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Control of broad-leaved weeds in wheat under eastern sub-Himalayan plains

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ABSTRACT

A study was undertaken during winter seasons of 2016-17 and 2017-18 at Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal to assess the comparative efficacy of various herbicides and to identify the effective herbicides for controlling broad-leaved weed flora in wheat. The experiment was laid out in a Randomized Block Design (RBD) with eleven herbicides combination *viz*. halauxifen-methyl ester+ florasulam 40.85% WG + polyglycol; metsulfuron methyl 20 WG + surfactant; carfentrazone 40 DF; 2,4-D Na 80 WP; 2,4-D E 38 EC; metsulfuron + carfentrazone +surfactant; 2,4-D-Na + carfentrazone; 2,4-D E + carfentrazone , halauxifen-methyl + florasulam+ carfentrazone + surfactant including a weedy check and weed free treatment. It was revealed that *Polygonum* alone constituted almost 72% of the total broad leaved weed population in both the years. Among the herbicidal treatments, metsulfuron + carfentrazone + surfactant recorded significantly lesser weed population (10.0 and 2.3/m^2 during 30 and 60 days after spraying of post-emergence herbicides, respectively) *vis-à-vis* weed dry weight (11.2 and 4.5 g/m^2 during 30 and 60 days after spraying of post-emergence herbicides, respectively) . This combination also recorded the highest broad leaf weed control efficiency (90.1 and 99.0% at 30 and 60 days after spraying, respectively) with the lowest weed index 6.0.The new molecule halauxifen-methyl ester + florasulam in combination with carfentrazone recorded 88.1 and 94.0% weed control efficiency. It was noted that *Polygonum* was killed by halauxifen-methyl ester + florasulam 40.85% WG + polyglycol, but it could not control *Physalis minima*, the second most important weed after *Polygonum*. Weed free treatment recorded significantly higher grain yield (5.39 t/ha) followed by metsulfuron + carfentrazone + surfactant treated plots (5.04 t/ha), the best performed treatments among various post-emergence herbicides combination used in the experiment. According to the linear regression, wheat crop was likely to produce very poor grain yield (less than 1.50 t/ha) when weed biomass exceeds 400 g/m^2.

INTRODUCTION

Weed infestation is one of the major biotic factors limiting wheat production and productivity. The losses caused by weeds depend on their types, abundance and environmental factor (Chhokar *et al*. 2012), and weeds account for 0-80% yield reduction depending upon the weed species and infestation and caused depletion of soil water up to 6.5 cm (Mehra and Gill 1988, Khera *et al*. 1995). Again, weeds tend to shift with the change in tillage, agronomic management, and cropping system although there are other factors that govern the changes in the weed flora. Despite being a serious problem in crop field, this problem always remains under-estimated although they cause higher reduction in economic yield of crops than other pests and diseases. Chemical herbicides are most important tools in weed management to maintain yield and quality of crop. Various researchers have investigated the efficacy of different herbicides for control of weeds in wheat crop mostly targeting towards *Phalaris minor*. But in those areas where *Phalaris* is not a big problem, alternate herbicides have to be tested. In this part of eastern sub-Himalayan plains, it has been reported that various species of *Polygonum, viz. Polygonum persicaria*, *Polygonum pensylvanicum*, *Polygonum hydropiper* and *Polygonum orientale* are notorious weeds in wheat, which accounts for a major share of total weed flora.

Severe problem of *Solanum nigrum* and *Physalis minima* were also reported from various parts of Eastern India (Chhokar *et al.* 2012). Broad leaved weeds posed a severe problem in these areas instead of grasses. Under this situation, farmers mostly depend on 2,4-D, which is not always very effective against these weeds. For control of broad-leaf weeds in wheat, three major herbicides used in India are metsulfuron, 2,4-D and carfentrazone (Chhokar *et al.* 2007b). Some of the post-emergence contact herbicides like carfentrazone-ethyl are less effective on weeds having advanced stage, as well as, unable to control the subsequent weeds emerging after application due to its lack of residual activity (half-life of carfentrazone is 2-5 days) in soil (Lyon *et al.* 2007, Willis *et al.* 2007). To broaden the spectrum of weed kill and to provide the long term residual weed control, the use of herbicide mixture/ combinations are advocated. Herbicide mixture besides providing control of complex weed flora will also help in managing and delaying the herbicide resistance problem. Keeping these aspects in background, the study was undertaken with the objectives to study the broad-leaved weed flora in wheat and to study the comparative efficacy of various herbicides for controlling broad-leaved weed flora in wheat.

