

## MANIPULATION OF AGRO-MANAGEMENT PRACTICES FOR WEED CONTROL AND ENHANCING WHEAT PRODUCTIVITY

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### ABSTRACT

Zero tillage and narrow row spacing can interactively supplement the herbicide performance in Wheat. Field studies were undertaken to evaluate the effect of tillage systems [zero tillage (ZT) and conventional tillage (CT)], row spacing (11.25, 15.00 and 22.50 cm), and herbicide application on weed dynamics and productivity of wheat in triplicated RCBD split-split arrangement. Results depicted that ZT reduced total weed density by 21% and dry biomass by 24% and 17% as compared with CT system during 2010-2011 and 2011-2012, respectively at 60 days after sowing (DAS). Application of herbicides also recorded up to 70% suppression of weed density and dry biomass at 60 DAS. Efficient weed control achieved by herbicide application in crop sown under ZT in narrow row spacing (11.25 cm), that recorded higher grain yield and yield components. Among herbicide treatments, isoproturon+carfentrazone application was found most effective treatment in improving wheat grain yield and its components. Application of isoproturon+carfentrazone gained maximum net benefits (Rs. 148281 and 148838 ha<sup>-1</sup> during 2010-2011 and 2011-2012, respectively) under ZT system and row spacing (11.25 cm). Conclusively, ZT, narrow row spacing and isoproturon+carfentrazone application reduced weed growth and enhanced wheat grain yield, suggesting that these approaches could contribute to weed management in wheat fields.

**Key words:** Herbicide application, narrow row spacing, weeds, wheat yield, zero tillage.

### INTRODUCTION

Wheat (*Triticum aestivum* L.) is a staple food in Pakistan and has a vital role to ensure food security in the country. In the back drop of increasing population and escalating food prices, any effort to enhance wheat production can play an important role in stabilizing the food prices directly or indirectly (Marwat *et al.*, 2011) and hence help to achieve food security. Delayed sowing, edaphic conflict of traditional rice-wheat cropping system, non-availability of quality seed, imbalanced use of fertilizers, shrinking irrigation resources and weed infestation are the major constraints limiting wheat productivity in Pakistan (Jamil, *et al.*, 2004). Weed infestation is a major constraint, accounting for more than 48% loss of potential wheat yields (Khan and Haq, 2002). By proper weed management wheat production could be improved by more than one million tons annually in Pakistan (Khan *et al.* (2011).

Herbicides are used for weed control in modern agriculture because they are highly effective against most weed species (Harker and Donovan, 2013). Out of total import of herbicides worth Rs.2.2 billion, 63% were used on wheat crop alone in Pakistan (Ashiq *et al.*, 2006). Satisfactory weed control in wheat can be achieved by the application of herbicides (Malik *et al.*, 2009). Herbicides are also reported to move agro-ecosystem towards declining species diversity besides causing

changes in structure and behavior of weed populations (Mahajan *et al.*, 2011). Such negative consequences of herbicide usage can be lessened to a great extent by adopting an Integrated Weed Management (IWM) approach (Alsaadawi *et al.*, 2013). There is growing consensus in recent years to manipulate cultural practices in conjunction with herbicides as an IWM tactic (Chauhan and Johnson, 2010). Integrating herbicides with cultural practices can have a broader impact on weeds and should be optimized with other agronomic practices that govern both crop and weed growth and their association. Such measures comprise of tillage, stale seed bed, planting time, crop residual mulching (surface or incorporated), intercropping, row spacing and seeding densities (Alsaadawi *et al.*, 2011). Manipulation of cultural practices like tillage and row spacing has gained researcher's attention as an integral component of IWM programs (Usman *et al.*, 2010).

Herbicides play an important role in facilitating adoption of ZT practices (Heap, 2012). Herbicide use has increased in CT as well as in ZT systems because it provides effective and economical weed control (Rao *et al.*, 2007) so that their efficacy varies in response to weed flora and site characteristics in ZT systems (Singh *et al.*, 2007). Tillage systems influence the crop and weed emergence by altering physico-chemical characteristics of the seedbed (Buhler, 1997), and have the potential to influence floristic composition of weed communities by changing their vertical seed distribution in the soil profile

(Buhler, 1995), dormancy and seed bank dynamics (Chauhan and Johnson, 2010). Tillage-herbicide-weed interaction can have definite implications for crop growth and yield (Acciaresi *et al.*, 2003). ZT even helped in managing weeds like canary grass that had developed resistance against isoproturon and other herbicides of urea group (Yadav and Malik, 2005). The virtue to control herbicide resistant canary grass due to reduced soil movement associated with ZT makes it promising technology for the Indo-Gangetic Plains (Mehta and Singh, 2005).

Field crops especially the cereals are planted in distinct rows with various row spacing and plant densities (Chen *et al.*, 2008). Optimal row spacing plays crucial role to improve the crop productivity as plants growing in too wider rows may not efficiently utilize the light, water and nutrient resources; whereas growing in too narrow rows may result in severe inter-row competition (Hussain *et al.*, 2012). Sowing crop in narrow rows imparts a competitive edge over weeds due to early and rapid canopy closure (Chauhan and Johnson, 2010). Wider crop rows facilitate weed control by inter-cultural operations; herbicides can effectively control both inter- and intra-row weeds in narrowly spaced crops (Bilbro and Fryrear, 1994). Narrow row spacing can provide supplemental weed control aiding to herbicide efficacy (Grichar *et al.*, 2004).

Agricultural productivity is under intermittent and pervasive menace due to the presence of weeds in agricultural fields even after the repetitive application of weed control measures (Riaz *et al.*, 2009). Effective weed control cannot be achieved through sole dependence on one method of weed control. Therefore, an integrated approach should be developed which not only effectively controls the weeds but also ensures the agricultural crop production on sustainable basis (Chauhan *et al.*, 2012). Information on the influence of tillage, herbicides, row spacing and their possible interactions on herbicide performance in wheat is lacking. It is hypothesized that ZT and narrow row spacing can interactively supplement the herbicide performance in wheat. Therefore, the present study was carried out for two years to quantify growth of wheat and associated weeds under different tillage systems and row spacing, and assess herbicide efficacy under such agronomic practices.

## MATERIALS AND METHODS

**Site description:** Field experiments were conducted at Agronomic Research Farm, Department of Agronomy, University of Agriculture, Faisalabad (184 m asl, longitude 73°74 East, latitude 30°31.5 North).

The soil had a pH of 7.6, organic matter 0.71%, total nitrogen 0.062%, phosphorus 13.1 ppm and potassium 179 ppm. The meteorological data during the course of crop growth were obtained from Agro. Met.

Observatory, Department of Crop Physiology, are presented in Fig. 1.

