Weed control in wheat (*Triticum aestivum* L.) under terai-agroecological region of West Bengal

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Abstract

Wheat is an ecologically suitable crop in *terai-agroecological* region of West Bengal. High residual soil moisture in this region creates an opportunity for zero tilled wheat as late planting due to delay in harvesting of prceeding rice crop and aggressive growth of weeds (several species of *Polygonum, Stellaria media* Cyrill, and *Oldenlandia diffusa* L.) cause low productivity of conventional wheat. Considerable reduction of growth of dominant weed flora *Polygonum persicaria* L., *P pensylvanicum* L. and *P orientale* L. was recorded in zero tilled wheat, however, growth of other broadleaved weeds *Stellaria media* Cyrill, *S aquatica* Cyrill, *Oldenlandia diffusa* L., *Vicia sativa* L. and *V hirsuta* L. and grasses *Cynodon dactylon* (L) Pers., *Setaria glauca* (L.) Beauv and *Digitaria sanguinalis* (Retz.) Koel was increased considerably in succeeding years leading to gradual reduction of grain yield. Continuous application of 2,4-D caused shift in weed flora from several species of *Polygonum* to *Physalis minina* L. and *Solanum nigram* L. and aggressive growth of these weeds in succeeding years resulted in poor weed control efficiency, lower grain yield, lower values of net return and return cost ratio. Among the weed control treatments post-emergence application of carfentrazone ethyl @ 25 g ha^{-1} controlled the weeds (*Physalis minima* L., *Solanum nigram* L., *Stellaria media* Cyrill, *S aquatica* Cyrill, *Oldenlandia diffusa* L., *Vicia sativa* L., *V hirsuta* L., several species of *Polygonum*, grasses and sedges) successfully resulting in highest grain yield and that, in turn, recorded highest net return. In comparison to conventional wheat more grain yield of 7.0 to 7.1 q ha^{-1} and more profit of Rs 10,490.00 to Rs 10,670.00 ha^{-1} were obtained in zero tilled wheat treated with glyphosate @ 1.5 kg ha^{-1} as pre-plant desiccators (stale seedbed) followed by post-emergence application of carfentrazone ethyl @ 25 g ha^{-1}.

Keywords: Shift in weed flora, zero tilled wheat, carfentrazone ethyl, economics, 2, 4-D

Introduction

Wheat is one of the most important winter cereals contributing approximately 30-35% of total food grain production in our country. Heavy infestation of weeds alone causing 33% reduction in yield is a serious constraint in sustaining productivity of wheat. The extent of yield reduction largely depends on growth behavior of individual weed species in relation to agro-ecological condition (Singh *et al.,* 1997). Among the herbicides, isoproturon and pendimethalin are being used for the last two decades in wheat for management of grassy weeds (Walia *et al.,* 1998 and Chopra *et al.,* 2001). For controlling broadleaved weeds along with grasses, application of isoproturon in combination with 2,4-D, and metsulfuron-methyl (MSM) are recommended (Pandey *et. al.*, 2006, Singh and Singh, 2002). Singh *et al.* (2004) reported that carfentrazone ethyl at the dose of 20 and 25 g ha^{-1} registered better value of weed control efficiency (90.6 to 100%.) than 2,4-D (500g ha^{-1}) and was comparable with metsulfuron-methyl (4 g ha^{-1}). Continuous use of isoproturon led to the development of evolutionary resistant biotype and shift in weed flora (Malik and Singh, 1995). Marczewska and Rola (2003) reported that long-term use of a particular herbicide with incorrect dose and the genetic make-up of the weed contributed to the development of resistance against the active substances containing herbicides. Beckie and Jana (2000) reported the occurrence of triallate resistance in wild oat (*Avena fatua*) between 1996 and 1998 from two long-term crop rotations that included continuous cropping of spring wheat and wheat-fallow cropping system since 1979. Stachler *et al.* (2000) reported that the differential response of wild carrot to 2,4-D in field research was due to the development of resistance among the individuals and control of wild carrot with the application of 2,4-D ranged from 18 to 91%. Chlorsulfuron resistant chickweed (*Stellaria media*) was reported by Seefeldt *et al.,* 2001 from New Zealand and O'Donovan *et al.,* 1994 from Canada. These resistant plants were also having cross and multiple resistant capacity to other herbicides normally effective on chickweed. This population was not controlled by mecoprop, methabenzthiazuron and pendimethalin, and was partially controlled by bromoxynil + ioxynil, diflufenican + isoproturon and diflufenican + bromoxynil.