MATERIALS AND METHODS

The experiment was carried out in the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal located at 26°24'02.2"N latitude, 89°23'21.7"E longitude and at an elevation of 43 meters above mean sea level. It was carried out for two consecutive years, *i.e.*, *Rabi* seasons of 2016-17 and 2017-18. The soil, on which the experiment was carried out, was sandy loam in texture having good drainage facility with 0.89% organic C, 153 kg/ha of mineralizable N, 19.2 kg/ha of available phosphorus, 141 kg/ha of available potassium and a pH of 5.54.

The experiment was laid out in a randomized block design (RBD) with 3 replicates. Eleven various herbicides combination including a weedy check and weed free treatment were randomly allotted to various plots under each replication. The sizes of each experimental plot was 5 x 3 m. The treatments comprised of the following : halauxifen-methyl ester + florasulam 40.85% WG at 12.76 g/ha + polyglycol (surfactant) at 750 ml/ha; metsulfuron-methyl 20 WG at 4 g/ha + surfactant; carfentrazone 40DF at 20 g/ha; 2,4-D Na 80 WP at 500 g/ha; 2,4-D E 38 EC at 500 ml/ha; metsulfuron (4 g/ha) + carfentrazone (20 g/ha) + surfactant; 2,4-D Na (500 g/ha) + carfentrazone (20 g/ha); 2,4-D E (500 ml/ha) + carfentrazone (20 g/ha); halauxifen-methyl + florasulam (12.76 g/ha) + carfentrazone (20 g/ha) + surfactant; weedy check and weed free.

The variety used in the experiment was '*K 0307*', an irrigated timely sown variety for '*NEPZ*'. Seeds were sown in lines 22.5 cm apart with a seed rate of 100 kg/ha. The fertilizer dose was kept at 150 kg nitrogen, 60 kg phosphorus and 40 kg potassium/ha. Nitrogen fertilizers were applied in three splits (75 kg/ha as basal, 37.5 kg/ha each at 3 weeks and 6 weeks after sowing). A blanket dose of clodinafop 60 g/ha was applied 5 days before the broad-leaf herbicide application to control grassy weeds and all the post-emergence herbicides were applied at 30-32 days after sowing. Herbicides were applied with the use of a knapsack sprayer fitted with a flat-fan nozzle and water as a carrier at 375 litre/ha for post-emergence spray. A three nozzles boom with flat fan nozzle tip was used for spraying. For tank mix herbicides, herbicides were properly mixed in stock solution prior to adding in spray tank avoiding mixing the herbicides directly in spray tank. Quadrates (50 x 50 cm) were established in each plot after pre-emergence applications, 1-2 days after seeding. Initial broad-leaf weed count was taken from four permanent quadrates before application of post-emergence herbicides. For broad-leaf count and weed biomass at 30 days after post-emergence herbicide application, count was taken from all four permanent quadrates and weed biomass from only two random quadrates. The broad leaf count and biomass 60 days after post-emergence herbicide application were taken from the two remaining permanent quadrates. Weeds were cut at ground level, washed with tap water, sun-dried, oven-dried at 70 degree centigrade for 48 hours, and then weighed. Yield attributes were taken accordingly at harvest, while the grain yield was measured from the entire plot area of 15 m^2 and expressed in kg/ha at 14% moisture.

Weed control efficiency (WCE) and weed index (WI) was also calculated on the basis of weed biomass and grain yield, respectively. Herbicides Efficiency Index (HEI), indicating the weed killing potential of different herbicide treatments and their phyto-toxicity related to the crop,was calculated by the following formula as given by Krishnamurthy *et al.* (1995): HEI= [(Yield in treated plot – Yield in control plot)/ Yield in control plot]x 100. Data on weed density and dry weight were subjected to $(\sqrt{x+1})$ square root transformation to normalize the distribution. Mean separations for different treatments under different parameters were performed using Least Significance Difference

(LSD) test $\sqrt{x+0.5}$. Entire statistical analysis was carried out using statistical analysis system (SAS) software (version 9.2).

