting herbicide (RiceStar®) should be applied three weeks after planting/sowing. Panicles were harvested at the physiological maturity. The variables recorded were seedling emergence time (SET), plant height after two weeks (H1) and one month (H2), whole plant biomass at maturity (BM) were measured. Whole panicle weight (PW) and the weight of total de-husked seed sample (yield) of each of the plant were measured to calculate the productive yield (Y) as follows. The statistical analyses were carried out using SPSS v. 14.0.

$$\text{Productive yield (Y)} = \left(\frac{\text{Seed weight}}{\text{Whole panicle weight}}\right) \times 100$$

RESULTS AND DISCUSSION

According to the results given in Table 1, only ten out of the 13 rice genotypes used in this study have shown successful germination on pre-planting herbicide (Count-up®) treated soil. The wild rice genotypes *O. eichingeri*, *O. rhizomatis* and *O. granulata* were not germinated. SET and the H1 were significantly ($p \geq 0.5$) affected by the herbicide Count-up® in 0.5 g/l and 1.0 g/l concentrations for all the rice genotypes. BG- and AT-varieties showed an extended germination time 2.5 and 4.0 days consecutively for the two different concentrations compared to the control (1 day). H1 and H2 were also reduced correspondingly to 12.03 cm and 29.02 cm in BG- varieties and 9.87cm and 28.06 cm in AT-varieties compared to the control (14.83 cm and 42.50 cm). However, the traditional and wild genotypes showed relatively a shorter SET and increased height compared to BG- and AT-varieties.

The growth parameters, H2, BM and yield showed an inhibitory effect by Count-up® and RiceStar®. Yield of the genotypes was reduced compared to controls. Single and double doses of both herbicides indicated a significant yield loss as well as reduced BM. Herbicide tolerance was significantly greater in AT-varieties in terms of yield/plant (5.03g) and BM (189.67g) than BG-varieties which showed an average of 3.98g yield/plant and a BM of 112.56g. Compared to AT- and BG-varieties, the traditional varieties ("Machel", "Kurulutuda", "Madathawaru") showed significantly a higher tolerance to both herbicides in terms of all the recorded parameters. The tolerance was higher in successfully germinated wild genotypes (*O. nivara*, *O. rufipogon*) compared to all other genotypes.

The percentage yield loss of the developed varieties is nearly 30% when the plants are treated with single doses of pre- and post-planting herbicides and the treatments with double doses have shown nearly a 80% yield loss. However, the traditional and wild genotypes have shown relatively a less yield loss even under the treatments with double doses of pre- and post-planting herbicides.

The results revealed the significance of evaluating herbicide tolerance in terms of their concentrations among cultivated rice varieties to minimize the crop and yield damage due to herbicide application.

Rice is the staple food for more than half of the world population including Sri Lanka. Herbicides have been used to control rice weeds since the introduction of herbicides as it is the easiest and effective mean of weed control. Early studies reported that herbicides have drastically reduced the yield with similar effect as weed population (Hager *et al*., 2003). However, there were no comprehensive studies carried out on effects of pre- and post- planting herbicides on rice in Sri Lanka.

The previous studies have revealed that there is a significant reduction of rice yield due to application of pre- planting herbicides (Davis *et al*., 2009). Franz *et al*. (1997) and Schuette (1998) suggested that the chemical characteristics of glyphosate such as hydrolysis half life (>35 days), soil adsorption coefficient (average over several soil pH levels) (61 g/m^3), anaerobic half life (22.1 days), aerobic half life (96.4 days), field dissipation days (44 days) are high and its mobility, tendency to leach in soil and volatility are very low, hence cause unfavorable effects on growth performance and yield of rice.

Table-1. **Growth parameters and Yield data of the 13 rice genotypes used in the study (GT- Genotype; T- Treatment; SET- Seedling emergence time; PW – Panicle weight (g); BM- Biomass (g); Y –Productive Yield; H1 – Height after 2 weeks; H2- Height after 4 weeks; NG- Not germinated; NA- Not Applicable)**.

