Efficacy of pyrazosulfuron-ethyl to manage weeds of rainy season rice under non-puddled field condition and its effect on the subsequent wheat crop

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Summary Non-puddled transplanting is a promising establishment technique for rainy season rice. A study was carried out at Mymensingh, Bangladesh in transplanted rainy season rice to evaluate weed control efficiency of pyrazosulfuron-ethyl alone or in sequential application with post-emergence herbicide under non-puddled strip-tilled field condition. Residual effects of those herbicides were also examined on germination and growth of the subsequently grown crop in rice-wheat cropping pattern. Seven treatment combinations comprised of four herbicides, 1 pre-emergent (PEM): pyrazosulfuron-ethyl, 1 early post-emergent (EPOST): orthosulfamuron, and 2 late post-emergent (LPOST): butachlor plus propanil and 2,4-D amine, along with one weedy check and one weed-free check were tested. Grasses and sedges were the major weeds in non-puddled strip-tilled rice with *Cynodon dactylon* (L.) Pers. the most dominant species. Herbicide treatments provided a wide range of control (above 50–95%) on all types of weeds. Sequential application of PEM with EPOST or LPOST or both offered higher weed control than sole application of PEM by 27–65%. Pyrazosulfuron-ethyl (PEM) followed by (fb) orthosulfamuron (EPOST) fb butachlor plus propanil (LPOST) gave the most effective weed control as well as maximum rice grain yield. Moreover, bioassay study showed that tested herbicides had no adverse effect on germination and growth of the next season wheat crop. Therefore, the study suggests sequential application of pyrazosulfuron-ethyl with post-emergence herbicide(s) in any of the tested combinations to attain the optimum rice yield, however rotational use of herbicides along with maintaining appropriate rates and timing needs to be strictly followed to obtain maximum benefit.

Keywords Non-puddled rice, herbicide, herbicide persistence, weed control.

INTRODUCTION

Rice-wheat is the main cropping system of Bangladesh (Sarker *et al.* 2014) and traditionally puddling is done to transplant rainy season rice. But, the strip-tilled non-puddled transplanting technique is gaining popularity over the conventional puddled system because of less cultivation cost involvement (Islam *et al.* 2014), conservation of soil health (Lindwall and Sonntag 2010) and production of more yield than the conventional system (Haque *et al.* 2016).

Weed management always plays a vital role to achieving rice yield. But high labour costs are causing farmers to shift from manual weeding to chemical weeding. Pyrazosulfuron-ethyl is a very common and effective pre-emergence herbicide, usually used to control grass and broadleaf weeds of puddled transplanted rice (Naveen *et al.* 2012). However, the efficacy of this selective herbicide in the diversified weed community of strip-tilled non-puddled transplanted rainy season rice is not well known. Moreover, the persistence of this herbicide in the soil and the residual effect of the herbicide on the subsequent crop is a matter of great concern. Therefore, the study was done to evaluate performance of pyrazosulfuron-ethyl alone, or in a sequential application with post-emergence herbicide(s) to obtain most effective weed control in non-puddled transplanted rainy season rice, and to examine the residual effect of herbicides on the subsequent wheat crop.

MATERIALS AND METHODS

The study was initiated in a sandy clay loam soil (pH 7.2) at Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from July 2014 to February 2015. The monthly average of maximum air temperature (T_{max}) ranged from 23.9–33.5°C and average minimum temperature (T_{min}) was 13.5–26.7°C. The highest T_{max} was in April and the lowest T_{min} was in January. The experimental site received 1951.4 mm of rainfall during the study period. The highest rainfall was recorded in August and no rain occurred in November and December.

Main experiment Efficacy of pyrazosulfuron-ethyl was tested using seven treatments:

- T_1: Pre-emergent (PEM) Pyrazosulfuron-ethyl (15 g ai ha^{-1}).
- T_2: PEM Pyrazosulfuron-ethyl (15 g ai ha^{-1}) followed by (fb) late post-emergent (LPOST) butachlor plus propanil (0.7 kg ai ha^{-1}).
- T_3: PEM Pyrazosulfuron-ethyl (15 g ai ha^{-1}) fb LPOST 2,4-D amine (1.6 kg ai ha^{-1}).
- T_4: PEM Pyrazosulfuron-ethyl (15 g ai ha^{-1}) fb early post-emergent (EPOST) orthosulfamuron (75 g ai ha^{-1}) fb LPOST butachlor plus propanil (0.7 kg ai ha^{-1}).
- T_5: PEM Pyrazosulfuron-ethyl (15 g ai ha^{-1}) fb EPOST orthosulfamuron (75 g ai ha^{-1}) fb LPOST 2,4-D amine (1.6 kg ai ha^{-1}).
- C_1: Weed-free check (4 × manual weeding).
- C_2: Weedy check.

