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Optimizing herbicide dose for sustainable productivity of wheat (*Triticum aestivum* L.) under diverse seed pre-treatments and tillage systems

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Abstract

Time is the most important thing which reduces wheat yield in conventional rice-wheat cropping system, conservation agriculture might be a chance to resolve these conflict in Indo-Gangetic Plains. In this one-year field study; Wheat was raised in zero tillage and conventional tillage systems after harvesting rice grown in flooded systems. Wheat seed was hydro-primed and no-primed. To optimize herbicide dose sulfusulfuron at different doses was applied i.e. recommended dose, 75%, 50% and 25% of recommended dose. The main effects and interactions of the factors were studied. Eight types of weeds were observed throughout the experiment swine cress (*Cronopus didymus* L.), toothed dock (*Rumex dentatus* L.), sweet clover (*Melilotus indica* L.), pimpernel (*Anagalis arvensis* L.), Lambsquarter (*Chenopodium album* L.), field bindweed (*Convulvus arvensis* L.), *Avena fatua* L., *Phalaris minor* Retz. And burclover (*Medicago polymorpha* L.). Amongst the tillage systems in conventional tillage stand establishment, morphological and yield traits were better as compared to zero tillage. Similarly, hydro-primed treatment performed better as compared to non-primed showing more number of plants in final emergence count. Herbicide's reduced doses did not performe better as compared to recommended. More weeds were observed in zero tillage as compared to control but less in hydro-primed as compared to no-primed. Conventional tillage with hydroprimed seed under recommended dose of sulfusulfuron performed best and gave maximum grain yield (4.72 $t ha^{-1}$) and biological yield (11.70 $t\ ha^{-1}$).
Keywords: Hydropriming, Zero-tillage, Conventional Tillage, Dual purpose herbicide.

Introduction

Rice-Wheat cropping system occupies an area of 24 M ha in Asia with 13.5 M ha in South Asia (Anonymous, 2007). Wheat was cultivated on 9.039 million hectares which produced 25.3 million tonnes (Govt. of Pakistan, 2014). Rice is followed by wheat as major winter crop in rice-wheat cropping system, covering 2.8 million hectares of cultivated area of rice-wheat cropping system in Pakistan (FAO, 2004). Weeds responsible for yield loss of 48-52% (Khan and Haq, 2002). About 28 weed species belonging to different families are reported to infest wheat fields in Punjab-Pakistan (Anjum *et al*., 2002). The inverse relationship between weed biomass and crop yield at harvest indicates that weed suppression is directly translated into crop yield (Weiner *et al*., 2001). Weed infestation is a key issue contributing to direct loss in quality and quantity of the produce. It is the most persistent class of pest interfering with crop plants through competition and allelopathy (Gupta, 2004). Extensive use of herbicide is one of the major tools for managing weed population and maintains economical food supply in agriculturally developed countries. However, increasing herbicide resistant in certain weeds (Torra *et al*., 2010). Weed threshold is one of the key components of integrated weed management system (Jones and Medd, 2000) that helps the farmers to determine the necessity of herbicides application (Fleck *et al*., 2002; Portugal and Vidal, 2009). Bostrom and Fogelfors (2002) stated that the aim of weed management is to keep the weed population at an acceptable level rather than to keep the crop totally free of weeds. Nordblom *et al*. (2003) explained that as a general principle low dose of herbicide at favorable conditions can kill weeds while a higher rate of herbicide will be fail under unfavorable conditions. Post applied herbicides (2, 4-D +MCPA at 1.5 L ha^{-1}, bromoxynil+MCPA) at 1.5 L ha^{-1}, nicosulfuroan and furamsulfuron at 2 L ha^{-1} were applied in corn for weed control. Efficacy of nicosulfuron and furansulfuron against barnyard grass was good while against common purslane was moderate. All herbicides were safe for the crop (Pourazar and Baghestani, 2010). Barros *et al*. (2005) noted that reduced doses of mixture of herbicides diclofop-methyl+fenoxaprop-p-ethyl+mefenepir-diethyl can be used for effective control of *Loliumrigidum* G. than recommended dose in wheat.

