Bangladesh Agron. J. 2016, 19(2): 95-103

RESIDUAL EFFECT OF HERBICIDES APPLIED IN UNPUDDLED TRANSPLANTED *AMAN* RICE ON THE SUCCEEDING CROPS ASSESSED BY BIOASSAY TECHNIQUE

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Key words: Herbicide, herbicide residue, rice, unpuddled transplanting

Abstract

The residual effect of eight herbicides (pendimethalin, pyrazosulfuron-ethyl, butachlor, pretilachlor, orthosulfamuron, acetochlor + bensulfuron methyl, butachlor + propanil and 2,4-D amine) was applied in unpuddled transplanted *aman* rice in aa weedy and a hand weeded controls, was evaluated for succeeding crops *viz*. wheat, lentil and sunflower by following bioassay technique. A study was conducted at Bangladesh Agricultural University, Mymensingh from November 2013 to January 2014 after harvest of unpuddled transplanted *aman* rice. All herbicides were imposed as weed management practice of unpuddled transplanted *aman* rice during July to August 2013. The experiment was laid out in a randomized complete block design (RCBD) with three replications. As a consequence, the residual effect of those herbicides on the succeeding wheat, lentil and sunflower crops was evaluated in term of germination, leaf chlorophyll content, seedling shoot length and dry matter. The results showed that seedling germination of all these succeeding crops in the herbicide treated plots did not differ significantly from those of weedy and hand weeded control plots. Moreover, leaf chlorophyll content, seedling shoot length and dry matter of wheat, lentil and sunflower were not adversely affected by any of the herbicide treatments imposed in *aman* rice. It was concluded that herbicides used in unpuddled transplanted *aman* rice had no residual effect on the germination and leaf chlorophyll content, seedling shoot length and dry matter of the succeeding wheat, lentil and sunflower crops.

Introduction

Increasing labor crisis and high wage of labor encourages farmers to use herbicides for weed control in rice. Several researches demonstrated that some herbicides can be accumulated in soil (Machado-Neto and Victoria-Filho, 1995; Heeney *et al.*, 1981) and some herbicides may not be accumulated but their residues might be present in the soil (Tworkoski *et al.*, 2000). If residue of herbicide may persist in the soil, the vigor of the non-target species and the succeeding crops can be reduced (Houge and Neilsen, 1988). Wyk and Reinhardt (2001) found excessive amount of imazethapyr residue caused injury to corn grown after soybean. Moreover, Janki *et al.* (2015) and Hernandez-Sevillano (2001) reported that few sulfonylurea herbicide residues in soil can affect rotational crops even at low concentrations. But, farmers usually use herbicides without knowing or testing the residual effect of herbicides on the succeeding crops. Moreover no research has been done in Bangladesh on the residual effect of herbicides on the succeeding crops. Generally, a soil chemical test or bioassay can be used to determine the presence of herbicides in the soil (Hager and Nordby, 2007). However, chemical analysis is costly, and therefore a bioassay can be conducted to predict the presence of herbicides in soil which will be more feasible. Although a bioassay does not measure the amount of herbicide residue present in the soil, but it

may indicate whether or not enough residue is present in soil to injure a sensitive succeeding crop. The bioassay can be carried out in pot trial by collecting the soil from the herbicide applied field or by in-situ trial in the micro-plots which is more convenient and more representative to express the residual effect of herbicides in the field situation. Therefore, a bioassay study had conducted in the field after harvesting of unpuddled transplanted *aman* rice to evaluate the residual effect of rice herbicides on the succeeding crops.

Materials and Methods

The study was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from November 2013 to March 2014. The experimental site is located at 24°75′ N latitude and 90°50′ E longitude in the south-west part of Old Brahmaputra under the agro-ecological zone Old Brahmaputra Floodplain (AEZ-9) belonging to non-calcareous dark grey floodplain soil. The experimental field was a well drained medium high land with sandy clay loam soil texture (sand-50.0%, silt-23.4% and clay-26.6%) having a pH of 6.8. The climate of the experimental area was under the subtropical region and characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds during the *kharif season* (April to September) and scanty rainfall associated with moderately low temperature during *rabi season* (October to April). Weather information regarding monthly average maximum and minimum air temperature and monthly total rainfall prevailed at the experimental site during the study period is presented in Fig. 1.