The study was laid out in a randomised complete block design with three replications. Pre-planting Roundup® (glyphosate) was applied at 1.54 kg ai ha^{-1} in the experimental site prior to transplanting of rice seedlings. After one week of pre-planting spray, the land was fertilised and strip-tilled. The land was then inundated for 48 hours and after two days, rice seedlings (cultivar BINA dhan-7) were transplanted within the strips maintain 20 cm line to line distance and 15 cm hill to hill distance. Herbicides were applied by hand operated knapsack sprayer fitted with flat-fan nozzle at a spray volume of 300 L ha^{-1}. PEM, EPOST and LPOST herbicides were applied at 3 days after transplanting (DAT), at 15 DAT and at 22 DAT, respectively. Weed related data were recorded from randomly selected three quadrats (50 cm × 50 cm) in each plot. Grain and straw yields were recorded from central area of the plots at crop maturity.

Residual effect study This study had received the same treatments and design of the main rice experiment by following a micro-plot bio-assay technique. Micro-plots of 1 m^2 were established within each plot with 100 wheat seeds. Data on emergence, shoot length and dry matter of wheat were recorded up to 25 days after sowing.

Recorded data were analysed by using statistical package program 'R' (version 3.3).

RESULTS

The rice field was infested by seven weed species namely *Cynodon dactylon* (L.) Pers., *Echinochloa colona* (L.) Link, *Cyperus rotundus* L., *Cyperus difformis* L., *Fimbristylis miliaceae* (L.) Vahl, *Ludwigia decurrens* Walter and *Cynotis auxillaris* (L.) Sweet.

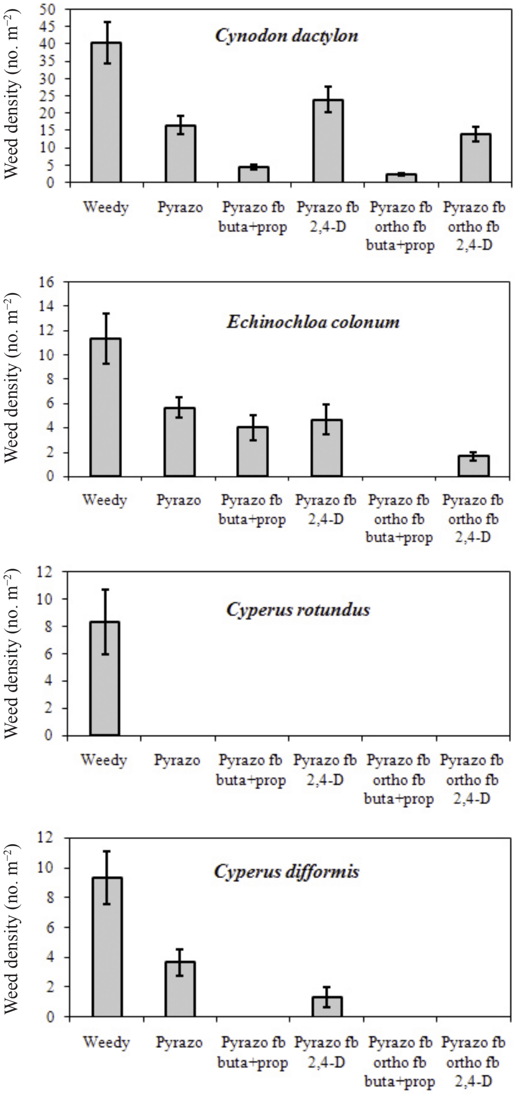
The highest densities of all the species were found in the weedy plots and the herbicide treatments offered a significant reduction in the densities of all species by 40–100% during 35 days after transplanting (Figure 1). Except for *C. dactylon*, the densities of all weed species were lower in those plots that received pyrazosulfuron-ethyl and one early post- or both early and late post-emergence herbicides in a sequential application in comparison to the sole PEM pyrazosulfuron-ethyl. Application of PEM pyrazosulfuron-ethyl followed by EPOST orthosulfamuron fb LPOST butachlor plus propanil gave complete reduction of all the species except *C. dactylon*; however this grass weed was reduced by 98% in terms of weed density and by 95% in terms of weed biomass compared to the weedy check (Table 1). On the other hand, the application of PEM followed by LPOST butachlor plus propanil or PEM followed by EPOST orthosulfamuron fb LPOST 2,4-D amine also offered 85–90% and 82–86% reductions of total weed density and biomass, respectively. Among the herbicide treatments, pyrazosulfuron-ethyl alone gave the lowest reduction in total weed density and biomass.

Rice grain yields also varied with herbicide treatments (Table 1). The lowest yield was recorded from the weedy check and the highest yield was obtained from PEM pyrazosulfuron-ethyl followed by EPOST orthosulfamuron fb LPOST butachlor plus propanil

Table 1. Effect of herbicide treatments on total weed density (TWD, plants m^{-2}) and biomass (TWB, g m^{-2}) at 35 days after transplanting and grain yield (GY, t ha^{-1}) of non-puddled rainy season rice during 2014.