Late harvesting of rainy season rice, high residual soil moisture, multiple nutrient deficiency and high weed pressure of broadleaved weeds are the charateristic features of this *terai-agroclimatic* region. Wheat is an ecologically suitable crop and high residual soil moisture creates an opportunity for zero tilled wheat as late planting of prceeding rice crop and aggressive growth of weeds cause low productivity of conventional wheat. Yadav *et al.* (2005) reported that zero tillage resulted in improvement of growth and yield attributes like plant height, effective tillers, grains ear^{-1} and 1,000 grain weight of wheat. The improvement in yield attributes might have occurred owing to better establishment of crop plant as a result of less weed-crop competition under zero tillage system. The significantly higher yield (7.7%) of wheat was recorded with zero tillage in comparison to conventional tillage. Keeping these in view, present study was conducted with the objectives to study weed dynamics in conventional tillage and zero tillage; to find out herbicide(s) for controlling weeds and to study economics of the systems.

Materials and Methods

The field experiments were carried out in wheat under rice-wheat cropping system in which rice was grown in puddled transplanted condition. The experiments were

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conducted during four consecutive winter seasons of 2007, 2008, 2009 and 2010 in the farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal. The soil was sandy loam in texture having a pH 5.4-5.8 and 0.65% organic carbon, low in available nitrogen (93.84 kg ha^{-1}), medium in available phosphorus (16.24 kg ha^{-1}), low in available potassium (74.65 kg ha^{-1}). Experiment was laid out in Complete Randomized Block Design (CRBD) with 10 treatments combination for the year 2007 and 2008, and it was replicated thrice in a plot size of 15 X 3 m^2. The treatments comprised (T_1) zero tillage + glyphosate (1.50 kg ha^{-1} as pre-plant desiccators) + weedy control, (T_2) zero tillage + glyphosate + 2,4-D (0.50 kg ha^{-1} applied at 35 days after sowing/DAS), (T_3) zero tillage + glyphosate + pendimethalin (0.50 kg ha^{-1} as pre-emergence), (T_4) zero tillage + glyphosate + isoproturon (0.70 kg ha^{-1} as pre-emergence), (T_5) Zero tillage + weed-free control (T_6) conventional tillage + weedy control, (T_7) conventional tillage + 2,4-D (0.50 kg ha^{-1} at 35 DAS), (T_8) conventional tillage + pendimethalin (0.50 kg ha^{-1} as pre-emergence), (T_9) conventional tillage + isoproturon (0.70 kg ha^{-1} as pre-emergence), (T_{10}) conventional tillage + weed-free control. Based on the results obtained from first two years experiments another two treatments (T_{11}) Zero til lage+glyphosate+carfentrazone ethyl (25 g ha^{-1} at 35 DAS) and (T_{12}) Conventional Tillage+ carfentrazone ethyl (25 g ha^{-1} at 35 DAS) were included in the experiment for the year 2009 and 2010. Glyphosate in zero tillage was applied 5 days before sowing of wheat. Wheat variety "PBW 343" was sown 22.5 cm apart on 22nd November, 15th November, 19th November and 17th November in the year 2007, 2008, 2009, and 2010, respectively, in zero tillage, however, in conventional tillage the seeds were sown on 3rd December, 29th November, 2nd December and 30th November of respective four years. The crop in conventional tillage was fertilized with 120 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}. Half dose of nitrogen and full dose of phosphorus and potassium were applied as basal in the form of urea, single super phosphate and muriate of potash at the time of sowing and remaining nitrogen was top dressed in two equal splits after first and second irrigation. The crop in zero tillage was fertilized with 140 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}. NPK of 10:26:26 granular fertilizer according to the dose of 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} was applied through zero tillage machine and remaining nitrogen was top dressed in two equal splits after first and second irrigation in the form of urea. The weed dry weight was recorded using quadrate (0.50 m^2) placed randomly at 3 places in each plot and expressed as g m^{-2}. The data on weed dry weight was recorded at 60 days after sowing (DAS) and data on total weed dry weight was analyzed after subjecting to square-root transformation {$\sqrt{(X + 1)}$}. Weed Control Efficiency (%) and Weed Index (%) values were determined by using the following formulas.

