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Tillage and weed control effect on weeds and wheat productivity

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ABSTRACT

A 3-year study was conducted to assess the impact of tillage and weed control practices on weed flora and wheat productivity. Experiments were conducted during *Rabi* season of 2012-13 to 2014-15 at GBPUA&T, Pantnagar, with clay-loam soil. There were five crop establishment methods, *viz.* Transplanted rice (conventional tillage) (TPR)– wheat (conventional tillage) (CTW) (TPR-CTW), Transplanted rice (conventional tillage)– wheat (zero tillage)- *Sesbania* green manuring (S) (TPR-ZTW-S), Direct-seeded rice (conventional tillage)- wheat (conventional tillage)- *Sesbania* incorporation (S) (DSR-CTW-S), Direct-seeded rice (zero tillage)- wheat (zero tillage)- *Sesbania* brown manuring (S) (ZTR-ZTW-S) and Direct-seeded rice (zero tillage) + residue retention- wheat (zero tillage) + residue retention- *Sesbania* brown manuring (S) (ZTR + R-ZTW+R-ZTS) and three weed control methods [(weedy check, recommended herbicide (Recommended ready-mix herbicide clodinafop 15% + MSM 1% (60 + 4 g/ha) and integrated weed management *i.e.,* clodinafop 15% + MSM 1% 60 + 4 g/ha *fb* manual weeding at 45 days after seeding (DAS)]. Continuous zero-till cropping system along with residue retention and brown manuring of *Sesbania* has resulted in the lowest total weed biomass at 60 DAS and greatly reduced the density of *Phalaris minor, Medicago denticulata, Polygonum plebeium* and *Coronopus didymus.* However, density of *C. didymus, Rumex acetosella* and *Vicia sativa* was reduced under conventionally tilled wheat. Ready mix application of clodinafop 15% + MSM 1% supplemented with one hand weeding at 45 DAS greatly reduced the density and biomass of weeds. The maximum wheat grain (4.5 t/ha) and straw (6.3 t/ha) yields was achieved under zero-tilled wheat with rice residue retention and *Sesbania* as brown manure. The integration of clodinafop 15% + MSM 1% with 1 HW at 45 DAS resulted in an increase in grain and straw yields by 45.5% and 30.8%, respectively, over weedy check. It may inferred that in wheat cultivation conventional tillage could be replaced with zero-tillage along with residue retention by growing of *Sesbania* and the application of 2,4-D at 30 days stage to attain sustainability of rice-wheat cropping system.

INTRODUCTION

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system is the most important cropping system of the Indo-Gangetic plains (IGP) in India (Singh *et al.* 2014). India is the second largest consumer as well as producer of wheat in the world, with production of 99.70 million tonnes (Anonymous 2018). The traditional method of wheat establishment involves excessive tillage which is time and energy consuming (Tripathi *et al.* 2002). The sowing of wheat after harvest of transplanted rice is generally delayed due to intensive tillage operation for seed bed preparation under conventional system. This results in reduced yield due to reduced crop duration, equivalent to an extent of 1.0-1.5% yield loss/hectare/day (Gathala *et al.* 2011). Under such condition, conservation agriculture (CA) practices like direct-seeding, zero tillage along with retention of residues have several advantages, *viz.* advance sowing, conserve the energy, more moisture availability for wheat seed germination by reducing turn-around time and also reduced number of weeds due to lesser

turning of soil. Weeds are one of the major constraints in wheat production (Sharma and Singh 2010). Weeds reduce the crop yield, deteriorate quality, and reduce market value of grains. Weed causes yield reduction in wheat from 50-80% (Chhokar and Malik 2002, Jain *et al.* 2007). Sowing wheat under ZT further saves fuel costs (Chauhan and Johnson 2009) and energy (Erenstein and Laxmi 2008). Many researchers observed that with the adoption of ZT, there is shift in weed species (Rao *et al.* 2007 and Shahzad *et al.* 2016) which need to be controlled by appropriate methods. Farooq *et al.* (2011) suggested to include integrated weed management as a component of CA. The current three year field study was conducted to evaluate the impact of different tillage and weed control practices on weed growth and wheat productivity.