Treatments	TWD	TWB	GY
T_1	36.7 b	10.11 b	3.58 d
T_2	10.7 c	4.19 d	5.30 b
T_3	33.3 b	6.40 c	4.68 c
T_4	2.3 d	1.24 e	6.18 a
T_5	15.7 c	3.33 d	6.01 a
C_1	105.3 a	23.82 a	2.69 e
C_2	–	–	5.99 a
Level of significance	***	***	***
CV (%)	8.68	10.28	3.18

In a column, figure(s) with different letters are significantly different at 5% level of significance (as per Tukey's Honest Significant Difference Test).
*** = 0.1% level of significance.



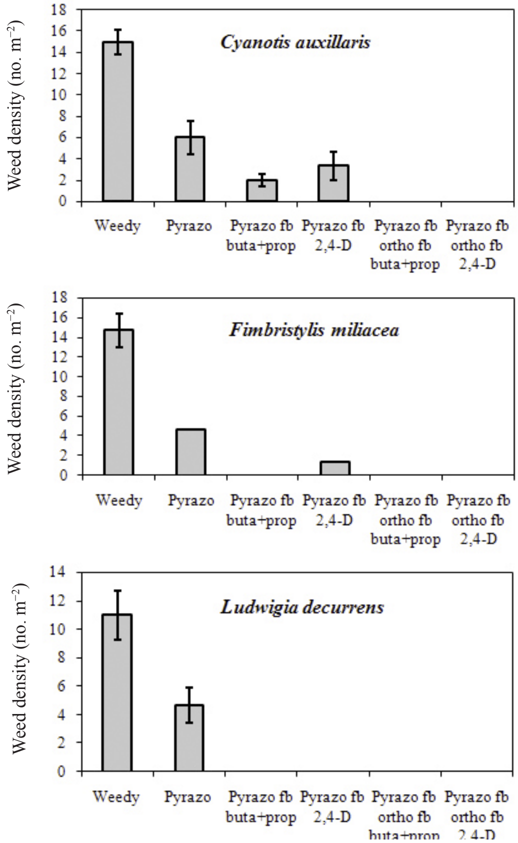


Figure 1. Effect of herbicide treatments on densities of different weed species at 35 days after transplanting of rainy season rice in strip-tilled non-puddled field, Mymensingh, Bangladesh during 2014.

treatment that had a rice yield more than double that of the weed-free check.

Results of the residual effect study showed that emergence, shoot length and biomass of the succeeding wheat were not significantly affected by the herbicides applied in the preceding rice crop (Table 2).

Table 2. Residual effect of herbicide treatments on emergence (EMER, %) and shoot length (SL, cm) and biomass (WDM, g m^{-2}) of wheat at 25 days after sowing during 2014.

Treatments	EMER	SL	WDM
T_1	87.7	26.0	12.20
T_2	89.0	28.7	10.97
T_3	84.0	24.3	9.33
T_4	90.7	27.4	10.33
T_5	84.3	25.4	11.83
C_1	86.0	24.8	8.84
C_2	87.7	26.6	10.80
Level of significance	ns	ns	ns
CV (%)	4.47	9.79	15.7

ns = non-significant.

DISCUSSION

The strip-tilled non-puddled rice field was infested by seven weed species, and, except for *Cynodon dactylon*, all species were successfully controlled by herbicide treatments. This might be related to the regenerative ability of *C. dactylon* from its stolons. However, the pyrazosulfuron-ethyl followed by butachlor plus propanil was effective on *C. dactylon* both with and without addition of orthosulfamuron into the sequence.

The weed control of PEM followed by LPOST 2,4-D amine was similar to the sole application of PEM pyrazosulfuron-ethyl and the performance of both these treatments was poorer than any other sequential herbicide treatments. Only PEM is not sufficient to provide control of all types of weeds for the whole crop growing period. Application of PEM and POST will control all types of weeds effectively for a long period and therefore proper crop growth can be ensured. But, an application of 2,4-D amine as LPOST with PEM did not offer any additional benefit in weed control because 2,4-D amine had no effect on grass weeds and the experimental field was mostly dominated by *C. dactylon* (Figure 1).

Treatments with PEM pyrazosulfuron-ethyl followed by EPOST orthosulfamuron followed by LPOST butachlor plus propanil or LPOST 2,4-D amine provided similar rice grain yield as the weed-free check. Moreover, the emergence of the succeeding wheat crop was not significantly affected by any of the herbicide sequences applied in the rice. Shoot length and biomass of wheat were also not adversely affected by the residue of rice herbicides. Vaghasia and Nadiyadhara (2013) reported similar findings with other herbicides: that emergence of wheat was not affected by imazethapyr, imazamox, quizalofop-p-ethyl and fenoxaprop-p-ethyl applied in the preceding groundnut crop.

The persistence of herbicide in the soil is highly dependent on several soil and climatic factors and also on herbicidal properties. However, the half-lives of the tested herbicides are not more than three months and the half-life of pyrazosulfuron-ethyl ranges between 16–21 days if applied at 25–50 g ai ha^{-1} (Naveen *et al.* 2012). Curran (2001) indentified some factors that largely influence herbicide persistence in soil such as rainfall, organic matter content and pH of soil. As such, the residual effect of herbicides could vary from soil to soil and location to location.

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