One of the most important seed invigorations methods is "priming". Priming involves soaking of viable seeds in different solutions of low osmotic potential (Ruan *et al*., 2002) to initiate early events of germination without allowing radicle emergence and then drying seeds to their original weight before sowing (Tiriki *et al*., 2009). Hydropriming enhances seed germination, seedling growth and crop establishment (Meena *et al*., 2013). Planting density has been suggested as an effective tool in ameliorating the impact of weed competition (Khaliq *et al*., 2012). Early emergence of primed seed can ensure better crop stand establishment and crop cover (Basra *et al*., 2003). The possible loss in yield of the late sown wheat can be partially compensated by seed priming which not only improves the stand establishment but also triggers the growth (Kant *et al*., 2006). Seed priming is contributed to increase the speed and synchrony of seed germination, increased and accelerated germination, improved seedling establishment and enhanced plant growth (Pirasteh-Anosheh *et al*., 2011). Shivankar *et al*. (2003) noted hydropriming practically ensures rapid and uniform germination accompanied with low abnormal seedling percentage. Basra *et al*. (2006) who reported that hydro-primed seeds of sunflower and wheat could germinate faster and produced taller seedlings when compared with untreated seeds.

The composition of weed communities is greatly influenced by the tillage system (Arif*et al*., 2007). Certain types of weeds are controlled by tillage (Swanton *et al*., 2000); nonetheless tillage may also increase the emergence of other certain weed species (Shrestha *et al*., 2003). Sidhu *et al*. (2007) found that ZT is an alternative option which instantly cuts cultivation cost and makes possible 2-3 weeks early sowing through drill in previous crops residues. Conservation Tillage can provide some extra benefits, such as improving soil structure and raising soil organic matter levels (Peng and Horn, 2008; Rusu *et al*., 2009; Moraru and Rusu, 2010). Conservation agriculture offers a reasonable option to resolve the edaphic conflict in the conventional rice-wheat system (Hobbs *et al*., 2007). Wheat planting with conservation tillage is the most successful resource conservation technology in Indo-Gangetic Plains (Erenstein *et al*., 2008). Sans *et al*. (2011) noted that reduced tillage is a beneficial tool for organic cropping system, but proper management is required for perennial and monocotyledonous weeds, which are often problematic for annual crops. Calado *et al*. (2013) compared ZT and CT with post-emergence herbicide application and found there was more weed-crop competition of monocotyledonous weeds. In other studies, shifting from conventional tillage to zero tillage in wheat decreased input costs by 20-59% and increased net revenue by 28-33% (Aryal *et al*., 2014). In contrast, A few studies also showed little difference or even lower wheat yield under zero tillage than conventional tillage (Tahir *et al*., 2008; Tripathi *et al*., 2007). Liu *et al*. (2013) observed that conservation tillage practices considerably increases the soil moisture by regulating grain filling of wheat and this process is significantly relates to balance of hormones in the grains.

Materials and Methods

Experimental site

The proposed study was conducted at the Student Research Farm, Department of Agronomy, University of Agriculture Faisalabad (31° N latitude, 73° E longitude, and 184.4 m altitude) during winter 2013-2014 to find out the effects of tillage systems, hydropriming and reduced doses of herbicide on weed dynamics and productivity of wheat.

Soil

The experimental area belongs to Layallpur soil series (Haplicyermosols in FAO and aridisol-fine-silty, mixed, HaplargidhypertermicUstalfic in USDA classification scheme) (Cheema and Khaliq, 2000)

Plant Material

Seed of wheat cultivar “Punjab-2011” obtained from wheat research institute, Ayyub Agriculture Institute Faisalabad, Pakistan were used as experimental material.