**Experimentation:** Experiment was carried out for two growing seasons, i.e. winter 2010-11 and 2011-12 and comprised of three factors (1) tillage systems as zero tillage (ZT) and conventional tillage (CT), (2) row spacing (11.25, 15.00 and 22.5 cm) and (3) weed management through broad-spectrum post-emergence herbicides. (1) iodo-mesosulfuron at 15 g a.i ha<sup>-1</sup> + 240 ml adjuvant, (2) pinoxaden at 37 g a.i ha<sup>-1</sup> + bromoxynil+MCPA at 445 g a.i ha<sup>-1</sup>, (3) and isoproturon+carfentrazone at 1000 g a.i ha<sup>-1</sup> were applied as early post-emergence at 30 DAS; (days after sowing). Season long weedy (weedy check) and weed-free plots were maintained for comparison., Wheat was sown on 11<sup>th</sup> November in year 2010-11 and 15<sup>th</sup> November in 2011-12, respectively in ZT plots into undisturbed soil after rice harvest using a single row hand drill in a single pass operation. Sowing in CT plots was achieved by plowing the soil with a disc plow, and then cultivating thrice with a tractor mounted cultivator followed by planking each time. A randomized complete block design (RCBD) with split-split arrangement employing three replications was used. Tillage systems were kept in main plots, while row spacing and weed control treatments were assigned to sub- and sub-sub-plots, respectively. The net plot size was 8 m × 1.8 m. The previous crop in main plots was direct seeded rice that also received the same tillage practices as for the preceding wheat crop. Glyphosate (Roundup, Monsanto Agritech, Pakistan) was applied in ZT plots 20 days before sowing to curtail established weeds that were controlled through cultivation in CT. Seed of wheat cv. Sehar-2006 was collected from Wheat Research Institute, Ayub Agricultural Research Institute, Faisalabad. Seed rate of 100 kg ha<sup>-1</sup> was used in the experiment. A fertilizer dose of nitrogen (N) at 120 kg ha<sup>-1</sup> and phosphorus (P<sub>2</sub>O<sub>5</sub>) at 85 kg ha<sup>-1</sup> was applied in the form of urea (46% N) and diammonium phosphate (DAP 18% N; P<sub>2</sub>O<sub>5</sub> 46%), respectively. One third of the nitrogen and whole of phosphorus was applied at the time of sowing and the remaining N was applied in two equal splits at jointing and booting stages. The first irrigation was given 10 days after crop emergence and subsequent irrigations were given at critical crop stages (tillering, booting, anthesis and grain development). In all, five irrigations each of 7.50 cm depth were applied during the whole season. Irrigation was skipped if there was effective rainfall at any time.

**Data Collection:** Data on weed density and dry biomass were recorded from two randomly selected quadrats of 50 cm × 50 cm (0.25 m<sup>2</sup>) from each plot at 60 DAS. Weeds within quadrat were identified, counted and clipped off above soil surface. These were kept separately in respective Kraft paper bags and oven dried at 70 °C for

72 h to record their dry biomass using a digital balance (TX323L, Shimadzu, Japan). The average of two quadrats was computed and used for further analyses. Total number of productive tillers was counted from two randomly selected sites of one square meter (100 × 100 cm) in each plot and averaged thereof. Individual spikes from ten randomly selected tillers were threshed separately. Number of grains was counted and average was computed. Two random samples of 1000-grains were drawn from the produce of each plot and weighed on an electric balance to obtain 1000-grain weight. The crop was harvested manually on April 25 and 30 during 2011 and 2012, respectively. After harvesting, crop was tied into bundles; total weight of bundles was recorded and after threshing grain weight was recorded for each plot and was converted into t ha<sup>-1</sup>.

Economic analyses based on variable costs and prevailing market prices of herbicides and wheat were carried out. Gross income and net benefit (the value of increased yield produced as a result of weed management practices, less the cost of such practices) was computed as described by CIMMYT (1988).

**Statistical Analyses:** All the data were statistically analyzed by employing the Fisher's analysis of variance technique (Steel *et al.*, 1997) and differences among treatment's means were separated using Tukey's honest significance difference (HSD) test at *P* 0.05. Data were analyzed separately for two growing seasons. Regression analyses were carried out to ascertain relationship between different variables.

## RESULTS

**Weed dynamics:** ZT plots recorded significantly less (21%) weed density than CT during both the years at 60 DAS (Table 1). During 2010-2011, total weed density in plots sown in 11.25 and 15.00 cm spaced rows was suppressed by 34 and 19%, respectively as compared with row spacing of 22.50 cm. The corresponding reduction amounted to 30 and 16% during 2011-12. All the herbicide treated plots significantly reduced weed density by 60-69% as compared with weedy check; nevertheless, weed density remained statistically similar (*p* 0.05) for all weed control treatments during both years. Significant differences for weed density were also observed between years, and total weed density at 60 DAS was 21% higher in 2<sup>nd</sup> year as compared with that in 1<sup>st</sup> year (Table 1).

Significantly less weed dry biomass (24 and 17% during 2010-2011 and 2011-2012, respectively) was recorded at 60 DAS under ZT as compared with CT system (Table 2). Herbicide application significantly (*p* 0.05) reduced total weed dry biomass over weedy check; nevertheless, all herbicide treatments exhibited statistically similar (59-72 and 50-59%) level of weed

suppression during both the years. Total weed dry biomass showed gradual reduction as the row spacing was narrowed. Crop sown in 11.25 and 15.00 cm spaced rows recorded 21-35% and 15-28% less weed dry biomass than that sown in 22.50 cm row spacing during 2010-11 and 2011-12, respectively. Total weed dry biomass also varied significantly between years and 26% less weed dry biomass was noticed during 2010-2011 than 2011-2012 at 60 DAS (Table 2).

**Wheat Crop:** Plots sown under ZT recorded 24% and 20% more productive tillers (m<sup>-2</sup>) than CT during 2010-2011 and 2011-2012, respectively. Among row spacing treatments, more number of productive tillers (m<sup>-2</sup>) was observed in plots sown in narrow spaced (11.25 cm) crop rows (466 and 443 tillers m<sup>-2</sup> during 2010-11 and 2011-12, respectively) (Table 3). Maximum number of productive tillers was recorded in weed-free plots during both years (469 and 436 m<sup>-2</sup> during 2010-11 and 2011-2012, respectively); however, during 2011-2012, weed-free plot was statistically at par (*p* 0.05) with plots treated with isoproturon+carfentrazone (419 m<sup>2</sup>) for number of productive tillers. In ZT plots, number of grains per spike was 6% higher than that in CT plots. During 2010-2011, higher number of grains per spike was noticed in plots sown under row spacing of 11.25 (49.79) and 15.00 cm (49.21); nonetheless, during 2011-12 row spacing of 15.00 (46.53) and 22.50 cm (47.60) recorded higher number of grains per spike. During 2010-11, higher (10%) number of grains per spike was observed in weed free plots which were statistically at par (*p* 0.05) with iodo+mesosulfuron, and isoproturon + carfentrazone. All the tested herbicides were statistically similar with each other and with weed free plots during 2011-12. Furthermore, more number of grains per spike (5%) was noticed during 2010-2011 as compared to 2011-2012 (Table 4). In both years, ZT plots furnished higher (5%) 1000-grain weight than that with CT system. In 2010-11, weed free plots were statistically similar (*p* 0.05) with all herbicide treated plots. However, in 2011-12, weed free plots and all herbicide treated plots recorded statistically (*p* 0.05) similar but significantly higher (9%) 1000-grain weight than weedy check plots. Furthermore, row spacing of 11.25 cm and 15.00 cm recorded higher (3%) 1000-grain weight and were statistically similar (*p* 0.05) with each other during 2010-2011. However, during 2011-2012, plots under row spacing of 22.50 cm recorded more 1000-grain weight and it was statistically similar with the plots under spacing of 15.00 cm (Table 5). While, minimum 1000-grain weight was recorded in plots with 11.25 cm row spacing which was statistically at par (*p* 0.05) with 15.00 cm crop rows (Table 5). The ZT plots also recorded 16% and 12% higher grain yield of wheat during 2010-2011 and 2011-2012 growing seasons, respectively as compared with that recorded under CT system. Regarding