$$WCE1 = \frac{\text{Dry weight of weed in weedy control plot - Weed dry weight in treated plot}}{\text{Dry weight of weed in weedy control plot}} \times 100$$

$$WCE2 = \frac{\text{Dry weight of weed in weedy control plot of conventional tillage - Weed dry weight in treated plot}}{\text{Dry weight of weed in weedy control plot of conventional tillage}} \times 100$$

$$WI = \frac{\text{Grain yield in weed-free control plot - Grain yield in treated plot}}{\text{Grain yield in weed free plot}} \times 100$$

Results and Discussion

Effect on Weed, Weed Control Efficiency and Weed Index

The major weed flora, recorded in the weedy plot of conventional tillage, were broadleaved weeds like *Polygonum pensylvanicum, P. orientale* and *P. persicaria , Stellaria media* Cyrill*, Stellaria aquatica* Cyrill and *Oldenlandia diffusa* L., however, in zero tilled weedy plot, diversity of weed flora like grasses *Cynodon dactylon* (L) Pers., *Setaria glauca* (L.) Beauv and *Digitaria sanguinalis* (Retz.) Koel, sedges *Cyperus rotundus* L. and broadleaved weed *Vicia sativa* L.*, V hirsuta* L., along with *Stellaria media* Cyrill, *Stellaria aquatica* Cyrill and *Oldenlandia diffusa* L., was observed

On contrary of conventional tillage, considerable reduction on growth of several species of *Polygonum* was recorded in zero tilled plot, however, growth of the other broadleaved weeds *Stellaria media* Cyrill*, S. aquatica* Cyrill*, Oldenlandia diffusa* L., *Vicia sativa* L. and *V hirsuta* L. and grasses *Cynodon dactylon* (L) Pers., *Setaria glauca* (L.) Beauv and *Digitaria sanguinalis* (Retz.) Koel was increased considerably in succeeding years (Table 1). Total weed dry weight in zero tilled weedy control plot was significantly lower than corresponding conventional tilled plot and thus, zero tillage+glyphosate alone registered weed control efficiency of 36.9 to 42.4 per cent while considering the weed growth in conventional weedy control treatment for computing this value (Table 2).

Shift in weed flora was recorded in 2,4-D treated plot during second year onwards of the experiment. 2,4-D successfully controlled several species of *Polygonum* in first year of the experiment recording higher values of weed control efficiency (71.8% and 62.8% in conventional and zero tilled system, respectively) and lowest values of weed index (4.9% and 4.5% in conventional and zero tilled system, respectively) (Table 2 and Table 3). Successful control of *Polygonum* by 2,4-D resulted in emergence of 2,4-D tolerant weeds *Physalis minima* L. and *Solanum nigram* L. and reemergence of *Stellaria media* Cyrill, *Stellaria aquatica* Cyrill. Continuous use of 2,4-D in succeeding years caused aggressive growth of the weeds leading to very poor weed control efficiency (14.2% and 27.0% in conventional and zero tilled system, respectively) and higher weed index values at the final year of experiment (Table 1 and 2).

Application of carfentrazone ethyl was effective in controlling 2,4-D tolerant weeds leading to highest weed control efficiency of more than 86% and lowest weed index values of 1.1 to 3.7% in both tillage systems (Table 2 and 3).

Pendimethalin recorded moderate values of weed control efficiency of 53.9 to 58.7% in zero tilled plot, however, it registered relatively higher weed control values of 70.2 to 72.9% in conventional tillage. As zero tillage in combination with glyphosate has the capacity to reduce the growth of *Polygonum*, therefore, pendimethalin in zero tilled system registered higher weed control efficiency of 70.9 to 76.2% than conventional system while considering the weed growth in weedy control treatment of conventional tillage. Continuous application of pendimethalin reduced weed control efficiency in succeeding year due to emergence of *Hydrocotyl ranunculoide* and *Eclipta alba.* Isoproturon was ineffective as it has failed to control the weeds in both the tillage systems.

Table1. Effect of treatments on weed dry weight (g m^{-2}) of different broadleaved weeds