MATERIALS AND METHODS

A field experiment was conducted at G.B. Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar, Uttarakhand, India, during 2012-15. Pantnagar falls in the *'Tarai'* zone (a lowland region that has outer hills of Himalayas), adjoining the foothills of 'Shivalik' range of the Himalayas and situated at 29°N latitude and 79.32°E longitude having an altitude of 243.8 meter above the mean sea level. The climate falls under sub-humid, sub-tropical climatic zone. Summer is being warm and humid. The mean annual rainfall is about 1400 mm, of which 80 to 90 per cent is received during *Kharif* season (June to September). Frost generally occurs towards the end of December and may continue till the end of January. Winters are very cold and extend from November to March. The daily average minimum temperature in the coldest month varies from 1.0-9.0°C and during summer, the maximum temperature varies from 30-43°C. The soil had a clay loam texture and classified under order mollisols (Deshpande *et al.* 1971), with slightly alkaline reaction (pH 7.7) and moderately fertile, being low in organic carbon (0.41%) and available nitrogen (168.2 kg/ha) and medium in available phosphorus (14.8 kg/ha) and potassium (194.6 kg/ha). The field experiment was laid out in a strip plot design, sub-plot size of 3.6 x 10 m with five tillage establishment methods in vertical strip and three weed control treatments in horizontal strip, replicated thrice (**Table 1)**.

Field was prepared mechanically according to the treatments. Before sowing of rice, *Sesbania*, with seed rate of 40 kg/ha, was sown with seed drill and incorporated in the field as green manure with puddling under conventional transplanted rice and incorporated into the soil with the help of harrow in direct-seeded rice, while in zero-till rice, the *Sesbania* was knocked out by the application of 2,4-D at 45 DAS and considered as brown manure. During *Rabi* season, the same experimental plots after rice harvesting were prepared mechanically with the help of small harrow and power tiller for conventional sown wheat; while in case of zero tillage, directly the seeds were sown with zero-till-ferti seed drill, without any disturbance of the permanent layout of the experiment. Sowing of wheat variety '*UP 2572*' was done between second and third week of November, each year after rice harvest, with seed rate of 100 kg/ha, manually by opening furrow at 22.5 cm apart with the help of furrow opener in case of conventional plots while in zero tillage, seed and fertilizer was placed directly with the help of zero-till-ferti seed drill.

A dose of 150 kg N, 60 kg P and 40 kg K per hectare was applied through urea (46% N) and NPK mixture (12:32:16% of nitrogen, phosphorus and potassium). Half of nitrogen, full dose of phosphorus and potassium was applied as basal while remaining nitrogen was applied in two splits at the time of tillering and heading stage. After sowing of the crop, residue of the previous crop (rice residue in wheat and wheat residue in rice) was left in experimental plots according to the treatments. Harvesting was done manually with sickle from the net plot (10 m^2), when more than 90 per cent of grains in the panicle were fully ripe and free from greenish tint. The produce of individual plot was threshed by Pullman thresher. Grain yields were reported at 14% moisture content.

Weed samples were collected at 60 DAS by placing a quadrate (0.5 x 0.5 m) from the area marked for observation in each plot. Species wise weed counts were recorded and grouped into grasses, sedges and broad-leaved weeds (BLW) and expressed as no./m^2. Weeds enclosed in a quadrate were removed at ground level and separated as grasses, sedges and broad-leaved weeds. After sun drying, the samples were kept in hot air oven at 60 ± 10°C till constant dry weight is obtained. The total weed biomass was obtained by adding the weight of all the weed groups and expressed as g/m^2. All the data obtained during the course of investigation were subjected to statistical analysis by using CPCS-1 programme, designed and developed by Punjab Agriculture University, Ludhiana, (Cheema and Singh 1991) for determining the statistical difference between the treatments and to draw conclusions. The data on weed density and their biomass were subjected to square root transformation ($\sqrt{x+1}$) to

reduce heterogeneity of variance. The original values were given in the parentheses. The analyzed data are presented in tables.