weed control treatments, maximum grain yield was recorded by weed free plots during both the years (5.04 and 5.08 t ha<sup>-1</sup> during 2010-2011 and 2011-2012, respectively). Plots treated with iodo+mesosulfuron and isoproturon + carfentrazone were statistically similar with weed-free plots during both years. Isoproturon + carfentrazone treated plots recorded higher grain yield (38 and 34% during 2010-2011 and 2011-2012, respectively). In 2010-11, narrowly spaced crop rows 11.25 and 15.00 cm recorded maximum (19 and 8%) grain yield. However, in 2011-12, it was achieved by 19 and 12% in narrow row spacing of 11.25 and 15 cm respectively. In 2010-2011, wheat grain yield was 6% higher than that recorded in 2011-2012 (Table 6).

Application of isoproturon+carfentrazone to plots sown under row spacing (11.25 cm) and ZT system gained maximum net benefits (Rs. 148281 and 148838 ha<sup>-1</sup> during 2010-2011 and 2011-2012, respectively). Under CT system, highest net benefit was observed for plots treated with isoproturon + carfentrazone during

2010-2011 (Rs. 146625 ha<sup>-1</sup>) and weed free plots sown in narrow rows (11.25 cm) during 2011-2012 (Rs. 148363 ha<sup>-1</sup>).

**Relationship among weed dry biomass, wheat grain yield and number of productive tillers:** In order to determine the relationships among different attributes, coefficients of determination (R<sup>2</sup>) and correlation coefficients (r) were calculated. Data (Table 7) depicted a strong negative association of weed dry biomass with number of productive tillers (R<sup>2</sup>=0.77-0.99) and grain yield (R<sup>2</sup>= 0.61-0.96) of wheat under different row spacing and tillage systems during both years. Nevertheless, number of tillers manifested a positive linear relationship with grain yield under different row spacing and tillage systems. The relationships of grain yield with weed dry biomass and number of productive tillers were significant for all the treatments except 22.50 cm row spacing under ZT in 2010-11 (Table 7).

**Table 1. Interactive effect of tillage and row spacing with weed control treatments on total weed density (m<sup>2</sup>) at 60 DAS in wheat**

Year	2010-11				2011-12			
	TS × WC							
	Tillage systems (TS)			Tillage systems (TS)				
Weed control treatments (WC)	ZT	CT	Mean WC	ZT	CT	Mean WC		
WC <sub>1</sub> : Iodo+mesosulfuron	37.44 (-61)	49.11 (-59)	<b>43.28 B (-60)</b>	46.11 (-58)	60.33 (-56)	<b>53.22 B (-57)</b>		
WC <sub>2</sub> :Pinoxaden+(bromoxynil+MCPA)	33.33 (-66)	45.00 (-63)	<b>39.17 B (-64)</b>	43.00 (-61)	57.56 (-58)	<b>50.28 B (-59)</b>		
WC <sub>3</sub> : Isoproturon+carfentrazone	30.89 (-68)	37.11 (-69)	<b>34.00 B (-69)</b>	40.44 (-63)	48.06 (-65)	<b>44.25 B (-64)</b>		
WC <sub>4</sub> : Weedy check	96.78	119.78	<b>108.28 A</b>	110.33	137.33	<b>123.83 A</b>		
Mean TS	<b>49.61 B</b>	<b>62.75 A</b>		<b>59.97 B</b>	<b>75.82 A</b>			
HSD ( <i>p</i> 0.05)	TS= 4.834, WC =14.463 , TS ×WC= ns			TS =6.538 , WC =12.534 , TS×WC =ns				
	Row spacing (RS)				Row spacing (RS)			
Weed control treatments (WC)	11.25 cm	15.00 cm	22.50 cm	Mean WC	11.25 cm	15.00 cm	22.50 cm	Mean WC
WC <sub>1</sub> : Iodo+mesosulfuron	36.00 (-60)	40.67 (-63)	53.17 (-58)	<b>43.28 B (-60)</b>	45.33 (-57)	51.17 (-59)	63.17 (-55)	<b>53.22 B (-57)</b>
WC <sub>2</sub> :Pinoxaden+(bromoxynil+MCPA)	28.33 (-68)	38.33 (-65)	50.83 (-59)	<b>39.17 B (-64)</b>	38.67 (-63)	50.17 (-60)	62.00 (-56)	<b>50.28 B (-59)</b>
WC <sub>3</sub> : Isoproturon+carfentrazone	25.83 (-71)	32.50 (-70)	43.67 (-65)	<b>34.00 B (-69)</b>	35.75 (-66)	42.50 (-66)	54.50 (-62)	<b>44.25 B (-64)</b>
WC <sub>4</sub> : Weedy check	89.67	110.00	125.17	<b>108.28 A</b>	105.00	124.83	141.67	<b>123.83 A</b>
Mean RS	<b>44.96 B</b>	<b>55.38 AB</b>	<b>68.21 A</b>		<b>56.19 B</b>	<b>67.17 AB</b>	<b>80.33 A</b>	
Mean (Year)	<b>56.18 B</b>				<b>67.90 A</b>			
HSD ( <i>p</i> 0.05)	RS = 14.977, WC = 14.463, RS × WC=ns				RS =14.271 , WC =12.534, RS × WC = ns			
Year ( <i>p</i> 0.05)	Year=7.482							

Interaction means not sharing a letter in common differ significantly at 5% probability level by Tukey’s HSD test. Values in parenthesis denote percent reduction over weedy check plots

**Table 2. Interactive effect of tillage and row spacing with weed control treatments on total weed dry biomass (g m<sup>-2</sup>) at 60 DAS in wheat**

Year	2010-11			2011-12		
	TS × WC					
	Tillage systems (TS)			Tillage systems (TS)		
Weed control treatments (WC)	ZT	CT	Mean WC	ZT	CT	Mean WC
WC <sub>1</sub> : Iodo+mesosulfuron	27.40 (-61)	37.42 (-58)	<b>32.41 B (-59)</b>	42.03 (-50)	51.56 (-50)	<b>46.79 B (-50)</b>
WC <sub>2</sub> :Pinoxaden+(bromoxynil+MCPA)	24.10 (-66)	34.40 (-61)	<b>29.25 B (-63)</b>	39.21 (-54)	47.57 (-54)	<b>43.39 B (-54)</b>
WC <sub>3</sub> : Isoproturon+carfentrazone	20.02 (-71)	25.14 (-72)	<b>22.58 B (-72)</b>	35.53 (-58)	40.82 (-60)	<b>38.18 B (-59)</b>
WC <sub>4</sub> : Weedy check	70.02	88.90	<b>79.46 A</b>	84.77	102.49	<b>93.63 A</b>
Mean TS	<b>35.38 B</b>	<b>46.46 A</b>		<b>50.39 B</b>	<b>60.61 A</b>	