Treatment	Weed dry weight																			
	Polygonum sp.				*Physalis minima and Solanum nigram*				*Stellaria media , S aquatica and Oldenlandia diffusa*				*Vicia sativa and V hirsuta*				*Hydrocotyl ranunculoides and Eclipta alba*			
	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
ZT+Glyphosate+weedy control	96.8	76.4	58.3	52.6	15.4	21.3	24.6	30.4	56.4	62.5	74.6	78.5	13.4	32.6	56.5	72.4	2.4	1.6	1.5	0.9
ZT+Glyphosate+2,4-D	28.6	24.8	19.7	18.3	14.7	35.4	48.6	57.4	12.3	34.6	52.4	68.5	7.4	9.4	11.5	16.3	0.0	0.6	1.4	1.8
ZT+Glyphosate+Pendimethalin	26.5	22.4	18.6	18.0	12.4	16.8	18.4	22.3	20.6	23.4	26.7	32.2	5.4	6.8	4.7	8.4	12.3	18.7	26.5	32.5
ZT+Glyphosate+isoproturon	84.2	68.3	52.8	46.4	16.3	20.6	22.6	28.9	43.4	56.8	64.3	72.4	12.6	28.4	45.3	64.3	1.2	2.1	0.9	0.0
ZT+Glyphosate+carfentrazone	-	-	7.5	6.4	-	-	2.5	3.4	-	-	4.3	5.3	-	-	5.4	6.2	-	-	0.0	0.0
ZT+Weed-free control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CT+Weedy control	210.4	235.7	248.4	263.7	9.6	5.2	2.4	3.2	134.6	150.2	166.2	183.5	3.2	4.6	6.5	5.4	3.4	1.6	1.2	2.3
CT+2,4-D	35.7	42.6	48.3	50.4	23.5	118.6	158.4	234.2	42.6	58.4	75.3	108.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CT+Pendimethalin	32.4	38.2	36.7	39.7	15.6	16.8	20.8	18.7	34.2	36.8	40.3	42.6	0.0	0.0	0.0	0.0	15.6	23.7	28.4	34.7
CT+Isoproturon	126.7	156.4	164.5	178.2	11.4	9.8	7.3	4.3	73.6	84.2	92.4	104.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CT+Carfentrazone	-	-	15.4	16.8	-	-	10.6	16.5	-	-	22.4	26.8	-	-	0.0	0.0	-	-	0.0	0.0
CT+weed-free control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ZT-Zero tillage and CT-Conventional Tillage

Table 2. Effect of treatment on weed dry weight (g m^{-2}) and weed control efficiency (%)

Treatment	Weed dry weight												Weed control efficiency 1				Weed control efficiency 2 (WCE2)			
	Broadleaved				Grasses+sedges				Broadleaved+Grasses+sedges				(WCE1)							
	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
ZT+Glyphosate+ weedy control	184.4	194.4	215.5	234.8	23.4	32.6	43.7	54.2	14.5 (207.8)	15.1 (227.0)	16.1 (259.2)	17.1 (289)	-	-	-	-	42.4	42.8	38.9	36.9
ZT+Glyphosate+ 2,4-D	63.0	104.8	133.6	162.3	17.2	25.6	38.7	48.4	8.8 (77.21)	11.5 (130.4)	13.2 (172.3)	14.5 (210.7)	62.8	42.5	33.5	27.0	78.6	67.1	59.4	54
ZT+Glyphosate+ Pendimethalin	77.2	88.1	94.9	113.4	8.6	12.3	17.4	19.6	9.3 (85.8)	10.0 (100.4)	10.7 (112.3)	11.6 (133)	58.7	55.7	56.6	53.9	76.2	74.7	73.5	70.9
ZT+Glyphosate+ isoproturon	141.4	176.2	163.3	212.0	12.4	16.3	22.4	27.5	13.0 (170.1)	13.0 (192.5)	14.5 (208.3)	15.5 (239.5)	18.1	15.1	19.6	17.1	52.9	51.5	50.9	47.7
ZT+Glyphosate+ carfentrazone ethyl	-	-	19.7	21.3	-	-	15.3	18.4	-	-	6 (35.0)	6.4 (39.7)	-	-	86.4	86.2	-	-	91.7	91.3
ZT+Weed-free control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-	-	-	-
CT+Weedy control	361.2	397.3	424.7	458.1	0.0	0.0	0.0	0.0	19.0 (361.2)	19.1 (397.3)	20.6 (424.7)	21.4 (458.1)	-	-	-	-	-	-	-	-
CT+2,4-D	101.8	219.6	282.0	393.0	0.0	0.0	0.0	0.0	10.1 (101.8)	14.8 (219.6)	16.8 (282.0)	19.8 (393.0)	71.8	44.7	33.6	14.2	71.8	44.7	33.6	14.2
CT +Pendimethalin	97.8	115.5	126.2	135.7	0.0	0.0	0.0	0.0	9.9 (97.8)	10.7 (115.5)	11.3 (126.2)	11.7 (135.7)	72.9	70.9	70.2	70.3	72.9	70.9	70.2	70.3
CT+Isoproturon	211.7	250.4	264.2	287.1	0.0	0.0	0.0	0.0	14.5 (211.7)	15.8 (250.4)	16.2 (264.2)	16.1 (287.1)	41.3	36.9	37.7	37.3	41.3	36.9	37.7	37.3
CT+Carfentrazone ethyl	-	-	48.4	60.1	-	-	0.0	0.0	-	-	7 (48.4)	7.8 (60.1)	-	-	88.6	86.8	-	-	88.6	86.8
CT+weed-free control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1(0.0)	1 (0.0)	1 (0.0)	1 (0.0)	-	-	-	-	-	-	-	-
LSD (0.05)									0.36	0.64	0.45	0.63								