Experimental design and layout

Diverse types of tillage systems, hydropriming and reduced doses of herbicide were arranged in randomized complete block design (RCBD) with split-split plot arrangement using three replications. Applied herbicide doses were; 25.5, 19.13, 12.75 and 6.38 g a.i ha^{-1}of sulfusulfuron. Tillage systems were kept in main plots, while hydroprimed seed and reduced herbicide doses were allotted to sub-plots and sub-sub-plots respectively. Net plot size was 5.0 m × 2.7 m. A wheat cultivar (Punjab-2011) was sown on 3rd, December 2013 using a seed rate of 125 kg ha^{-1}. Fertilizer was applied at the rate of 125 kg N, 75 kg P_2O_5, 60 K_2O kg ha^{-1} using urea (N 46%), diamonium phosphate (18% N, 46% P_2O_5) and sulphate of potash (50% K_2O). The whole of the phosphorus and potassium and half of the nitrogen is applied at the time of sowing. The remaining half nitrogen is applied in two equal splits with first and second irrigation. Five irrigations were given throughout the growth period of the crop. First irrigation was applied at the completion of germination, second after twenty-five days of first irrigation, third after twenty days of 2nd irrigation, fourth at the flowering time and the last irrigation was applied at the seed formation time. All other agronomic operations except those under study were kept normal and uniform for all the treatments. The crop was harvested on 16th of May 2014. The crop was threshed with small thresher (A Model by Naeem agricultural implement industry, Faisalabad). The produce obtained from each plot was cleaned and then weighed separately.

Results and Discussion

Final Emergence Count

Results indicated that hydropriming improved final emergence by 5%. Similarly, in conventional tillage emergence was 18% more than zero tillage. The interactive effect of priming treatments, tillage systems and weed control treatments (Table 1) was also significant ($p \leq 0.05$). Weed control treatments revealed significance ($p \leq 0.05$) but herbicide application at recommended dose and at 25% of recommended (6.38 g a.i ha^{-1}) were similar ($p \leq 0.05$), similarly sulfusulfuron at 50% of recommended (12.75 g a.i ha^{-1}) and weedy check were similar. Hydropriming enhanced seed germination, seedling growth and crop establishment (Meena *et al*., 2013). The poor performance of non-primed might be the result of failure of immediate availability of moisture to the seed as compared to hydroprimed seed.

Total weed density and dry biomass

Weed flora of the experimental site consisted of swine cress (*Cronopus didymus* L.), toothed dock (*Rumex dentatus* L.), sweet clover (*Melilotus indica* L.), pimpernel (*Anagalis arvensis* L.), Lambs quarter (*Chenopodium album* L.), field bindweed (*Convulvus arvensis* L.), *Avena fatua, Phalaris minor* Retz. and burclover (*Medicago polymorpha* L.).

Total weed density (m^2) 40 days after sowing (DAS)

Total weed density (40 DAS) showed that all weed control treatments significantly ($p \leq 0.05$) reduced weed density over weedy check (Table 2). Recommended herbicide dose with hydropriming treatment under conventional tillage system gave 84% weed suppression as compared to weedy check. Similarly, application of 75, 50 and 25% of recommended dose of herbicide gave 58, 44 and 28% of weed suppression as compared to weedy check respectively. Less number of weeds were recorded in conventional tillage as compared to zero tillage. Similarly, hydropriming also significantly suppressed weeds as compared to no-priming. The interactive effect of tillage, priming and herbicide application was also significant ($p \leq 0.05$) for weed density. Sharma and Chandar (1996) and Anil and Bhan (1998) reported higher weed density in weedy check. Hydropriming enhances seed germination, seedling growth and crop establishment (Meena *et al*., 2013) so in this way weeds were suppressed by priming. The results relating to herbicide were contradictory to Barros *et al.* (2007) who reported that mixture of herbicide could be used at low rate than recommended one, but in present study sulfusulfuron was used alone at reduced rate

Total weed density (m^2) 60 days after sowing (DAS)

The total weed density (60 DAS) was significantly ($p \leq 0.05$) suppressed by various weed control treatments over weedy check (Table 2). Recommended herbicide dose with hydropriming treatment under conventional tillage system gave 82% weed suppression as compared to weedy check. Similarly, application of 75, 50 and 25% of recommended dose of herbicide gave 76, 44 and 27% weed suppression, respectively as compared to weedy check. Hydropriming significantly reduced weeds as compared to no-priming. The interactive effect of tillage, priming and herbicide application was non-significant ($p \leq 0.05$) for weed control. Less number of weeds were recorded in conventional tillage as compared to zero tillage. Hydropriming showed better crop stand establishment that led to less weed-crop competition. Mishra and Singh (2012) reported that total weed density was 66% lower in herbicide treated than in untreated plots. Better stand establishment increases competitiveness against weeds and ultimately maximizes yields (Clark *et al*., 2001) that was obtained by priming techniques. It was further reported that sulfusulfuron herbicide controls winter annual grass weeds effectively (Olson *et al*., 2000).