RESULTS AND DISCUSSION

Weed flora

The broad-leaf weed flora in wheat as emerged in the experiment was identified and their sequence of emergence with special characteristics was noted by regular survey on weeds throughout the growing period. At 60 days after sowing, the major broad-leaved weeds found in the field were *Polygonum persicaria*, *Polygonum pensylvanicum, Polygonum hydropiper, Polygonum orientale, Chenopodium album, Physalis minima, Oxalis corniculata, Portulaca oleracea* , *Gnaphalium luteo-album, Centella asiatica* and *Cronopus didymus* . Various species of *Polygonum* was dominant in all the stages of crop growth. During 60 days, *Polygonum* alone constituted almost 72% of the total broad-leaved weed population in both the years (**Table 1**). It was further noted that *Polygonum hydropiper* was dominant up to the tillering stages of the crop; later on *Polygonum orientale* emerged and become dominant at later stages. Rahaman and Mukherjee (2008) also reported that the major weed flora observed in *terai* region of West Bengal were various species of *Polygonum.* Among the weed species other than the *Polygonum*, *Physalis minima* shared 7.27 and 8% of the total broad leaved weeds in 2016-17 and 2017-18, respectively.

Weed density and dry weight

Weed density at various stages of growth varied significantly under various herbicides application **Table 2**. Except weedy check, all the herbicides combination used in the experiment reduced the broad-leaved weed population significantly after 30 and 60 days of spraying post-emergence herbicides, but the degree of reduction is different in different combination of herbicides. Among the herbicidal treatments, metsulfuron + carfentrazone + surfactant recorded significantly lesser weed population (10.0 and 2.3/m^2 during 30 and 60 days after spraying of post-emergence herbicides, respectively); however, when these two herbicides were applied separately the degree of reduction in broad-leaved weeds was much lesser than their combination reflecting the superiority of this combination in suppressing the broad-leaved weed flora in wheat. The weedy check treatments recorded as high as 124.7 and 178.7/m^2 of broad-leaved weeds during 30 and 60 days after spraying of post-emergence herbicides, respectively. Singh *et al.* (2011) observed that pre-mix carfentrazone + metsulfuron 25 g/ha with 0.2% NIS reduced the population of weeds in wheat by 97 and 99% during 2009-10 and 2010-11, respectively. On an average, it provided 95% control of infested weeds. There was significant variation in dry weight of the weeds obtained under various herbicides treatment during both the years of experimentation. The lowest weed dry weight (11.2 and 4.5 g/m^2 during 30 and 60 days after spraying of post-emergence herbicides, respectively) was also achieved with metsulfuron + carfentrazone + surfactant treatment.

Table 1. Distribution of various broad-leaved weed species in weedy check plot in wheat

Weed species	2016-17		2017-18	
	Total no./m^2	Total weeds (%)	Total no./m^2	Total weeds (%)
Polygonum persicaria	13	7.9	21	16.8
Polygonum pensylvanicum	30	18.2	18	14.4
Polygonum hydropiper	64	38.8	45	36.0
Polygonum orientale	12	7.3	7	5.6
Chenopodium album	8	4.8	4	3.2
Physalis minima	12	7.3	10	8.0
Oxalis corniculata	0	0	7	5.6
Portulaca oleracea	7	4.2	0	0.0
Gnaphalium luteo-album	11	6.7	8	6.4
Centella asiatica	3	1.8	5	4.0
Cronopus didymus	5	3.0	0	0
Total	165		125	

WCE, WI and HEI

Among the herbicidal treatments, the highest broad-leaf weed control efficiency (90.1 and 99.0% at 30 and 60 days after spraying, respectively) was achieved with metsulfuron + carfentrazone + surfactant treatment (**Table 3**) though the weed free plot recorded 100% weed control efficiency. It was followed by halauxifen-methyl + florasulam + carfentrazone + surfactant (88.8 and 94.4% at 30 and 60 days after spraying, respectively). It was noted that when these herbicides were sprayed alone, the weed control ability was much lesser than their combination with carfentrazone. At 60 days after spraying, the combination metsulfuron + carfentrazone + surfactant was as good as weed free treatment. It was evident that post-emergence herbicides, *viz.* halauxifen-methyl ester + florasulam 40.85% WG + polyglycol, metsulfuron-methyl and carfentrazone had a better broad-leaf killing ability as reflected from the WCE value over 2,4-D Na and 2,4-D E, the traditional chemical broad-leaf killer. When these herbicides were combined with carfentrazone, the WCE was much higher than their respective sole