RESULTS AND DISCUSSION

Weed density

Dominant weed species in weedy check were *Phalaris minor* (44.0%) among grassy, *Medicago denticulata* (30.3%), *Polygonum plebeium* (9.5%), *Coronopus didymus* (2.1%), *Rumex acetosella* (1.4%), *Melilotus alba* (5.5%), *Chenopodium album* (6.3%) and *Vicia sativa* (0.9%) among BLW at 60 days after seeding (DAS) (**Figure 1**). Majority of weeds in the wheat field under rice-wheat cropping system were *Phalaris minor*, *Avena ludoviciana*, *Cyperus rotundus*, *Coronopus didymus*, *Chenopodium album*, *Anagallis arvensis*, *Convolvulus arvensis*, *Melilotus indica*, *Melilotus alba, Medicago denticulate, Rumex* spp. and *Vicia sativa* (Usman *et al.* 2010[a,b,] Kumar *et al.* 2012, Kumar *et al.* 2013 and Shyam *et al.* 2014). Singh *et al.* 2015[a,b] revealed the dominance of *Phalaris minor* (40.7%) as a grassy weed and *Chenopodium album* (13.3%), *Coronopus didymus* (10.4%), *Melilotus indica* (9.4%), *Rumex* spp. (4.8%) and *Fumaria parviflora* (3.8%),as major broad-leaved weeds infesting experimental area of wheat.

Among grassy weeds, significantly the lowest density was recorded under zero-till wheat with or without residue retention along with the *Sesbania* grown as brown manure. CT favoured *Phalaris minor* (Chhokar *et al.* 2007, 2009, Usman *et al.* 2010a, Shyam *et al.* 2014 and Punia *et al.* 2016). Clodinafop 15% + MSM 1% (60+4 g/ha) supplemented with one hand weeding achieved the least density of *P. minor* (**Table 1**). Zero-till wheat with and without residue retention along with the *Sesbania* as brown manure recorded the lowest density with integration of IWM practices (**Table 2**). Chhokar *et al.* (2007) at Karnal, Haryana reported that if zero tillage is practiced with residue retention then weed infestation will be lesser. The ready-mix doses of clodinafop + metsulfuron (UPH-206) at 35 DAS in wheat at 60 + 4 g/ha provided good control of dominant grassy weeds, *viz. Phalaris minor* and broad-leaf weeds like *Chenopodium album*, *Melilotus indica*, *Rumex* spp.and *Coronopus didymus* over unweeded check (Chopra and Chopra 2010, Singh *et al.* 2012 and Chopra *et al.* 2015).

Figure 1. Dominant weed species in weedy check at 60 DAS

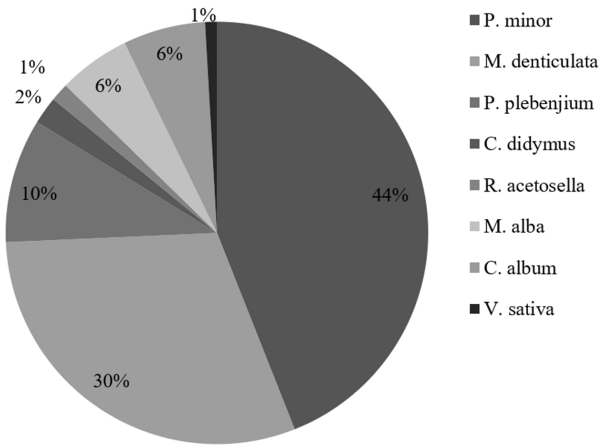

Table 1. Effect of establishment methods and weed management on weed density and total weed biomass of wheat in rice-wheat cropping system at 60 DAS (pooled data of 3 years)