HSD ( <i>p</i> 0.05)	TS = 2.545, WC = 12.593, TS × WC = ns				TS = 8.007, WC = 10.916, TS × WC = ns			
	RS × WC				RS × WC			
	Row spacing (RS)			Mean WC	Row spacing (RS)			Mean WC
Weed control treatments (WC)	11.25 cm	15.00 cm	22.50 cm		11.25 cm	15.00 cm	22.50 cm	
WC <sub>1</sub> : Iodo+mesosulfuron	25.86 (-60)	30.20 (-62)	41.16 (-57)	<b>32.41 B</b> (-59)	39.99 (-50)	45.06 (-52)	55.34 (-49)	<b>46.79 B</b> (-50)
WC <sub>2</sub> : Pinoxaden+(bromoxynil+MCPA)	19.79 (-70)	30.76 (-61)	37.20 (-61)	<b>29.25 B</b> (-63)	34.54 (-57)	45.61 (-51)	50.04 (-54)	<b>43.39 B</b> (-54)
WC <sub>3</sub> : Isoproturon+carfentrazone	15.26 (-77)	21.41 (-73)	31.07 (-67)	<b>22.58 B</b> (-72)	31.17 (-61)	37.23 (-60)	46.13 (-57)	<b>38.18 B</b> (-59)
WC <sub>4</sub> : Weedy check	65.18	78.51	94.68	<b>79.46 A</b>	80.28	93.00	107.61	<b>93.63 A</b>
Mean RS	<b>31.52 B</b>	<b>40.22 AB</b>	<b>51.03 A</b>		<b>46.49 B</b>	<b>55.22 AB</b>	<b>64.78 A</b>	
Mean (Year)	40.92 B				55.50 A			
HSD ( <i>p</i> 0.05)	RS = 14.843, WC = 12.593, RS × WC = ns				RS = 13.474, WC = 10.916, RS × WC = ns			
Year ( <i>p</i> 0.05)					Year = 7.463			

Interaction means not sharing a letter in common differ significantly at 5% probability level by Tukey's HSD test. Values in parenthesis denote percent reduction over weedy check plots

**Table 3. Interactive effect of tillage and row spacing with weed control treatments on number of productive tillers (m<sup>2</sup>) of wheat**

Year	2010-11			2011-12				
	Tillage systems (TS)			Tillage systems (TS)				
Weed control treatments (WC)	ZT	CT	Mean (WC)	ZT	CT	Mean (WC)		
WC <sub>1</sub> : Weed free	505.44	433.56	<b>469.50 A</b>	472.33	400.56	<b>436.44 A</b>		
WC <sub>2</sub> : Iodo+mesosulfuron	474.44	376.56	<b>425.50 BC</b>	434.89	369.00	<b>401.94 BC</b>		
WC <sub>3</sub> : Pinoxaden+(bromoxynil+MCPA)	450.44	360.22	<b>405.33 C</b>	412.22	344.11	<b>378.17 C</b>		
WC <sub>4</sub> : Isoproturon+carfentrazone	484.78	392.33	<b>438.56 B</b>	449.33	388.11	<b>418.72 AB</b>		
WC <sub>5</sub> : Weedy check	355.67	264.44	<b>310.06 D</b>	310.00	235.67	<b>272.83 D</b>		
Mean (TS)	<b>454.16 A</b>	<b>365.42 B</b>		<b>415.76 A</b>	<b>347.49 B</b>			
HSD ( <i>p</i> 0.05)	TS = 26.685, WC = 28.106, TS × WC = ns			TS = 32.566, WC = 30.893, TS × WC = ns				
	RS × WC			RS × WC				
Weed control treatments (WC)	Row spacing (RS)			Row spacing (RS)			Mean (WC)	
	11.25 cm	15.00 cm	22.50 cm	11.25 cm	15.00 cm	22.50 cm		
WC <sub>1</sub> : Weed free	524.00	469.33	415.17	<b>469.50 A</b>	502.33	433.17	373.83	<b>436.44 A</b>
WC <sub>2</sub> : Iodo+mesosulfuron	463.83	426.33	386.33	<b>425.50 BC</b>	464.00	407.67	334.17	<b>401.94 BC</b>
WC <sub>3</sub> : Pinoxaden+(bromoxynil+MCPA)	447.17	404.00	364.83	<b>405.33 C</b>	444.83	380.00	309.67	<b>378.17 C</b>
WC <sub>4</sub> : Isoproturon+carfentrazone	483.50	437.17	395.00	<b>438.56 B</b>	476.33	419.83	360.00	<b>418.72 AB</b>
WC <sub>5</sub> : Weedy check	365.83	315.17	249.17	<b>310.06 D</b>	328.67	276.00	213.83	<b>272.83 D</b>
Mean (RS)	<b>465.87 A</b>	<b>410.40 B</b>	<b>362.10 C</b>		<b>443.23 A</b>	<b>383.33 B</b>	<b>318.30 C</b>	
Mean (Year)	409.79 A				381.62 B			
HSD ( <i>p</i> 0.05)	RS = 17.135, WC = 28.106, RS × WC = ns			RS = 21.655, WC = 30.893, RS × WC = ns				
Year ( <i>p</i> 0.05)				Year = 27.183				

Interaction means not sharing a letter in common differ significantly at 5% probability level by Tukey's HSD test.

**Table 4. Interactive effect of tillage and row spacing with weed control treatments on number of grains per spike of wheat**

Year	2010-11			2011-12			
	TS × WC						
	Tillage systems (TS)			Tillage systems (TS)			
Weed control treatments (WC)	ZT	CT	Mean (WC)	ZT	CT	Mean (WC)	
WC <sub>1</sub> : Weed free	52.76	49.07	<b>50.91 A</b>	49.76	46.57	<b>48.17 A</b>	
WC <sub>2</sub> : Iodo+mesosulfuron	51.07	48.26	<b>49.66 AB</b>	48.91	45.92	<b>47.41 A</b>	
WC <sub>3</sub> :Pinoxaden+(bromoxynil+MCPA)	50.45	47.48	<b>48.96 B</b>	48.39	45.13	<b>46.76 A</b>	
WC <sub>4</sub> : Isoproturon+carfentrazone	51.38	48.80	<b>50.09 AB</b>	49.01	46.28	<b>47.64 A</b>	
WC <sub>5</sub> : Weedy check	47.87	44.66	<b>46.26 C</b>	45.48	42.16	<b>43.82 B</b>	
Mean (TS)	<b>50.70 A</b>	<b>47.65 B</b>		<b>48.31</b>	<b>45.21</b>		
HSD ( <i>p</i> 0.05)	TS = 2.406, WC = 1.404, TS × WC = ns			WC = 1.941, TS = ns ,TS × WC = ns			
	RS × WC						
	Row spacing (RS)			Row spacing (RS)			Mean (WC)
Weed control treatments (WC)	11.25 cm	15.00 cm	22.50 cm	11.25 cm	15.00 cm	22.50 cm	
WC <sub>1</sub> : Weed free	51.82	50.89	50.02	47.38	48.12	49.00	<b>48.17 A</b>
WC <sub>2</sub> : Iodo+mesosulfuron	50.09	49.67	49.22	46.88	47.02	48.33	<b>47.41 A</b>
WC <sub>3</sub> :Pinoxaden+(bromoxynil+MCPA)	49.29	49.21	48.39	46.30	46.60	47.38	<b>46.76 A</b>
WC <sub>4</sub> : Isoproturon+carfentrazone	50.82	49.96	49.49	47.03	47.32	48.58	<b>47.64 A</b>
WC <sub>5</sub> : Weedy check	46.91	46.34	45.54	43.20	43.58	44.68	<b>43.82 B</b>
Mean (RS)	<b>49.79 A</b>	<b>49.21 AB</b>	<b>48.53 B</b>	<b>46.16 B</b>	<b>46.53 AB</b>	<b>47.60 A</b>	
Mean (Year)	<b>49.18 A</b>			<b>46.76 B</b>			
HSD ( <i>p</i> 0.05)	RS = 1.160 , WC =1.404,RS×WC=ns			RS = 1.192 , WC = 1.941, RS×WC =ns			
Year ( <i>p</i> 0.05)	Year =1.342						