Table 2. Broad-leaf weed density and dry weight as influenced by various post-emergence herbicides in different stages (pooled over 2 years)

Treatment	Weed density (no./m^2)			Weed dry weight (g/m^2)	
	Before spraying	30 DAS	60 DAS	30 DAS	60 DAS
Halauxifen-methyl ester + florasulam 40.85% WG + polyglycol	9.0 (80.7)	5.9 (34.3)	4.6 (20.7)	4.5 (19.1)	7.5 (55.3)
Metsulfuron-methyl 20 WG + surfactant	8.5 (70.7)	6.5 (42.0)	3.9 (14.3)	5.0 (23.9)	7.1 (50.1)
Carfentrazone 40DF	8.7 (74.0)	6.2 (38.0)	3.9 (14.4)	4.2 (16.9)	7.1 (45.2)
2,4-D Na 80 WP	11.6 (135.0)	6.7 (43.7)	8.6 (72.3)	6.2 (37.4)	13.7 (186.9)
2,4-D E 38 EC	9.4 (87.7)	5.7 (32.0)	6.1 (36.3)	5.6 (30.9)	10.7 (112.9)
Metsulfuron + carfentrazone + surfactant	7.3 (52.0)	3.3 (10.0)	1.8 (2.3)	3.5 (11.2)	2.3 (4.5)
2,4-D Na + carfentrazone	6.3 (39.3)	4.3 (17.3)	4.9 (22.7)	4.2 (16.3)	9.3 (85.3)
2,4-D E + carfentrazone	6.9 (46.3)	4.3 (18.0)	4.2 (16.7)	3.8 (13.3)	8.7 (75.4)
Halauxifen-methyl + florasulam + carfentrazone + surfactant	7.8 (59.7)	5.0 (24.0)	3.6 (12.3)	3.7 (12.5)	5.3 (27.4)
Weedy check	9.9 (96.7)	11.2 (124.7)	13.4 (178.7)	10.6 (111.8)	21.3 (451.5)
Weed free	1.0 (0)	1.0 (0.0)	1.0 (0)	1.0 (0)	1.0 (0)
LSD (p=0.05)	0.60	0.54	0.48	0.48	0.76

Figures in the parentheses are original values. Data subjected to ($\sqrt{x+1}$) square root transformation; DAS - Days after spraying

Table 3. Weed control efficiencies and weed index of various herbicidal treatments (pooled over 2 years)

Treatment	Weed control efficiency (%)		Weed index (%)	Herbicides efficiency index (%)
	30 DAS	60 DAS		
Halauxifen-methyl ester + florasulam 40.85% WG + polyglycol 26-2 N	82.9	87.7	17.5	248.40
Metsulfuron-methyl 20 WG + surfactant	78.6	88.9	13.1	260.50
Carfentrazone 40DF	84.9	88.9	26.9	211.20
2,4-D Na 80 WP	66.6	58.6	30.7	162.40
2,4-D E 38 EC	72.4	75.0	24.2	192.15
Metsulfuron + carfentrazone + surfactant	90.1	99.0	6.0	291.45
2,4-D Na + carfentrazone	85.4	81.1	12.8	254.25
2,4-D E + carfentrazone	88.1	83.3	10.3	258.40
Halauxifen-methyl + florasulam+ carfentrazone + surfactant	88.8	94.0	9.3	284.30
Weedy check	0.0	0.0	76.5	0.00
Weed free	100.0	100.0	0.0	318.60

application. It was reflected from the study that combination of herbicides in the form of tank mix formulation had a greater broad leaf controlling ability than sole application of the individual herbicides.

Among various weed control treatments, the lowest weed index was recorded in metsulfuron + carfentrazone + surfactant treatment (6%) closely followed by halauxifen-methyl + florasulam+ carfentrazone + surfactant treatment (9.3%). Lower values directly reflected the superiority of this combination in suppressing the weed flora with increased yield performances and selectivity. As far as the herbicides efficiency index was concerned, higher values were reflected with tank mixture of various post-emergence herbicides compared to their sole application. Metsulfuron + carfentrazone + surfactant recorded the maximum herbicides efficiency index (291.45%) closely followed by halauxifen-methyl + florasulam + carfentrazone + surfactant (284.30%).