Treatment	Weed density (no./m^2)									Total weed biomass (g/m^2) 60 DAS
	Grassy weeds	Broad-leaved weeds							Total BLWs	
	P. minor	*M. denticulata*	*P. plebeium*	*C. didymus*	*R. acetosella*	*M. alba*	*C. album*	*V. sativa*		
Establishment system										
TPR (CT)- wheat (CT)	8.0(101.3)	2.7(11.3)	1.8(4.0)	1.2(0.7)	1.2(0.9)	2.1(5.0)	2.3(8.2)	1.2(0.6)	4.1(29.9)	5.6(58.2)
TPR (CT)- wheat (ZT)- *Sesbania* (ZT)	5.0(32.2)	3.1(15.6)	1.8(5.6)	1.8(4.5)	1.2(0.6)	1.6(2.5)	1.4(1.3)	1.1(0.3)	4.1(30.0)	4.8(36.1)
DSR (CT)- wheat (CT)- *Sesbania* (ZT)	6.4(49.2)	4.3(32.6)	3.0(14.2)	1.3(1.0)	1.1(0.4)	2.1(6.2)	2.5(8.9)	1.1(0.2)	5.5(61.0)	5.2(43.5)
DSR (ZT)- wheat (ZT)- *Sesbania* (ZT)	4.0(26.7)	4.5(54.4)	2.6(12.0)	1.5(1.9)	1.7(2.4)	1.9(4.9)	1.9(4.3)	1.1(0.4)	5.7(79.7)	4.7(36.3)
DSR (ZT)+R- wheat (ZT)+R- *Sesbania* (ZT)	3.5(15.9)	2.4(12.6)	1.6(4.0)	1.2(0.9)	1.4(1.6)	1.8(4.0)	1.7(3.7)	1.6(1.9)	3.5(28.7)	3.5(20.3)
LSD (p=0.05)	1.1	1.0	0.6	0.3	0.3	NS	0.4	0.2	0.9	0.9
Weed management										
Clodinafop 15% + MSM 1% at 60+4 g/ha)	4.2(20.1)	1.8(3.1)	1.3(1.1)	1.0(0.2)	1.0(0.1)	1.1(0.4)	1.2(0.7)	1.0(0.0)	2.0(4.9)	3.2(13.1)
IWM (herbicide *fb* one HW)	2.7(9.5)	1.0(0.1)	1.0(0.1)	1.1(0.3)	1.0(0.1)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.1(0.5)	1.3(1.1)
Weedy check	9.3(105.5)	7.3(72.6)	4.2(22.7)	2.1(5.0)	1.9(3.4)	3.6(13.2)	3.6(15.1)	1.6(2.1)	10.6(132.1)	9.7(102.4)
LSD (p=0.05)	0.8	2.1	1.1	0.4	0.1	0.2	0.6	0.3	2.4	1.2

Vertical strip- TPR- CTW: Transplanted rice (conventional tillage) (TPR) – wheat (conventional tillage) (CTW); TPR- ZTW- S: Transplanted rice (conventional tillage)- wheat (zero tillage)- *Sesbania* green manuring(S); DSR- CTW- S: Direct-seeded rice (conventional tillage)- wheat (conventional tillage)- *Sesbania* incorporation(S); ZTR- ZTW- S: Direct-seeded rice (zero tillage)- wheat (zero tillage)- *Sesbania* brown manuring(S); ZTR+ R- ZTW+ R- ZTS: Direct-seeded rice (zero tillage) + residue retention- wheat (zero tillage) + residue retention- *Sesbania* brown manuring(S): Horizontal Strip- Recommended ready-mix herbicide (clodinafop 15% + MSM 1% 60+4 g/ha); IWM; Integrated weed management (clodinafop 15% + MSM 1% 60+4 g/ha *fb* manual weeding at 45 DAS)

Significantly the lowest population of *M. denticulata* and *P. plebeium* was recorded under ZT wheat with rice residue retention and *Sesbania* as brown manuring. Higher density of *C. didymus* was observed under ZT wheat with *Sesbania* as green manure which was significantly superior to other establishment methods. Whereas, significantly higher density of *R. acetosella* was observed under ZT wheat with *Sesbania* as brown manure. Significantly the lowest density of *C. album* was recorded under ZT wheat with *Sesbania* incorporated as green manure. Similar was reported by Chhokar *et al.* (2007) that *Phalaris minor* was dominant under the conventional tillage system and *Medicago denticulata* and *Coronopus didymus* was dominant under zero tillage system in wheat. All the establishment methods of wheat recorded significantly low weed density being at par with each other, except ZT wheat with residue retention of rice and brown manuring of *Sesbania*. The minimum density of all BLWs was achieved under IWM (clodinafop 15% + MSM 1% (60+4 g/ha) supplemented with one hand weeding at 45 DAS followed by alone application of ready-mix herbicide except *C. didymus* which have least density under sole herbicidal application at par with IWM approach and both the treatments reduced the population over weedy check (**Table 1**). Continuous ZT with effective weed management using recommended herbicide + one hand weeding was more remunerative (Mishra and Singh 2012).