GT	T	SET	Height (cm)		Yield (g)	BM	Y	% Yield	GT	T	SET	Height (cm)		Yield (g)	BM	Y	% Yield
			H1	H2								H1	H2				
BG 360	T1	2.0	12.26	35.26	3.73	152.43	92.00	98	**Mada-thawaru**	T1	1.5	10.05	29.08	2.87	209.46	97.0	97
	T2	2.0	12.58	31.46	2.574	140.87	90.50	69		T2	1.5	10.16	28.02	2.066	205.28	92.50	72
	T3	2.0	12.11	22.43	1.082	112.57	89.85	29		T3	1.5	10.20	25.02	1.866	195.28	92.30	65
	T4	2.5	12.14	33.49	2.574	127.98	90.00	69		T4	2.0	9.85	27.56	2.009	202.05	92.60	70
	T5	2.5	12.02	27.48	2.574	140.47	90.20	69		T5	2.0	9.67	28.02	2.066	202.25	92.60	72
	T6	2.5	12.03	21.01	1.044	112.76	88.90	28		T6	2.0	9.79	24.89	1.751	170.26	90.90	61
	T7	4.0	8.05	21.21	0.933	113.67	87.50	25		T7	NG	NA	NA	NA	NA	NA	NA
	T8	4.0	8.68	21.46	1.082	115.64	87.20	29		T8	NG	NA	NA	NA	NA	NA	NA
	T9	4.0	7.91	19.33	0.746	98.25	85.26	20		T9	NG	NA	NA	NA	NA	NA	NA
BG 352	T1	1.0	13.93	42.50	5.25	187.56	90.00	97	***O. nivara***	T1	1.0	15.45	36.78	4.65	198.67	98.00	98
	T2	1.0	13.95	37.36	3.728	172.49	89.50	71		T2	1.0	15.44	36.82	4.092	199.56	97.50	88
	T3	1.0	13.90	32.56	1.628	152.52	87.85	31		T3	1.0	15.67	34.26	3.86	195.27	96.20	83
	T4	1.5	13.00	37.03	3.675	170.36	89.00	70		T4	1.0	15.14	36.02	3.999	198.25	97.45	86
	T5	1.0	13.37	38.27	3.675	164.89	88.20	70		T5	1.0	15.02	36.02	4.092	198.89	97.60	88
	T6	1.5	13.05	30.26	1.575	142.76	86.90	30		T6	1.0	14.98	34.02	3.813	196.21	96.50	82
	T7	2.5	10.05	32.99	1.523	135.68	85.50	29		T7	1.0	12.39	32.56	3.534	196.25	96.20	76
	T8	2.5	10.20	32.57	1.575	132.78	85.20	30		T8	1.0	12.37	32.01	3.674	196.28	96.70	79
	T9	2.5	9.78	25.44	1.523	118.84	85.26	29		T9	1.5	12.47	32.05	3.488	192.05	96.26	75
BG 359	T1	2.0	11.10	32.86	2.98	122.89	95.00	98	***O. rufipogon***	T1	1.5	14.88	30.23	5.34	178.94	97.36	97
	T2	2.5	12.02	27.02	2.086	120.25	93.50	70		T2	1.5	14.99	30.02	4.646	177.86	97.20	87
	T3	2.0	12.11	22.05	0.894	118.04	89.75	30		T3	1.5	15.02	29.89	4.646	177.26	96.26	87
	T4	2.5	11.32	25.22	2.056	120.36	92.00	69		T4	2.0	14.02	30.00	4.646	178.05	96.85	87
	T5	2.5	11.46	25.35	2.056	118.02	93.20	69		T5	2.0	14.25	30.00	4.699	177.56	97.02	88
	T6	2.5	11.05	22.63	0.864	115.52	88.90	29		T6	1.5	14.16	29.85	4.539	175.28	96.56	85
	T7	NG	NA	NA	NA	NA	NA	NA		T7	2.5	12.55	29.29	4.539	172.56	95.28	85
	T8	NG	NA	NA	NA	NA	NA	NA		T8	1.5	12.78	29.25	4.592	170.29	96.45	86
	T9	NG	NA	NA	NA	NA	NA	NA		T9	2.5	12.47	29.02	4.379	165.30	92.03	82
AT 306	T1	2.0	12.57	40.53	3.59	145.95	91.05	96	**Machel**	T1	1.0	9.77	20.57	2.95	155.86	93.00	99
	T2	2.5	12.52	37.05	2.621	142.05	90.50	73		T2	1.0	9.68	20.01	2.626	155.56	91.50	89
	T3	2.5	12.41	32.05	1.257	142.32	88.85	35		T3	1.0	9.75	20.15	2.331	153.28	89.85	79
	T4	2.0	11.12	35.89	2.585	144.09	90.00	72		T4	1.0	9.70	20.26	2.508	155.26	91.00	85
	T5	2.5	11.92	35.26	2.585	144.69	90.20	72		T5	1.0	9.65	20.01	2.626	155.02	91.20	89