Interaction means not sharing a letter in common differ significantly at 5% probability level by Tukey’s HSD test.

**Table 5. Interactive effect of tillage and row spacing with weed control treatments on 1000-grain weight of wheat**

Year	2010-11			2011-12		
	TS × WC					
	Tillage systems (TS)			Tillage systems (TS)		
Weed control treatments (WC)	ZT	CT	Mean (WC)	ZT	CT	Mean (WC)
WC <sub>1</sub> : Weed free	47.79	45.38	<b>45.38 A</b>	45.69	43.23	<b>44.46 A</b>
WC <sub>2</sub> : Iodo+mesosulfuron	46.88	44.59	<b>44.59 A</b>	45.02	42.68	<b>43.85 A</b>
WC <sub>3</sub> :Pinoxaden+(bromoxynil+MCPA)	46.30	44.04	<b>44.04 A</b>	44.71	42.36	<b>43.53 A</b>
WC <sub>4</sub> : Isoproturon+carfentrazone	46.97	44.76	<b>44.76 AB</b>	45.28	43.01	<b>44.15 A</b>
WC <sub>5</sub> : Weedy check	45.04	42.43	<b>42.43 B</b>	42.35	39.57	<b>40.96 B</b>
Mean (TS)	<b>46.60 A</b>	<b>44.24 B</b>		<b>44.61 A</b>	<b>42.17 B</b>	
HSD ( <i>p</i> 0.05)	TS = 1.571 , WC = 1.673, TS × WC = ns			TS = 0.585 , WC = 1.718, TS × WC = ns		
	RS × WC					
	Row spacing (RS)			Row spacing (RS)		

Weed control treatments (WC)	11.25 cm	15.00 cm	22.50 cm	Mean (WC)	11.25 cm	15.00 cm	22.50 cm	Mean (WC)
WC <sub>1</sub> : Weed free	47.21	46.89	45.66	<b>45.38 A</b>	43.78	44.43	45.18	<b>44.46 A</b>
WC <sub>2</sub> : Iodo+mesosulfuron	46.21	46.17	44.82	<b>44.59 A</b>	43.10	43.93	44.53	<b>43.85 A</b>
WC <sub>3</sub> :Pinoxaden+(bromoxynil+MCPA)	45.51	45.46	44.56	<b>44.04 A</b>	42.95	43.66	44.00	<b>43.53 A</b>
WC <sub>4</sub> : Isoproturon+carfentrazone	46.32	46.32	44.94	<b>44.76 AB</b>	43.40	44.35	44.70	<b>44.15 A</b>
WC <sub>5</sub> : Weedy check	44.64	44.41	42.16	<b>42.43 B</b>	39.66	41.53	41.68	<b>40.96 B</b>
Mean (RS)	<b>45.98 A</b>	<b>45.85 A</b>	<b>44.43 B</b>		<b>42.58 B</b>	<b>43.58 AB</b>	<b>44.02 A</b>	
Mean (Year)	45.42 A				43.39 B			
HSD ( <i>p</i> 0.05)	RS = 0.807 , WC = 1.673, RS×WC=ns				RS = 1.236 , WC = 1.718, RS×WC =ns			
Year ( <i>p</i> 0.05)					Year=0.748			

Interaction means not sharing a letter in common differ significantly at 5% probability level by Tukey's HSD test.

**Table 6. Interactive effect of tillage and row spacing with weed control treatments on grain yield (t ha<sup>-1</sup>) of wheat**

Year	2010-11			2011-12			
	TS × WC						
Weed control treatments (WC)	Tillage systems (TS)			Tillage systems (TS)			
	ZT	CT	Mean (WC)	ZT	CT	Mean (WC)	
WC <sub>1</sub> : Weed free	5.39	4.69	<b>5.04 A</b>	5.28	4.89	<b>5.08 A</b>	
WC <sub>2</sub> : Iodo+mesosulfuron	4.85	4.09	<b>4.47 AB</b>	4.89	4.35	<b>4.62 AB</b>	
WC <sub>3</sub> :Pinoxaden+(bromoxynil+MCPA)	4.57	3.78	<b>4.18 BC</b>	4.61	4.06	<b>4.33 B</b>	
WC <sub>4</sub> : Isoproturon+carfentrazone	5.30	4.61	<b>4.95 A</b>	4.96	4.41	<b>4.69 AB</b>	
WC <sub>5</sub> : Weedy check	4.07	3.10	<b>3.59 C</b>	3.76	3.25	<b>3.51 C</b>	
Mean (TS)	<b>4.84 A</b>	<b>4.05 B</b>		<b>4.70 A</b>	<b>4.19 B</b>		
HSD ( <i>p</i> 0.05)	TS = 0.705 , WC = 0.592, TS ×WC = ns			TS = 0.077 , WC = 0.728, TS ×WC = ns			
	RS × WC						
Weed control treatments (WC)	Row spacing (RS)			Row spacing (RS)			
	11.25 cm	15.00 cm	22.50 cm	11.25 cm	15.00 cm	22.50 cm	Mean (WC)
WC <sub>1</sub> : Weed free	5.25	5.08	4.78	5.36	5.14	4.75	<b>5.08 A</b>
WC <sub>2</sub> : Iodo+mesosulfuron	5.11	4.33	3.97	4.83	4.75	4.28	<b>4.62 AB</b>
WC <sub>3</sub> :Pinoxaden+(bromoxynil+MCPA)	4.69	4.06	3.78	4.67	4.50	3.83	<b>4.33 B</b>
WC <sub>4</sub> : Isoproturon+carfentrazone	5.29	4.99	4.58	5.00	4.83	4.22	<b>4.69 AB</b>
WC <sub>5</sub> : Weedy check	3.94	3.53	3.29	4.08	3.40	3.04	<b>3.51 C</b>
Mean (RS)	<b>4.86 A</b>	<b>4.40 AB</b>	<b>4.08 B</b>	<b>4.79 A</b>	<b>4.52 A</b>	<b>4.02 B</b>	
Mean (Year)	4.45 A			4.18 B			
HSD ( <i>p</i> 0.05)	RS = 0.734 , WC = 0.592, RS×WC=ns			RS = 0.416 , WC = 0.728, RS×WC =ns			
Year ( <i>p</i> 0.05)	Year=0.183						

Interaction means not sharing a letter in common differ significantly at 5% probability level by Tukey's HSD test.