The lowest density of all BLWs was achieved under zero-till wheat with rice residue retention followed by *Sesbania* as brown manuring under zero-till rice. IWM achieved the least density of BLWs being at par with herbicidal application (**Table 1**). The surface retention of rice residue of more than 4 t/ha in combination with no-till system reduced the weed abundance in wheat (Chhokar *et al.* 2014). Effective control of broad-leaved weeds with high yield attributes was found by application of clodinafop-propargyl + metsulfuron-methyl 400 g/ha (Tiwari *et al.* 2015). Conventional wheat with *Sesbania* incorporated as green manure recorded the lowest density with integration of IWM practices. Along with zero-till wheat with as well as without retention of rice residue with *Sesbania* as brown manuring with IWM and sole application of herbicide (**Table 3**). Chhokar *et al.* (2007) at Karnal, Haryana reported that if zero tillage is practiced with residue retention then weed infestation will be lesser. Continuous ZT with effective weed management using recommended herbicide + one hand weeding was more remunerative (Mishra and Singh 2012).

Table 2. Interaction effect of establishment methods and weed management on total grassy weeds of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	TPR(CT)-wheat (CT)	TPR(CT)-wheat (ZT)-*Sesbania* (ZT)	DSR(CT)-wheat (CT)-*Sesbania* (ZT)	DSR(ZT)-wheat (ZT)-*Sesbania* (ZT)	DSR(ZT)+R-wheat (ZT)+R-*Sesbania* (ZT)	Mean
Clodinafop 15% + MSM 1% at 60+4 g/ha)	5.2	3.7	5.9	2.9	3.1	4.2
IWM (herbicide *fb* one hand weeding)	2.8	3.3	3.3	2.1	2.2	2.7
Weedy check	16.1	8.1	10.1	7.1	5.1	9.3
Mean	8.0	5.0	6.4	4.0	3.5	
LSD(p=0.05)			1.6			

Table 3. Interaction effect of establishment methods and weed management on total BLWs of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	TPR(CT)-wheat (CT)	TPR(CT)-wheat (ZT)-*Sesbania* (ZT)	DSR(CT)-wheat (CT)-*Sesbania* (ZT)	DSR(ZT)-wheat (ZT)-*Sesbania* (ZT)	DSR(ZT)+R-wheat (ZT)+R-*Sesbania* (ZT)	Mean
Clodinafop 15% + MSM 1% at 60 + 4 g/ha)	2.2	1.9	2.8	2.2	1.0	2.0
IWM (herbicide *fb* one hand weeding)	1.1	1.5	1.0	1.0	1.1	1.1
Weedy check	8.9	8.8	12.8	13.8	8.5	10.6
Mean	4.1	4.1	5.5	5.7	3.5	
LSD(p=0.05)			1.2			

Table 4. Interaction effect of establishment methods and weed management on total biomass of weeds of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	TPR(CT)-wheat (CT)	TPR(CT)-wheat (ZT)-*Sesbania* (ZT)	DSR(CT)-wheat (CT)-*Sesbania* (ZT)	DSR(ZT)-wheat (ZT)-*Sesbania* (ZT)	DSR(ZT)+R-wheat (ZT)+R-*Sesbania* (ZT)	Mean
Clodinafop 15% + MSM 1% at 60+4 g/ha)	3.3	3.4	4.3	3.3	1.9	3.2
IWM (herbicide *fb* one hand weeding)	1.2	1.5	1.5	1.2	1.3	1.8
Weedy check	12.2	9.6	9.8	9.6	7.5	9.7
Mean	5.6	4.8	5.2	4.7	3.5	
LSD(p=0.05)			1.5			

Table 5. Effect of establishment methods and weed management on yield and yield attributes of wheat in rice-wheat cropping system (pooled data of 3 years)