Total weed dry biomass (g m^{-2}) 40 days after sowing (DAS)

Total weed dry biomass (40 DAS) showed that variable weed control treatments significantly ($p \leq 0.05$) reduced total weed dry biomass (Table 3). Recommended herbicide dose with hydropriming treatment under conventional tillage system gave 79% weed dry biomass suppression as compared to control. Application of 25% herbicide dose did not suppress dry biomass of weeds to significant level. However, 75 and 50% of the recommended doses suppressed weed dry biomass by 44 and 31%, and were similar ($p \leq 0.05$) to each other in this regard. Interactive effect of weed control treatment and tillage systems was significant. The interactive effect of tillage, priming and herbicide application was non-significant ($p \leq 0.05$) for weed dry biomass. However, priming did not influence the weed dry biomass to significant level as compared with non-primed plots. Shehzad *et al.* (2012) reported that weed biomass was severely affected by post-emergence weed control treatments.

Table: 1 Influence of tillage systems and seed priming treatments with weed control treatments on final germination count of wheat.

Weed control treatments	Zero Tillage		Conventional Tillage		Means
	No Priming	Hydro Priming	No Priming	Hydro Priming	
Weedy check	156.0 l	170.0 i	189.3 e	200.0 c	178.8 C
Weed free	158.3 k	173.0 h	191.0 d	211.0 a	183.3 A
Sulfusulfuron(25.5g a.i ha^{-1}; Recommended (R))	155.0 lm	173.0 h	186.0 g	209.0 b	180.8 B
Sulfusulfuron (19.13 g a.i ha^{-1}; 75% of R)	154.0 m	163.3 j	186.0 g	208.7 b	178.0 D
Sulfusulfuron (12.75 g a.i ha^{-1}; 50% of R)	156.0 l	163.3 j	187.3 f	209.0 b	178.9 C
Sulfusulfuron (6.38 g a.i ha^{-1}; 25% of R)	155.7 l	171.0 i	188.0 f	208.0 b	180.7 B
Means (P)	155.8 D	168.9 C	187.9 B	207.6 A	
Main effects (Means)	ZT = 162.4 B,	CT = 197.8 A,	NP = 171.9 B,	HP = 179.9 A	
HSD (p≤0.05)	P = 0.15, T = 0.15, T×P = 0.29, W = 0.39, T = T×P×W = 1.16				
Tukey's **HSD =** (Honest Significant Difference)					

Means sharing a letter in common (for all interactions and main effects) don't differ significantly at 5% level of probability; T= Tillage, W= Weed control treatment. P= Priming, ZT= zero tillage, CT= conventional tillage, NP= no priming, HP= hydropriming.

Table: 2 Influence of tillage systems and seed priming with weed control treatments on weed density (m^2) of weeds at 40 and 60 DAS of wheat

Weed control treatments	40 Days After Sowing (DAS)					60 Days After Sowing (DAS)				
	Zero Tillage		Conventional Tillage		Means	Zero Tillage		Conventional Tillage		Means
	No Priming	Hydro Priming	No Priming	Hydro Priming		No Priming	Hydro Priming	No Priming	Hydro Priming	
Weedy check	55 a	38.6 b	31 bc	29.3 bc	38.50 A	57.33	31.33	32	28	37.17 A
Weed free	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Sulfusulfuron (25.5 g a.i ha^{-1}; Recommended (R))	12.0 f-h	08.0 g-i	4.0 hi	0.67 i	06.17 E	8.66	9.67	2.67	6.33	06.83 D
Sulfusulfuron (19.13 g a.i ha^{-1}; 75% of R)	26.0 cd	17.33 d-g	12.67 f-h	8.33 g-i	16.08 D	17.33	12	11.33	10	12.67 D
Sulfusulfuron (12.75 g a.i ha^{-1}; 50% of R)	29.33 bc	25.33 c-e	16 d-g	15.33 e-g	21.50 C	30	16	21.33	15.33	20.67 C
Sulfusulfuron (6.38 g a.i ha^{-1}; 25% of R)	38.0 b	29.33 bc	22.0 c-f	21.33 c-f	27.67 B	45.33	20.66	25.33	17.33	27.17 B
Means (P)	26.72	19.77	14.27	12.50		26.44	14.94	15.44	12.83	
HSD (p≤0.05)	**T × P × W = 8.85,**	**T × P = NS,**	**W = 3.40**			**T × P × W = NS,**	**T × P = NS,**	**W = 5.87**		
Tukey's **HSD =** (Honest Significant Difference)		**NS** = Non-Significant								