**Table 7. Coefficients of determination (R<sup>2</sup>) and correlation coefficients (r) denoting goodness of fit and association strength between different variables**

2010-11													
		ZT						CT					
		11.25 cm		15.00 cm		22.50 cm		11.25 cm		15.00 cm		22.50 cm	
X- variable	Y-variable	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r
WDB (g m <sup>-2</sup> )	Grain yield (t ha <sup>-1</sup> )	0.80	-0.89*	0.88	-0.94**	0.61	-0.78 <sup>ns</sup>	0.81	-0.90*	0.74	-0.86*	0.91	-0.95**
WDB (g m <sup>-2</sup> )	Tillers (m <sup>2</sup> )	0.93	-0.96**	0.94	-0.97**	0.91	-0.95**	0.93	-0.96**	0.99	-0.99***	0.90	-0.94**
Tillers (m <sup>2</sup> )	Grain yield (t ha <sup>-1</sup> )	0.91	0.95**	0.96	0.98**	0.56	0.75 <sup>ns</sup>	0.77	0.87*	0.74	0.86*	0.91	0.95**
2011-12													
		ZT						CT					
		11.25 cm		15.00 cm		22.50 cm		11.25 cm		15.00 cm		22.50 cm	
X- variable	Y-variable	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r	R <sup>2</sup>	r
WDB (g m <sup>-2</sup> )	Grain yield (t ha <sup>-1</sup> )	0.96	-0.98**	0.88	-0.94**	0.82	-0.91*	0.92	-0.96**	0.89	-0.94**	0.89	-0.94**
WDB (g m <sup>-2</sup> )	Tillers (m <sup>2</sup> )	0.89	-0.94**	0.84	-0.91*	0.88	-0.94**	0.88	-0.93**	0.83	-0.91*	0.77	-0.87*
Tillers (m <sup>2</sup> )	Grain yield (t ha <sup>-1</sup> )	0.91	0.95**	0.99	0.99***	0.98	0.99***	0.93	0.96**	0.98	0.99***	0.78	0.88*

WDB: weed dry biomass. \*, \*\*, \*\*\* denote significance at 0.05, 0.01, and 0.001 probability level, respectively.

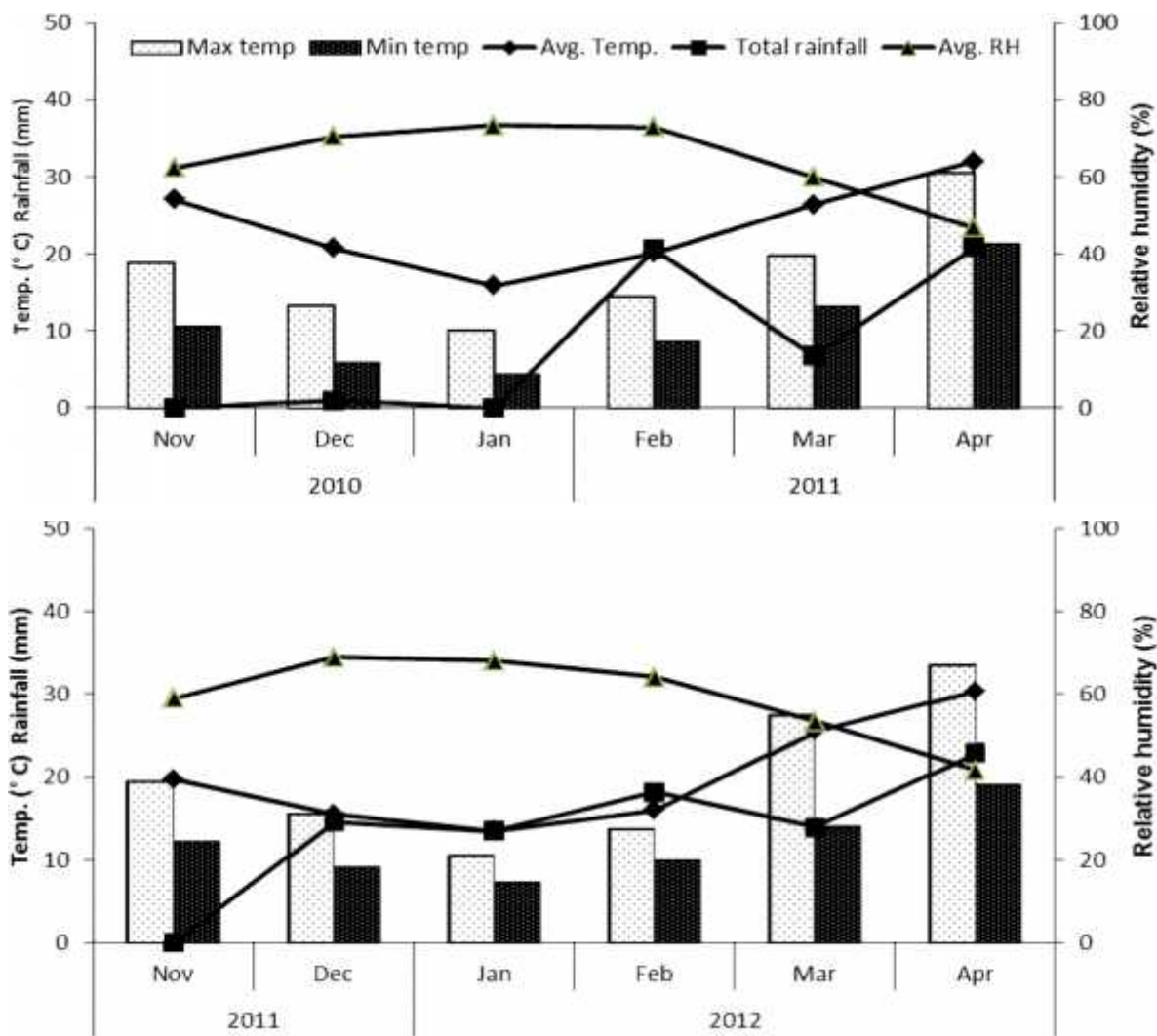


Fig. 1. Meteorological data during the course of experimentation during Rabi 2010-11 and 2011-12

### DISCUSSION

Present study demonstrated the significant impact of tillage systems, row spacing and herbicide application treatments on weed growth and crop performance. ZT was effective in averting weed growth, hence reduced crop yield losses by weeds as compared with CT system. Lower weed density and biomass in ZT plots (Table 1-2) might be attributed to the absence of soil disturbance (Mann *et al.*, 2004) and unsuitable growing conditions for weeds like physical hindrance posed by surface residues under ZT and unavailability of light to weed seeds buried in soil (Benech-Arnold *et al.*, 2000). Streit *et al.* (2002) observed less weed densities in no-till plots compared with CT because of undisturbed soil and plant residues cover. The higher weed dry biomass under CT might be attributed to higher weed density presumably because of wake up of weed seeds from dormancy in response to soil incorporation under

CT (Table 1-2). Less weed density and poor weed growth in ZT due to vigorous crop stand led to less weed dry biomass as compared with CT system (Table 1-2).