Values in parentheses are the original total dry weight values, ZT-Zero tillage and CT-Conventional Tillage

Table 3. Effect of treatment on grain yield (q ha^{-1}), weed index (%), net return (Rs ha^{-1}) and return cost ratio

Treatment	Yield				Weed Index				Net Return				Return Cost Ratio			
	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
ZT+Glyphosate+weedy control	29.4	27.2	24.5	23.8	37.0	41.3	47.4	47.9	7940	5930	920	155	0.41	0.30	0.03	0.01
ZT+Glyphosate+2,4-D	44.6	39.8	35.4	29.2	4.5	14.0	24.0	36.1	20687	16727	12432	5232	1.01	0.82	0.42	0.18
ZT+Glyphosate+Pendimethalin	43.2	42.4	40.8	40.1	7.5	8.4	12.5	12.3	18740	18130	17640	16920	0.90	0.87	0.60	0.57
ZT+Glyphosate+isoproturon	31.6	28.4	28.6	27.3	32.3	38.7	38.7	40.3	9143	6233	4478	3023	0.45	0.30	0.15	0.10
ZT+Glyphosate+carfentrazone ethyl	-	-	45.8	45.2	-	-	1.7	1.1	-	-	23267	22682	-	-	0.80	0.78
ZT+Weed-free control	46.7	46.3	46.6	45.7	-	-	-	-	-	-	-	-	-	-	-	-
CT+Weedy control	11.2	10,6	09.5	09.2	72.3	73.2	76.4	76.6	-9160	-9650	-18405	-18705	-0.45	-0.48	-0.60	-0.60
CT+2,4-D	38.4	27.3	22.4	11.6	4.9	30.9	44.3	70.5	14207	4432	-4478	-16673	0.68	0.21	-0.14	-0.52
CT+Pendimethalin	38.2	36.6	36.2	35.8	5.5	7.4	9.9	8.9	13370	12010	9625	9235	0.62	0.56	0.30	0.29
CT+Isoproturon	27.4	25.3	25.7	24.6	32.2	35.9	36.1	37.4	4543	2858	-1287	-4022	0.22	0.14	-0.04	-0.13
CT+Carfentrazone ethyl	-	-	38.7	38.2	-	-	3.7	2.8	-	-	12597	12192	-	-	0.40	0.39
CT+weed-free control	40.4	39.5	40.2	39.3	-	-	-	-	-	-	-	-	-	-	-	-
LSD (0.05)	0.92	0.84	1.64	1.24												

ZT-Zero tillage and CT-Conventional Tillage

Yield and Economics

Successful control of 2,4-D tolerant weeds by the carfentrazone ethyl registered highest grain yield of 45.2 to 45.8 q ha^{-1} in zero tilled wheat statistically at per with the yield of 45.7 to 46.7 q ha^{-1} obtained in zero tilled weed-free control treatment and this, in turn, led to record highest net return of Rs 22,682.00 to Rs 23,267.00 by carfentrazone ethyl in zero tilled wheat (Table 3). 2,4-D and Isproturone was ineffective in controlling weeds leading to negative values on net return in conventional wheat during final two years of experiment. Apart from carfentrazone ethyl, pendimethalin recorded satisfactory grain yield of 40.1 to 43.2 q ha^{-1} in zero tilled wheat and 35.8 to 38.2 q ha^{-1} in conventional wheat (Table 3).Highest return cost ratio of 0.78 to 0.80 was recorded by carfentrazone ethyl under zero tillage condition.

In comparison to conventional wheat more grain yield of 7.0 to 7.1 q ha^{-1} and more profit of Rs 10,490 to Rs 10,670 ha^{-1} were obtained in zero tilled wheat treated with glyphosate at the rate of 1.5 kg ha^{-1} as pre-plant desiccators (stale seedbed) followed by post-emergence application of carfentrazone ethyl at the rate of 25 g ha^{-1}

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