Means sharing a letter in common (for all interactions and main effects) don't differ significantly at 5% level of probability; T= Tillage, W= Weed control treatment, P= Priming.

Table: 3 Influence of tillage systems and seed priming treatments with weed control treatments on weeds dry biomass (gm^{-2}) of weeds at 40 and 60 DAS of wheat

Weed control treatments	**40 Days After Sowing (DAS)**					**60 Days After Sowing (DAS)**				
	Zero Tillage		**Conventional Tillage**		**Means**	**Zero Tillage**		**Conventional Tillage**		**Means**
	No Priming	**Hydro Priming**	**No Priming**	**Hydro Priming**		**No Priming**	**Hydro Priming**	**No Priming**	**Hydro Priming**	
Weedy check	4.49	3.58	2.63	3.07	3.45 A	24.09	11.63	7.9	7.2	12.71 A
Weed free	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Sulfusulfuron (25.5 g a.i ha^{-1}; Recommended (R))	1.30	0.86	0.53	0.16	0.72 C	1.95	1.82	0.97	1.37	1.53CD
Sulfusulfuron (19.13 g a.i ha^{-1}; 75% of R)	2.44	2.07	1.83	1.13	1.94 B	7.35	3.30	2.4	3.07	4.03 C
Sulfusulfuron (12.75 g a.i ha^{-1}; 50% of R)	2.77	2.46	2.43	1.8	2.37 B	12.47	5.77	4.63	4.23	6.78 B
Sulfusulfuron (6.38 g a.i ha^{-1}; 25% of R)	3.42	3.16	2.83	2.43	2.96 A	15.56	6.73	6.1	6.57	8.74 B
Means (P)	2.41	2.02	1.71	1.43		10.24	4.87	3.67	3.74	
HSD ($p \leq 0.05$)	**T × P × W = 8.85,**		**T × P = NS,**		**W = 0.52**	**T × P × W = NS,**		**T × P = NS,**		**W = 2.65**

Tukey's **HSD =** (Honest Significant Difference) **NS** = Non-Significant

Means sharing a letter in common (for all interactions and main effects) don't differ significantly at 5% level of probability; T= Tillage, W= Weed control treatment, P= Priming.

Table 4. Determining effect of different tillage systems, seed pre-treatment and different weed control treatments on wheat yield attributes

Treatments	Plant Height (cm)	Number of productive tillers (m^2)	Number of Spikelets per spike	Number of grains per spike	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})
Tillage Systems							
T_1	89.41 B	260.53 B	11.58 B	34.50 B	33.35 B	7.10 B	2.76 B
T_2	94.77 A	325.39 A	12.30 A	36.74 A	35.68 A	9.90 A	4.02 A
HSD ***($p \leq 0.05$)***	**2.08**	**25.62**	**0.62**	**1.91**	**0.64**	**0.25**	**0.11**
Seed Priming							
P_1	91.26	285.08 B	11.77 B	35.08 B	33.66 B	7.95 B	3.14 B
P_2	92.91	300.83 A	12.12 A	36.16 A	34.83 A	9.05 A	3.64 A
HSD ***($p \leq 0.05$)***	**1.45**	**8.39**	**0.29**	**0.64**	**0.64**	**0.25**	**0.11**
Weed control Treatments							
W_1	89.62 C	269.42 D	11.02 E	32.76 E	30.60 E	6.39 E	2.44 E
W_2	95.94 A	331.67 A	13.06 A	39.08 A	38.37 A	11.44 A	4.72 A
W_3	93.51 AB	310.25 B	12.51 B	37.39 B	37.01 B	9.91 B	4.03 B
W_4	91.93 BC	290.42 C	12.05 BC	35.96 BC	35.51 C	8.62 C	3.44 C
W_5	91.24 BC	281.0 CD	11.69CD	34.87 CD	34.04 D	7.79 D	3.07 D
W_6	90.28 C	275.0 CD	11.31 DE	33.65 DE	31.55 E	6.86 E	2.65 E
HSD ***($p \leq 0.05$)***	**2.86**	**16.68**	**0.50**	**1.56**	**1.02**	**0.65**	**0.29**