In present study, higher weed density and dry biomass (Table 1-2) were observed under wider wheat rows (22.50 cm); which might be attributed to lack of an overlapping canopy early in growing season that resulted in substantial weed growth and consequent competition. In contrast, sowing of wheat in narrow spaced rows allowed the crop to efficiently exploit the available space, minimizing the space available for weed growth. Results of present study are in line with Das and Yaduraju (2012), who reported crop sown at widely spaced rows have more weed infestation as compared to narrow rows. In addition, higher plant densities and narrow row spacing permit full ground cover earlier in the season than do wider rows. Rapid canopy closure and reduced light transmission to weeds resulted in a competitive crop stand under narrow row spacing. Decreased light

availability to weeds was caused by higher leaf area of wheat crop under narrow row spacing and greater light interception per unit leaf area (Liebman *et al.*, 2001).

It was observed that all the herbicides were effective in suppressing weed density and dry biomass, which presumably due to their ability to skirmish both narrow and broad-leaved weeds (Table 1-2). These findings are in confirmation with Chhokar *et al.* (2007), who also reported that herbicide application significantly reduced the total weed density and dry biomass in wheat. In present study, isoproturon+carfentrazone was somehow better in controlling weeds than either of the herbicidal treatments. Iodo+mesosulfuron, pinoxaden + (bromoxynil + MCPA) and isoproturon + carfentrazone reduced the total weed density and dry biomass to the tune of 60, 64 and 72%, respectively over control (Table 1-2). Khan *et al.* (2004) also reported that isoproturon + carfentrazone was the best treatment as compared to other herbicidal treatments. They further concluded that herbicides are time saving and economical than other weed control methods. Efficacy of herbicides against some grassy and broad-leaved weeds in wheat is in line with Khaliq *et al.* (2011). Effective weed suppression in herbicide treated plots could be attributed to the highest phytotoxic effects of herbicides against diverse flora of weeds.

Wheat grain yield and its different components (number of productive tillers; number of grains per spike, 1000-grain weight) were significantly higher for wheat sown under ZT system as compared with CT (Table 3-6). Better crop growth and yield under ZT might be attributed to effective weed control in these plots, therefore, the crop plants efficiently utilized the available resources (Usman *et al.*, 2010). Work carried out by Mann *et al.*, (2008) under wide array of soil type and farmers with contrasting socio-economic background in Pakistan also suggested that the effectiveness of ZT technology increased yields and farmer's profits. Due to weed infestation, less number of tillers and grains per spike have been reported (Shahzad *et al.*, 2012). Irrespective of row spacing and tillage system, number of tillers per unit area was negatively associated with weed dry biomass during both the years (Table 7). The decreased tillering in wheat in response to weed infestation was presumably because of synchronization of active tillering stage with period of maximum weed growth. Less grain yield in wider wheat rows could be due to the vigorous weed growth and their consequent competition which reduced yield (Table 6). In contrast, sowing wheat at narrow row spacing allowed the crop to efficiently exploit space thus resulting in higher grain yield. Acciaresi and Chidichimo (2007) concluded that using narrow row spacing led to greater uniformity in leaf and root distribution, which allowed the crop to intercept more photosynthetically active radiation and efficiently

use available resources to attain higher growth rates and yield.

In present study, higher yield and its components in herbicide treated plots compared with weedy check plots might be due to better crop growth in the absence of weeds and increased transfer of photosynthates towards grains as a consequence of supportive action of herbicides that help lessened weed-crop competition. These results are in accordance with Baghestani *et al.* (2008) and Santos (2009) who reported that herbicides proffer sizeable increase in crop productivity corresponding to their weed control spectrum. Grain yield of wheat was also negatively associated with weed dry biomass (Table 7). The negative influence of weeds on wheat yield might be due to competition by weeds for important factors such as nutrients, water, light and space for their growth and reproduction.

Varying climatic regimes particularly the amount and pattern of rainfall can be regarded as the attributes for the significant year effect during 2010-11 (Fig. 1). As against the first year, reduced grain yield during the second year can be attributed to the reduced grain weight and number of grains per spike. This reduction in grain weight and number of grains could be due to slight increase in mean daily temperatures during reproductive and grain filling phases (Fig. 1). Grain yield of wheat is seriously hampered by an increase in temperature, during reproductive and grain filling phases (Nawaz *et al.*, 2013).

Although narrow row spacing and ZT have been successfully opted and incorporated in wheat cropping systems worldwide, yet these approaches are still not very common in many Asian countries including Pakistan. Therefore, these results could be of worth for wheat growers particularly small land holders, because sowing of wheat in narrow rows under ZT will not only increase grain yield but will also reduce production costs and weed control requirements.

**Conclusion:** Present study demonstrated that narrow row spacing, zero tillage and herbicide application were effective for averting weed growth and enhancing productivity of wheat, suggesting that these approaches can be fundamental tools for weed management in wheat fields. Future studies should focus on the integration and optimization of cultural methods like stubble/residue management, organic additives, and crop densities with chemical weed control.