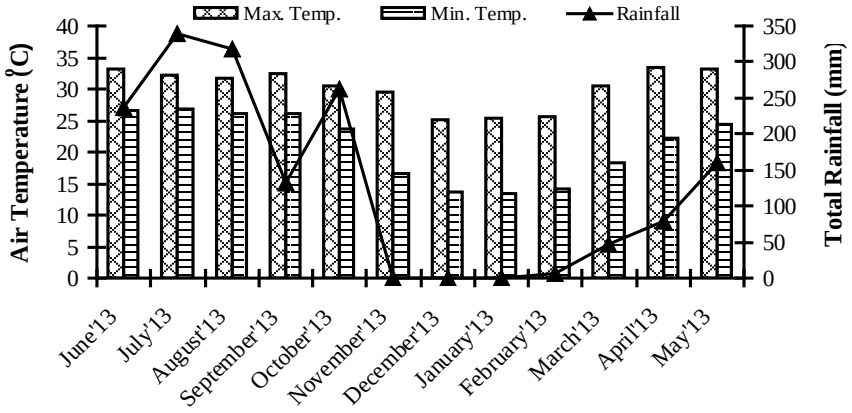

Fig.1. Monthly average maximum and minimum air temperature and total rainfall of the experimental site during June 2013 to May 2014 (Source: Weather Yard, Department of Irrigation and Water management, BAU, Mymensingh)

The study was conducted by following bioassay method to evaluate the residual effect of herbicides applied in unpuddled transplanted *aman* rice on the succeeding crops, such as wheat, lentil and sunflower. Each of these crops was sown in the same plots after harvesting of unpuddled transplanted *aman* rice. In unpuddled transplanted *aman* rice, 4 pre-emergence herbicides, 1 early post- and 3 post-emergence herbicides were applied in combinations of 18 herbicide treatments along with a weedy and a weed free control *viz*, T_1=Weedy control, T_2= Weed free (4 hand weeding), T_3=Pendimethalin followed by (fb) hand weeding (HW) at 25 days after transplanting (DAT), T_4=Pyrazosulfuron-ethyl fb HW at 25 DAT, T_5=Butachlor fb HW at 25 DAT, T_6=Pretilachlor fb HW at 25 DAT, T_7=Pendimethalin fb

(acetochlor + bensulfuron methyl), T_8=Pyrazosulfuron- ethyl fb (acetochlor + bensulfuron methyl), T_9=Butachlor fb (acetochlor + bensulfuron methyl), T_{10}=Pretilachlor fb (acetochlor + bensulfuron methyl), T_{11} =Pendimethalin fb orthosulfamuron fb (butachlor + propanil), T_{12}=Pyrazosulfuron-ethyl fb orthosulfamuron fb (butachlor + propanil), T_{13}=Butachlor fb orthosulfamuron fb (butachlor + propanil), T_{14}=Pretilachlor fb orthosulfamuron fb (butachlor+propanil), T_{15}= Pendimethalin fb orthosulfamuron fb 2,4-D amine, T_{16}=Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine, T_{17}=Butachlor fb orthosulfamuron fb 2,4-D amine and T_{18}= Pretilachlor fb orthosulfamuron fb 2,4-D amine. The experiment was set up in a randomized complete block design (RCBD) with three replications. Unit plot size was 3 m x 4 m. All herbicides were applied in unpuddled transplanted *aman* rice at their recommended rate (Table 1) from 25 July to 16 August 2013 (Pendimethalin, pyrazosulfuron-ethyl, pretilachlor and butachlor were applied at 3 days after rice transplanting (DAT), orthosulfamuron at 15 DAT, acetochlor + bensulfuron methyl, butachlor+propanil and 2,4-D amine at 25 DAT).

Table 1. Application rate of herbicides and name of their chemical group which were applied in unpuddled transplanted *aman* rice during 2013

Name of Herbicide	Chemical group of herbicide	Rate of application
Pendimethalin	Dinitroaniline	2.50 L ha^{-1}
Pyrazosulfuron-ethyl	Sulfonylurea	150 g ha^{-1}
Butachlor	Chloroacetamide	25 kg ha^{-1}
Pretilachlor	Chloroacetamide	1.0 L ha^{-1}
Orthosulfamuron	Sulfonylurea	150 g ha^{-1}
(Acetochlor+bensulfuron methyl)	Chloroacetamide+Sulfonylurea	0.74 kg ha^{-1}
(Butachlor+propanil)	Chloroacetamide+Amide	1.0 L ha^{-1}
2,4-D amine	Phenoxy-carboxylic-acid	2.25 L ha^{-1}