Yield components and grain yield

Data in **Table 4** indicated the superiority of weed free treatments in terms of grain yield. Weed free treatment recorded significantly higher grain yield (5.39 t/ha), which was followed by metsulfuron + carfentrazone +surfactant treated plots (5.04 t/ha), the best performed treatments among various post-emergence herbicides combination used in the experiment. There was no significant difference in yield achieved with weed free treatments and treatments comprising of metsulfuron + carfentrazone + surfactant. Halauxifen-methyl + florasulam + carfentrazone + surfactant treatment also recorded a better yield performance (4.91 t/ha), being at par with metsulfuron + carfentrazone + surfactant. In weedy check the grain yield was very poor (1.29 t/ha) signifying the huge weed pressure on the crop. The yield and yield components, *viz.* spike no./m^2, no. of grains/spike and 1000-grain weight were significantly increased with different herbicide treatments compared with weedy check. Among the herbicidal treatments, metsulfuron + carfentrazone + surfactant recorded significantly lesser weed population *vis-a-vis* lesser weed biomass reflecting the superiority of this combination in suppressing the broad-leaved weed flora in wheat. All sorts of broad leaved weeds were controlled through this

Table 4. Yield components and yields of wheat under various herbicides combination (pooled over 2 years)

Treatment	No. of spike/ m^2	No. of grains/ spike	Test weight (g)	Grain yield (t/ha)
Halauxifen-methyl ester + florasulam 40.85% WG + polyglycol 26-2 N	295	41.50	38.85	4.48
Metsulfuron-methyl 20 WG + surfactant	304	41.10	40.10	4.64
Carfentrazone 40DF	262	41.60	39.45	4.01
2,4-D Na 80 WP	254	38.50	38.45	3.37
2,4-D E 38 EC	272	41.95	38.05	3.75
Metsulfuron + carfentrazone + surfactant	336	44.55	42.45	5.04
2,4-D Na + carfentrazone	299	39.70	38.25	4.55
2,4-D E + carfentrazone	303	41.20	42.50	4.60
Halauxifen-methyl + florasulam + carfentrazone + surfactant	321	38.10	42.20	4.91
Weedy check	88	32.55	34.85	1.29
Weed free	351	46.15	43.00	5.39
LSD (p=0.05)	38.1	3.9	3.4	0.4

combination and it was almost weed free after 30-35 days of spraying. Though *Polygonum* was killed by halauxifen-methyl ester + florasulam 40.85% WG + polyglycol, it could not control *Physalis minima*. Even *Physalis minima* was not controlled by application of 2,4-D or carfentrazone when sprayed alone which ultimately reflected the trends of overall yield performances. Complete control of *Physalis* was achieved through metsulfuron + carfentrazone mixture only. Carfentrazone was able to kill all sorts of broad leaved weeds very fast, but could not control the second flushes of weeds.

The responses of wheat yield to weed biomass at 60 days after spraying of post-emergence herbicides were represented separately in a linear diagram (**Figure 1**). The functional relation between the weed biomass and grain yield was expressed in the equation $y = m.x + c$. The value of coefficient of regression (R^2) was 0.95 which implied that 95 % of the yield was contributed by the single factor, weed management. This strong correlation was suggestive of the influence of weed control on the ultimate output, *i.e.*, the grain yield of the crop. The results clearly highlighted the poor competitive ability of wheat with weeds and the need to control them effectively during the whole growing season. According to the linear regression, wheat crop was likely to produce very poor grain yield (less than 1.5 t/ha) when weed biomass exceeds 400 g/m^2. On the basis of this field study, it can be concluded that

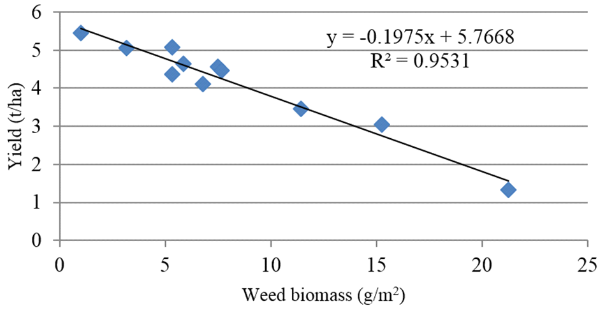

Figure 1. Relationship between weed biomass and grain yield

metsulfuron + carfentrazone + surfactant as post-emergence would be the most effective herbicides combination for controlling the broad-leaf weed flora in wheat under eastern sub-Himalayan plains.

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