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## REFERENCES

- Acciaresi, H.A. and H.O. Chidichimo (2007). Spatial pattern effect on corn (*Zea mays*) weeds competition in the humid Pampas of Argentina. *Int. J. Pest Manag.* 53:195-206.
- Acciaresi, H.A., H.V. Balbi, M.L. Bravo and H.O. Chidichimo (2003). Response of weed populations to tillage, reduced herbicide and fertilizer rates in wheat (*Triticum aestivum*) production. *Planta Daninha.* 21:49-55.
- Alsaadawi, I.S., A. Khaliq, A.A. Al-Temimi and A. Matloob. (2011). Integration of sunflower (*Helianthus annuus* L.) residues with a pre-plant herbicide enhances weed suppression in broad bean (*Vicia faba*). *Planta Daninha.* 29:849-859.
- Alsaadawi, I.S., A. Khaliq, N.R. Lahmod and A. Matloob (2013). Weed management in broad bean (*Vicia faba* L.) through allelopathic *Sorghum bicolor* (L.) Moench residues and reduced rate of a pre-plant herbicide. *Allelopathy J.* 32:203-212.
- Ashiq, M., N. Muhammad and N. Ahmad (2006). Comparative efficacy of different herbicides to control grassy weeds in wheat. *Pakistan J. Weed Sci. Res.* 12(3):157-161.
- Baghestani, M.A., E. Zand, S. Soufizadeh, M. Beheshtian, A. Haghighi, A. Barjasteh, D.G. Birgani and R. Deihimfard (2008). Study on the efficacy of weed control in wheat (*Triticum aestivum* L.) with tank mixtures of grass herbicides with broadleaved herbicides. *Crop Prot.* 27:104-111.
- Benech-Arnold, R.L., R.A. Sánchez, F. Forcella, B.C. Kruk and C.M. Ghersa (2000). Environmental control of dormancy in weed seed banks in soil. *Field Crops Res.* 67:105-122.
- Bilbro, J.D. and D.W. Fryrear (1994). Wind erosion losses as related to plant silhouette and soil cover. *Agron. J.* 86:550-553.
- Buhler, D.D. (1995). Influence of tillage systems on weed populations dynamics and management in corn and soybean in the central USA. *Crop Sci.* 35:1247-1258.
- Buhler, D.D. (1997). Effects of tillage and light environment on emergence of 13 annual weeds. *Weed Technol.* 11:496-501.
- Chauhan, B.S. and D.E. Johnson (2010). The role of seed ecology in improving weed management strategies in the tropics. *Adv. Agron.* 105:221-262.
- Chauhan, B.S., G. Mahajan, V. Sardana, J. Timsina and M. L. Jat (2012). Productivity and Sustainability of the Rice-Wheat Cropping System in the Indo-Gangetic Plains of the Indian Subcontinent: Problems, Opportunities, and Strategies. *Adv. Agron.* 117:315-369.
- Chen, C., K. Neill, D. Wichman and M. Westcott (2008). Hard red spring wheat response to row spacing, seeding rate, and nitrogen. *Agron. J.* 100:1296-1302.
- Chhokar, R.S., R.K. Sharma, G.R. Jat, A.K. Pundir and M.K. Gathala (2007). Effect of tillage and herbicides on weeds and productivity of wheat under rice-wheat growing system. *Crop Prot.* 26:1689-1696.
- CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo). (1988). *From Agronomic Data to farmers Recommendations: An Economics Training Manual*, pp. 31-33. CIMMYT, Mexico.
- Das, T.K. and N.T. Yaduraju (2012). The effects of combining modified sowing methods with herbicide mixtures on weed interference in wheat crops. *Intl. J. Pest Manag.* 58: 310-319.
- Grichar, W.J., B.A. Besler and K.D. Brewer (2004). Effect of row spacing and herbicide dose on weed control and grain sorghum yield. *Crop Prot.* 23:263-267.
- Harker, K. N. and J.T. O'Donovan (2013). Recent weed control, weed management, and integrated weed management. *Weed Technol.* 27:1-11.
- Heap, I. (2012). International Survey of Herbicide Resistant Weeds. [www.weedscience.com](http://www.weedscience.com). Accessed: March 2012.
- Hussain, M., Z. Mehmood, M.B. Khan, S. Farooq, D-J. Lee and M. Farooq (2012). Narrow row spacing ensures higher productivity of low tillering wheat cultivars. *Int. J. Agric. Biol.* 14:413-418.
- Jamil, M., M. Qasim, M. Umar and K. Rehman (2004). Impact of organic wastes (Sewage Sludge) on the yield of wheat (*Triticum aestivum* L.) in a calcareous soil. *Intl. J. Agric. Biol.* 6:465-467.
- Khaliq, A., A. Matloob, A. Tanveer, A. Areeb, F. Aslam and N. Abbas (2011). Reduced doses of a sulfonylurea herbicide for weed management in wheat fields of Punjab, Pakistan. *Chilean J. Agric. Res.* 71:424-429.
- Khan M.S., A. Zaidi and M. Aamil (2004). Influence of herbicides on chickpea *Mesorhizobium* symbiosis. *Agronomie* 24:123-127.
- Khan, B. M., M.A. Khan, S.H.K. Nawab and A.M. Khattak (2011). Integrated weed management. *Pakistan J. Bot.* 43:625-633.
- Khan, M. and N. Haq (2002). Wheat crop yield loss assessment due to weeds. *Sarhad J. Agric.* 18:449-453.
- Liebman, M., C.L. Mohler and C.P. Staver (2001). *Ecological management of agricultural weeds*. Cambridge University Press, New York. Extension Report No. 18. Louisiana Agriculture, Louisiana, USA.

- Mahajan, G., M.S. Ramesha and Rupinder-Kaur (2011). Screening for weed competitiveness in rice-wheat to sustainable rice production in the face of global climate change. Proc. Int. Conf. Feb., 6-8. Preparing Agri. Climate Change, Ludhiana, India.
- Malik, A.U., I. Hussain, M. Ahmad alias H.A. Bakhsh, M.A. Haji and M. Ali (2009). Demonstration and evaluation of effect of weedicides on broad leaved weeds on wheat yield. The J. Anim. Plant Sci. 19(4): 193-196.
- Mann, R.A., M. Ashraf and G. Hassan (2004). Wheat establishment with zero tillage for integrated weed management. Pakistan J. Weed Sci. Res. 10:17-24.
- Mann, R.A., M. Ramzan and A. Munir. (2008). Improving the sustainability of wheat production in irrigated areas of Punjab, Pakistan through conservation tillage technology. Intl. J. Agric. Biol. 10: 249-254.
- Marwat, K.B., M.A. Khan, S. Hashim, K. Nawab and A.M. Khattak (2011). Integrated weed management in wheat. Pakistan J. Bot. 43:625-633.
- Mehta, A.K. and R. Singh (2005). Transfer of resource conserving technologies through Krishi Vigyan Kendras. In: Abrol, I.P., R.K. Gupta and R.K. Malik (Eds.), Conservation
- Nawaz, A., M. Farooq, S.A. Cheema and A. Wahid (2013). Differential response of wheat cultivars to terminal heat stress. Int. J. Agric. Biol. 15, 1354-1358.
- Rao, A.N., D.E. Johnson, B. Shivaprasad, J.K. Ladha and A.M. Mortimer (2007). Weed management in direct-seeded rice. Adv. Agron. 93:153-255.
- Riaz, T., S.N. Khan and A. Javaid (2009). Weed flora of Gladiolus fields in district Kasur, Pakistan. The J. Anim. Plant Sci. 19(3): 144-148.
- Santos, B.M. (2009). Drip-applied metam potassium and herbicides as methyl bromide alternatives for *Cyperus* control in tomato. Crop Prot. 28:68-71.
- Shehzad, M.A., M. Maqsood, M. Anwar-ul-Haq and A. Niaz (2012). Efficacy of various herbicides against weeds in wheat (*Triticum aestivum* L.). Afr. J. Biotechnol. 11(4):791-799.
- Singh, M., P.S. Chandurkar and A. Kumar (2007). Weed management in rice based zero tilled sown wheat. Pakistan J. Weed Sci. Res. 13:183-189.
- Steel, R.G.D., J.H. Torrie and D.A. Dickey (1997). Principles and procedures of statistics: a biometric approach, 3<sup>rd</sup> Ed. McGraw Hill Book Co. Inc., New York. USA.
- Streit, B., B. Stephanie, B. Rieger, P. Stamp and W. Richner (2002). The effect of tillage intensity and time of herbicide application on weed communities and populations in maize in central Europe. Agric. Eco. Environ. 92:211-224.
- Usman, K., S. K. Khalil and M.A. Khan (2010). Impact of tillage and herbicides on weed density and some physiological traits of wheat under rice-wheat cropping system. Sarhad J. Agric. 26(4):475-487.
- Yadav, A. and R.K. Malik (2005). Herbicide resistant *Phalaris minor* in wheat-A Sustainability Issue. Resource Book. Department of Agronomy and Directorate of Extension Education, CCSHAU, Hisar, India.