Any two means not sharing a letter in common in a column differ statistically at 5% probability level; T_1= zero tillage; T_2= Conventional tillage; P_1= No-priming; P_2= Hydro-priming; W_1= weedy check; W_2= Weed free; W_3= Sulfusulfuron (25.5 g a.i ha^{-1}Recommended);W4= Sulfusulfuron (19.13 g a.i ha^{-1}; 75% of Recommended); W5= Sulfusulfuron (12.75 g a.i ha^{-1}; 50% of Recommended); W6= Sulfusulfuron (6.38 g a.i ha^{-1}; 25% of Recommended);ns= non-significant

Total weed dry biomass (m^2) 60 days after sowing (DAS)

Data regarding total weed dry biomass **(**60 DAS) showed that all weed control treatments significantly ($p \leq 0.05$) reduced total weed dry biomass (Table 3). Recommended herbicide dose with hydropriming treatment under conventional tillage system gave 79% weed dry biomass suppression as compared to weedy check. Application of 25 and 50% of recommended dose suppressed dry biomass of weeds but were similar ($p \leq 0.05$) in this regard. Application of recommended and 75% doses reduced dry biomass but were similar ($p \leq 0.05$). Interactive effect of weed control treatment into tillage systems was significant ($p \leq 0.05$). Priming also influenced total weed dry biomass significantly against non-primed treatment. The interactive effect of tillage, priming and herbicide application was non-significant ($p \leq 0.05$). Interactive effect of weed control treatment into tillage systems was significant. Kumar *et al*. (2013) noted that with every 1 g m^{-2} increase in weed dry weight, the grain yield of wheat was expected to fall by 41.55 kg ha^{-1}. Akhtar *et al*. (2000) reported that increased weed crop competition resulted in increased weed biomass.

Yield Attributes

Plant Height (cm)

Data (Table 4) indicated that all treatments significantly improved the plant height over weedy check. Maximum plant height (95.94 cm) was recorded in weed free plots which was similar ($p \leq 0.05$) with that (93.51 cm) obtained by application of sulfusulfuron at recommended dose. Better plant height (94.77 cm) in conventional tillage as compared to zero tillage (89.41 cm) was recorded which differ significantly ($p \leq 0.05$). Similarly, hydropriming significantly ($p \leq 0.05$) improved the plant height (92.91 cm) and less height (91.26) recorded in non-primed. Ali *et al*. (2013) stated that seed priming treatments increases plant height and Hamidi *et al*. (2013) who reported that both halo-and-hydro-priming increased plant height. Kumar *et al*. (2013) noted that due to weeds there was less plant height.

Number of Productive tillers (m^2)

Data pertaining to the number of productive tillers (Table 4) revealed significant ($p \leq 0.05$) difference of weed control treatments on it. Maximum number of productive tillers (331.67 m^{-2}) was recorded in weed free plots and was followed by treatment where sulfusulfuron was applied at recommended dose (310.25 m^{-2}).In conventional tillage 20% more number of productive tillers were produced as compared to zero tillage. In hydroprimed 5% more tillers were produced as compared to non-primed (Table 4.23). Ali *et al*. (2013) stated that the number of productive tillers also improved by different priming techniques.

Number of Spikelets per spike

A perusal of the data regarding number of spikelets per spike (Table 4) indicated the significant influence of all weed control treatments on it. Maximum number of spikelets per spike (13.06) was recorded in weed free plots followed by treatment where sulfusulfuron at recommended dose was applied (12.51). Application of recommended dose and 75% of recommended dose were similar ($p \leq 0.05$). Similarly, 50 and 25% of recommended dose were similar ($p \leq 0.05$) with respect to number of spikelets per spike. In conventional tillage, 6% more number of spikelets per spike were recorded as compared to zero tillage. In priming treatments primed produced 3% more number of spikelets per spike as compared to non-primed. Ekeleme *et al*. (2007) found that weed removal enhanced the spikelets production significantly, uncontrolled weed growth reduced spikelet number by 38%.