Aman rice was harvested on 04 November 2013 and after harvesting, pre-planting knockdown herbicide glyphosate @ 2.25 L ha^{-1} was applied on 16 November 2013 to kill the existing weeds of the field. Then wheat, lentil and sunflower were grown in 1m x 1m micro-plots within each of the main plots on 26 November 2013. Before seeding, micro-plots were prepared through required number of spading and other earth work and then the land was fertilized by phosphorus, potassium and sulphur @ 32, 25, 17 kg ha^{-1}, respectively in the form of triple super phosphate, muriate of potash and gypsum, respectively. Nitrogen fertilizer was applied @ 46 kg ha^{-1} into two installments at 0 and 15 days after sowing of wheat, lentil and sunflower in the form of urea. 100 seeds of wheat (var. BARI Gom-26), lentil (var. BARIMasur-6) and sunflower (var. BARI Surjomukhi-2) were sown in each of the micro-plots by dibbling. The crop was monitored frequently from date of sowing and data were collected from each of the micro-plots up to 25 days after sowing (DAS). Germination of the three crops was counted from 5 DAS to 25 DAS. Seedling shoot length was measured from the base (ground level) of the randomly selected five plants to the tip of the longest leaf. These plants were uprooted and cleaned with distilled water; oven dried at 70° C for 48 hrs and then shoot dry matter was recorded. In case of Leaf chlorophyll content, data were taken from two spots of the young, tender leaf of randomly selected five plants from each micro-plot by SPAD meter and the

average value was taken. The collected data were analyzed statistically and means were compared by DMRT using MSTAT-C.

Results and Discussion

Germination percentage

Table 2 showed that herbicides used in unpuddled transplanted *aman* rice had no significant effect on germination of wheat, lentil and sunflower. Previous studies also reported that germination of succeeding crops did not significantly affected by herbicides applied in onion (Rathod *et al.*, 2014) and in groundnut (Vaghasia and Nadiyadhara, 2013). In another study, Khokhar and Charak (2011) also reported that herbicides applied in wheat had no significant effect on germination of the three tested succeeding crops *viz.*, maize, green gram and cucumber. The reason might be the complete degradation of those used herbicides in the soil or might be the presence of those herbicides below the detectable level that might not adversely affect the germination of the succeeding crops. Several studies agreed that residues of most of the herbicides that were used in the present study persisted below of the detectable limit in the soil within 30-120 days after application (Sireesha *et al.*, 2012; Naveen *et al.*, 2012; Dharumarajan *et al.*, 2011).

Table 2. Residual effect of herbicides used in unpuddled transplanted *aman* rice on germination of wheat, lentil and sunflower during 2013

Treatments	Germination (%)		
	Wheat	Lentil	Sunflower
T_1= Weedy	87	71	86
T_2= Weed free by hand weeding (HW)	90	73	92
T_3= Pendimethalin fb HW	92	74	90
T_4= Pyrazosulfuron-ethyl fb HW	90	76	88
T_5= Butachlor fb HW	93	70	92
T_6= Pretilachlor fb HW	91	70	87
T_7= Pendimethalin fb (acetochlor + bensulfuron methyl)	88	75	87
T_8= Pyrazosulfuron-ethyl fb (acetochlor + bensulfuron methyl)	89	77	88
T_9= Butachlor fb (acetochlor + bensulfuron methyl)	92	74	90
T_{10}= Pretilachlor fb (acetochlor + bensulfuron methyl)	89	73	86
T_{11}= Pendimethalin fb orthosulfamuron fb (butachlor + propanil)	87	71	84
T_{12}= Pyrazosulfuron-ethyl fb orthosulfamuron fb (butachlor + propanil)	91	75	83
T_{13}= Butachlor fb orthosulfamuron fb (butachlor + propanil)	89	72	86
T_{14}= Pretilachlor fb orthosulfamuron fb (butachlor + propanil)	86	73	90
T_{15}= Pendimethalin fb orthosulfamuron fb 2,4-D amine	86	72	85
T_{16}= Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine	91	74	89
T_{17}= Butachlor fb orthosulfamuron fb 2,4-D amine	93	71	94
T_{18}= Pretilachlor fb orthosulfamuron fb 2,4-D amine	92	71	89
Level of significance	NS	NS	NS

CV (%)	3.79	6.76	4.82

NS = not significant, fb = followed by, HW = Hand Weeding, CV = Co-efficient of Variance

Leaf chlorophyll content (SPAD value)

In case of SPAD values of leaves of wheat, lentil and sunflower at 25 days after sowing (DAS), no significant difference was found among herbicides applied in unpuddled transplanted *aman* rice (Table 3). Though no literature was found on effect of herbicide residue on leaf chlorophyll content of the succeeding crops, but so many reports are available that claimed that herbicide residue had no adverse effect on growth and yield of the succeeding crops (Parthipan *et al.*, 2013; Sangeetha *et al.*, 2012). Despite the fact that the concentration of herbicide residue decrease exponentially with time and less than 1% of the initial concentration of herbicide applied in summer persist in the following winter (Tworkoski *et al.*, 2000), so there will be no chance to get affected the succeeding winter crops by herbicide residues of summer rice.