Treatment	Spikes (no./m^2)	Grains/ spikes	1000-grain weight (g)	Grain yield (t/ha)				Straw yield (t/ha)
				2012-13	2013-14	2014-15	Pooled	
Establishment system								
TPR (CT)- wheat (CT)	247.3	45.0	44.0	4.3	4.2	4.2	4.2	6.1
TPR (CT)- wheat (ZT)- *Sesbania* (ZT)	277.2	43.3	43.7	4.2	4.1	4.2	4.2	6.2
DSR (CT)- wheat (CT)- *Sesbania* (ZT)	282.9	42.2	43.5	4.2	4.0	3.9	4.0	6.2
DSR (ZT)- wheat (ZT)- *Sesbania* (ZT)	275.0	45.4	43.9	3.9	3.9	4.1	4.0	5.7
DSR (ZT)+R- wheat (ZT)+R- *Sesbania* (ZT)	258.9	42.7	45.2	4.2	4.7	4.7	4.5	6.3
LSD (p=0.05)	NS	NS	NS	0.24	0.35	0.34	NS	NS
Weed management								
Clodinafop 15 % + MSM 1% at 60+4 g/ha)	280.5	45.4	44.4	4.3	4.5	4.6	4.5	6.3
IWM (herbicide *fb* one hand weeding)	307.8	43.6	44.6	4.8	4.8	4.9	4.8	6.8
Weedy check	216.5	42.1	43.2	3.4	3.2	3.3	3.3	5.2
LSD(p=0.05)	33.5	NS	NS	0.31	0.40	0.43	0.3	0.4

Significantly lowest biomass was recorded under zero-till wheat with residue retention of rice along with *Sesbania* as brown manure. IWM achieved the least biomass of weeds (**Table 1**). Lowest weed biomass was achieved under zero-till wheat without residue retention with *Sesbania* as brown manure in combination with IWM (**Table 4)**. Zero-till wheat exhibited significantly lower weed dry weight per unit area than conventional method of wheat sowing (Shyam *et al.* 2014).

Effect on yield

Among different establishment system, the highest number of spike/m^2 (282.9), grains/spike (45.4) and 1000-grain weight (45.2 g) was achieved in conventional wheat after direct-seeded rice *fb Sesbania* incorporation, zero-till rice and wheat with *Sesbania* as brown manure and both zero-till rice and wheat with residue retention *fb Sesbania* as brown manure, respectively. Ram *et al.* (2010) reported higher yields of wheat under ZT with residue due to the cumulative effects of higher light interception more dry matter production, low soil and canopy temperature, more soil moisture, tillers, grains/spike and 1000-grain weight than no-residue application under ZT practices, as well as CT practices. Higher wheat grain (4.5 t/ha) and straw (6.3 t/ha) yields were recorded under zero-till rice and wheat with residue retention of rice along with brown manuring of *Sesbania*. An increase in number of spikes/m^2 (307.8), 1000-grain weight (43.6 g), grain (4.8 t/ha) and straw (6.8 t/ha) yields of wheat was recorded under IWM (clodinafop 15% + MSM 1% 60 + 4 g/ha *fb* one hand weeding) compared to weedy check (**Table 5**). The conservational tillage (no-till) for wheat generally resulted in yields that were better than or equal to yields obtained with conventional tillage (Punia *et al.* 2016). Integration of zero tillage + *Sesbania* + previous crop residue in rice -zero tillage + rice residue in wheat -zero tillage + residue in green gram along with weed control by bispyribac-sodium in rice and tank-mix of clodinafop and sulfosulfuron in wheat effectively controlled the weeds and enhanced the system productivity in rice-wheat-green gram cropping (Sapre *et al.* 2015). The ready-mix doses of clodinafop + metsulfuron at 35 DAS in wheat at 60 + 4 g/ha attained the grain yields similar to weed free check (Yadav *et al.* 2009, Kumar *et al.* 2012), about 18.5% higher than the sole application of herbicides (Chopra and Chopra 2010).

Conclusion

Continuous ZT with IWM (clodinafop 15% + MSM 1% 60+4 g/ha *fb* one hand weeding) resulted in highest yield by reducing the weed density and biomass of weeds.

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