Number of grains per spike

Data (Table 4) revealed that maximum number of grains were recorded in weed free plot. All of the treatments significantly ($p \leq 0.05$) affected number of grains. Amongst all herbicide doses, maximum number of grain was recorded with the application of recommended dose and was at par ($p \leq 0.05$) with that recorded for 75% of recommended dose of sulfusulfuron. Zero tillage and conventional tillage recorded significantly ($p \leq 0.05$) different number of grains per spike. Conventional tillage produced 6% more number of grains compared to zero tillage. Similarly, hydropriming recorded 3% more number of grains per spike ($p \leq 0.05$) as compared to non-primed seeds. Chaudhry *et al*. (2008) noted that maximum number of grains were recorded in plots where weed infestation remained for 30 DAS followed by weeds allowed to grow for 40, 50 and 60 days.

1000-grain weight

Data (Table 4) revealed that significantly maximum ($p \leq 0.05$) 1000-grain weight (38.37 g) for weed free plots and was followed by 37.01g for the recommended dose of sulfusulfuron. Application of 25% of the recommended dose application failed to improve 1000-grain weight over weedy check significantly ($p \leq 0.05$). There was significant effect of priming treatments on 1000-grain weight. Hydropriming improved (3.4%) grain weight as compared to non-primed. Ali *et al*. (2013) stated that seed priming treatments increased 1000-grain weight.

Siddique *et al*. (2010) reported that 1000-grain weight of wheat was significantly reduced by increase in weed density and dry biomass.

Biological yield (t ha^{-1})

All the treatments significantly ($p \leq 0.05$) affected the biological yield (Table 4). Maximum biological yield was recorded in weed free plots (11.44 t ha^{-1}) and was followed by sulfusulfuron (8.91 t ha^{-1}) applied at recommended dose. Both were 44 and 36% higher than weedy check, respectively. Weedy check and sulfusulfuron at 25% of recommended dose were similar ($p \leq 0.05$). Hydropriming improved ($p \leq 0.05$) biological yield by 12% as compared to no-priming (Table 4.38). The interactive effect of tillage and weed control treatments was non-significant while in tillage systems there was 30% more biological yield in conventional tillage as compared to zero tillage. Ali *et al*. (2013) reported that seed priming treatments increased biological yield. Significant increase in total biological yield of crops due to weed control methods also been reported by Pandey and Mishra (2002) and Roslon and Fogelfors (2003).

Grain yield (t ha^{-1})

Data regarding grain yield (Table 4) indicated that all weed control treatments significantly ($p \leq 0.05$) enhanced it as compared to weedy check. Maximum grain yield (4.72 t ha^{-1}) was recorded for weed free plots and was followed by grain yield of 4.03 t ha^{-1} recorded for recommended dose of sulfusulfuron. Grain yield was 48 and 39% higher in weed free and with recommended dose of sulfusulfuron, respectively, and the difference between the latter two doses of herbicides was 11%. Weedy check and Application of sulfusulfuron at 25% of recommended dose failed to improve grain yield (2.65 t ha^{-1}) significantly ($p \leq 0.05$) as compared with weedy check (2.44 t ha^{-1}). Hydropriming improved ($p \leq 0.05$) grain yield by 14% as compared to no-priming. In tillage systems there was 31% more grain yield was recorded in conventional tillage as compared to zero tillage. A few studies reported little difference or even lower wheat yield under zero tillage than conventional tillage (Tahir *et al*., 2008; Tripathi*et al*., 2007). In wheat, losses because of weeds were testified higher in ZT compared with CT in ZT wheat. (Chhokar*et al*., 2007, 2009).

Conclusion

Altogether, sulfusulfuron @ 25.5 g a.i ha^{-1} could be suggested as suitable dose for proper weed control in wheat. In hydroprimed seed, weeds were suppressed and grain yield was improved. In tillage systems, conventional tillage was better than zero tillage relating to weed suppression and wheat yield. Similar studies need to be carried out under varying soil and environmental conditions in various field crops.

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