Table 3. Residual effect of herbicides used in unpuddled transplanted *aman* rice on leaf chlorophyll content (SPAD value) of wheat, lentil and sunflower at 25 days after sowing during 2013

Treatments	SPAD value		
	Wheat	Lentil	Sunflower
T_1= Weedy	42.50	21.07	31.27
T_2= Weed free by hand weeding (HW)	44.13	19.13	33.23
T_3= Pendimethalin fb HW	45.10	21.57	33.43
T_4= Pyrazosulfuron-ethyl fb HW	46.80	19.37	34.90
T_5= Butachlor fb HW	43.90	18.10	35.43
T_6= Pretilachlor fb HW	43.83	20.67	35.90
T_7= Pendimethalin fb (acetochlor + bensulfuron methyl)	46.07	23.93	33.47
T_8= Pyrazosulfuron-ethyl fb (acetochlor + bensulfuron methyl)	45.40	19.27	33.17
T_9= Butachlor fb (acetochlor + bensulfuron methyl)	45.80	22.37	32.97
T_{10}= Pretilachlor fb (acetochlor + bensulfuron methyl)	44.33	18.23	32.10
T_{11}= Pendimethalin fb orthosulfamuron fb (butachlor + propanil)	44.97	20.43	33.03
T_{12}= Pyrazosulfuron-ethyl fb orthosulfamuron fb (butachlor + propanil)	45.20	19.73	31.80
T_{13}= Butachlor fb orthosulfamuron fb (butachlor+propanil)	43.93	22.53	32.00
T_{14}= Pretilachlor fb orthosulfamuron fb (butachlor+propanil)	47.67	22.37	31.83
T_{15}= Pendimethalin fb orthosulfamuron fb 2,4-D amine	46.10	22.87	34.20
T_{16}= Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine	44.47	23.43	33.80
T_{17}= Butachlor fb orthosulfamuron fb 2,4-D amine	44.00	24.50	35.67
T_{18}= Pretilachlor fb orthosulfamuron fb 2,4-D amine	45.43	22.80	32.57
Level of significance	NS	NS	NS
CV (%)	4.53	11.13	5.74

NS = not significant, fb = followed by, HW = hand weeding, CV = Co-efficient of variance

Shoot length (cm)

Table 4 demonstrated that herbicides applied in unpuddled transplanted *aman* rice had no significant effect on shoot length of wheat, lentil and sunflower at 25 DAS. This result is in agreement with Sangeetha *et al.* (2012), Bahrampor and Ziveh (2013) and Yadav *et al.* (2015) that no significant difference was found in shoot length of the succeeding crops with herbicides applied in the previous crop. But in some studies, plant height or dry or fresh weight was found to be sensitive to sulfonylurea herbicide (Stork and Hannah, 1996; Vicari *et al.*, 1994; Junnila *et al.*, 1994).

Table 4. Residual effect of herbicides used in unpuddled transplanted *aman* rice on shoot length of wheat, lentil and sunflower at 25 days after sowing during 2013

Treatments	Shoot length (cm)		
	Wheat	Lentil	Sunflower
T_1= Weedy	88.1	6.41	16.0
T_2= Weed free by hand weeding (HW)	84.4	5.54	17.7
T_3= Pendimethalin fb HW	90.5	6.17	17.2
T_4= Pyrazosulfuron-ethyl fb HW	89.7	6.41	17.1
T_5= Butachlor fb HW	85.9	6.30	16.3
T_6= Pretilachlor fb HW	85.5	5.95	17.7
T_7= Pendimethalin fb (acetochlor+bensulfuron methyl)	90.1	6.52	16.3
T_8= Pyrazosulfuron-ethyl fb (acetochlor+bensulfuron methyl)	85.5	6.01	15.3
T_9= Butachlor fb (acetochlor+bensulfuron methyl)	87.9	6.34	16.7
T_{10}= Pretilachlor fb (acetochlor+bensulfuron methyl)	90.0	5.53	16.4
T_{11}= Pendimethalin fb orthosulfamuron fb (butachlor+propanil)	87.9	4.75	15.8
T_{12}= Pyrazosulfuron-ethyl fb orthosulfamuron fb (butachlor+propanil)	90.5	6.30	18.8
T_{13}= Butachlor fb orthosulfamuron fb (butachlor+propanil)	91.0	6.22	18.8
T_{14}= Pretilachlor fb orthosulfamuron fb (butachlor+propanil)	86.1	5.87	16.7
T_{15}= Pendimethalin fb orthosulfamuron fb 2,4-D amine	85.9	5.67	15.9
T_{16}= Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine	91.4	5.95	16.1
T_{17}= Butachlor fb orthosulfamuron fb 2,4-D amine	88.9	5.23	17.0
T_{18}= Pretilachlor fb orthosulfamuron fb 2,4-D amine	86.6	6.24	18.6
Level of significance	NS	NS	NS
CV (%)	2.74	11.80	8.27