GT	T	SET	Height (cm)		Yield (g)	BM	Y	% Yield	GT	T	SET	Height (cm)		Yield (g)	BM	Y	% Yield
			H1	H2								H1	H2				
	T6	2.5	12.03	30.26	1.149	130.05	87.90	32		T6	1.0	9.62	19.02	2.301	152.69	88.90	78
	T7	3.5	10.52	33.52	1.113	132.05	87.50	31		T7	1.5	9.17	18.54	2.124	150.38	87.50	72
	T8	3.5	10.67	31.45	1.149	132.25	87.20	32		T8	1.5	9.02	18.26	2.095	152.02	87.20	71
	T9	3.5	10.70	28.06	1.077	125.26	87.02	30		T9	1.0	9.07	18.04	2.095	150.26	85.26	71
AT 308	T1	1.0	14.83	37.89	3.87	137.27	97.00	100	**Kurulu-thuda**	T1	1.0	12.03	30.27	3.46	125.73	92.00	95
	T2	1.0	14.52	35.26	2.903	137.05	95.50	75		T2	1.0	12.13	29.75	2.768	125.02	90.50	80
	T3	1.0	14.47	33.01	1.393	132.25	95.30	36		T3	1.0	12.05	28.12	2.733	120.06	89.85	79
	T4	1.5	13.25	34.25	2.786	136.25	95.60	72		T4	1.0	11.99	29.88	2.768	125.32	90.00	80
	T5	2.0	13.57	33.26	2.786	136.85	95.60	72		T5	1.0	12.03	29.86	2.733	125.03	90.20	79
	T6	1.5	13.20	33.52	1.238	130.26	87.90	32		T6	1.0	12.20	28.01	2.733	120.32	88.90	79
	T7	2.5	12.76	30.12	1.2	130.56	87.50	31		T7	1.5	10.98	28.12	2.699	119.00	87.50	78
	T8	2.5	12.58	30.59	1.238	130.02	87.20	32		T8	1.0	10.95	27.26	2.699	119.25	87.20	78
	T9	2.0	12.50	28.53	1.122	129.28	86.20	29		T9	1.0	11.14	28.02	2.664	115.02	85.26	77

**O. granulata*, *O. rhizomatis* and *O. eichingeri* Did not show any successful growth under pre- planting herbicide treatments.

In consistent with the previous studies, the present study has also revealed that pre- and post-planting herbicides have adverse effects on the growth performance and yield of rice genotypes available in Sri Lanka. The effects of Count-up® were significant which extended the seedling emergence time and consequently reduced the plant height at seedling stage. This has resulted in reduction of biomass of the plant and the yield. RiceStar® imposed a significant effect on plant height and biomass at mature stage and yield.

The current study proved that some of the cultivating rice varieties have nearly reduced 30% yield due to application of single dose (recommended dose of the manufacturer) of pre- and post-planting herbicides. However the same treatment has no effect on some rice weeds such as *Echinochloa* sp., *Cyperus rotundus* and *Ludwigia prostrata*. The double dose application of the pre- and post- planting herbicides has completely eradicated those weeds, but caused about 80% reduction in yield. In this study, the traditional and wild rice genotypes showed tolerance even to the double dose application of herbicides with a minimal yield loss of about 25%. These rice varieties may harbor herbicide tolerant genes which possibly will be able to incorporate in rice breeding programs.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Rice Research and Development Board (RRDI), Bathalagoda, Sri Lanka for providing rice seed samples and the proper guidance for this study.

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