NS = not significant, fb = followed by, HW = hand weeding, CV = Co-efficient of variance

Dry matter production

The results demonstrated that dry matter productions (g m^{-2}) of wheat and lentil were not significantly varied with herbicides applied in unpuddled transplanted *aman* rice. While dry matter of sunflower significantly differed with herbicides, but reduction in dry matter production of sunflower was not observed (Table 5). Therefore, results expressed that herbicides applied in rice had no adverse effect on the succeeding

wheat, lentil and sunflower crops. Similar result also reported by Rathod *et al.* (2014) and Bahrampor and Ziveh (2013) that dry matter production of the succeeding crops was not adversely affected by herbicide residue. Yadav and Bhullar (2014) also found that herbicides applied in soybean had no significant effect on dry matter accumulation of the succeeding crops (wheat, barley, spinach, pea, raya, canola and sugarbeet) because of the complete degradation of herbicides used in the previous crops.

Table 5. Residual effect of herbicides used in unpuddled transplanted *aman* rice on dry matter of wheat, lentil and sunflower at 25 days after sowing during 2013

Treatments	Crop dry matter (g m^{-2})		
	Wheat	Lentil	Sunflower
T_1= Weedy	9.40	2.76	21.58 ab
T_2= Weed free	11.47	2.78	20.94 b
T_3= Pendimethalin fb HW	9.71	2.58	24.22 ab
T_4= Pyrazosulfuron-ethyl fb HW	12.15	3.28	26.61 a
T_5= Butachlor fb HW	11.33	2.78	21.32 ab
T_6= Pretilachlor fb HW	10.08	2.95	21.15 b
T_7= Pendimethalin fb (acetochlor+bensulfuron methyl)	9.85	2.97	24.83 ab
T_8= Pyrazosulfuron-ethyl fb (acetochlor + bensulfuron methyl)	11.36	2.77	24.38 ab
T_9= Butachlor fb (acetochlor+bensulfuron methyl)	10.67	3.19	24.36 ab
T_{10}= Pretilachlor fb (acetochlor+bensulfuron methyl)	10.12	2.87	21.06 b
T_{11}= Pendimethalin fb orthosulfamuron fb (butachlor+propanil)	10.39	2.37	23.47 ab
T_{12}= Pyrazosulfuron-ethyl fb orthosulfamuron fb (butachlor+propanil)	11.12	3.32	26.29 ab
T_{13}= Butachlor fb orthosulfamuron fb (butachlor+propanil)	11.00	2.94	22.97 ab
T_{14}= Pretilachlor fb orthosulfamuron fb (butachlor+propanil)	10.30	2.35	22.91 ab
T_{15}= Pendimethalin fb orthosulfamuron fb 2,4-D amine	11.51	3.08	24.41 ab
T_{16}= Pyrazosulfuron-ethyl fb orthosulfamuron fb 2,4-D amine	11.93	2.65	26.67 a
T_{17}= Butachlor fb orthosulfamuron fb 2,4-D amine	11.75	2.77	26.10 ab
T_{18}= Pretilachlor fb orthosulfamuron fb 2,4-D amine	9.72	3.87	24.01 ab
Level of significance	NS	NS	*
CV (%)	11.28	14.40	7.43

In a column, figures with similar letters are not significantly different (as per DMRT)
NS = not significant, * = significant at 5% level of significance, fb = followed by, HW = hand weeding, CV = Co-efficient of variance

Conclusion

The results revealed that herbicides applied in unpuddled transplanted *aman* rice had no adverse effect on germination, leaf chlorophyll content, shoot length and dry matter of wheat, lentil and sunflower. Therefore, the study concluded that herbicides

applied in unpuddled transplanted *aman* rice had no residual effect on the succeeding crops. However, it is strictly advised to apply herbicide at the recommended rate by following proper rules and regulations.

Acknowledgements

This study was the part of the PhD research of the senior author and the author would like to acknowledge ACIAR (Project LWR/2010/080) for funding the research project and providing a scholarship by Dr. Richard W. Bell, Murdoch University.

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