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WEED MANAGEMENT IN WHEAT AS AFFECTED BY TILLAGE AND HERBICIDES

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ABSTRACT

To evaluate the impact of various tillage systems in combination with herbicides on weed density and grain yield of wheat under rice-wheat cropping system, an experiment was conducted in low precipitation zone of NWFP (Dera Ismail Khan), Pakistan during 2007–2009. The experiment was laid out in randomized complete block design with split plot arrangements replicated four times. The treatments comprised of 3 tillage systems, including conventional tillage with disk ploughing (CT), reduced tillage with shallow ploughing through rotavator (RT), and zero tillage with stubble direct drilling (ZT) as main plots while five weed control treatments viz. 2,4-D ester @ 1.25 L ha^{-1}, Puma super 75 EW @1.25 L ha^{-1}, 2,4-D + Puma super @1.25 L ha^{-1} each, Affinity 50 WDG @ 2 kg ha^{-1} and weedy check as subplots. Herbicides had significant effect on weed density, dry weed biomass (DWB), and grain yield. Tillage x herbicides interaction occurred for weed density and grain yield only. Maximum grain yield (6906.9 kg ha^{-1}) was recorded with Affinity. Maximum weed density m^{-2} (75.5) and DWB (220.4 g m^{-2}) were recorded in weedy check, while maximum grain yield (5583.8 kg ha^{-1}) was obtained from RT being statistically similar to grain yield (5575.1 kg ha^{-1}) in ZT. The lower grain yield (5479.3 kg ha^{-1}) in CT was due to maximum weed density m^{-2} (48.3), and DWB (136.5 g m^{-2}). Affinity was the most effective herbicide against grasses as well as broad-leaved weeds in combination with either ZT or RT and resulted in higher grain yield.

Key words: Tillage, herbicides, density, weed biomass, wheat yield.

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INTRODUCTION

Rice-wheat (RW) cropping system is one of the major cropping systems covering an area of 2.2 million ha in Pakistan (Mann et al., 2004). The system is highly exhaustive in nature and is continuously practiced in the same area for several decades. Wheat crop is more affected due to late harvest of preceding rice. Traditional tillage practices consist of several tractor operations and planking in order to ensure good seed bed preparation. This conventional method of wheat sowing in the paddy field is further delaying wheat sowing which results in low wheat yield. Wheat yield potential reduces by 30-35 kg ha^{-1} day^{-1} if planting occurs after mid-November (Gangwar *et al.*, 2006). Conventional tillage deteriorates soil and water quality due to excessive use of pesticides and poor water management causing dropping of water tables and increasing water logging and salinity (Qureshi *et al.*, 2003).

Zero tillage (ZT) or reduced tillage (RT) technology reduces land preparation cost, saves fuel, equipment, labor, and ensures good crop stand in addition to conservation of soil and water (Mann et al., 2002). However, this change of technology may affect weed density, weeds biology and insect pest infestation, which needs to be explored. Weeds represent one of the most costly and limiting factors in crop production, posing harvesting and storage problems (Rosskopf *et al.*, 1999). Weeds pose serious threat to the companion crop through its competition for nutrients, water, sunlight and space which cause considerable reduction in grain yield. Hence effective weed management strategy should be implemented. The use of ZT for wheat planting is emerging as a new tool in integrated weed management. It reduces weed population due to elimination of tillage (Mehla *et al.*, 2000) and in conjunction with new herbicides provides effective weed control at lower rates (Ali and Tunio, 2002).

Looking to the scenario of unsustainable CT and its impacts on soil nutrient and productivity decline, there is a need to modify current tillage practices while growing wheat after rice (Atreya *et al.*, 2006). ZT and RT with suitable and optimum use of herbicide have been suggested as the possible solution. However, a shift from an intensive tillage system to ZT/RT system can cause major changes in soil microclimates due to different tillage systems. No studies have been conducted in Pakistan to indicate whether use of herbicides should be adjusted to the new tillage systems. The overall objective of this study was to know the impact of tillage and herbicides on weed density, dry weed biomass and grain yield of wheat.

MATERIALS AND METHODS

Field experiments were conducted at Research Farm, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan during the years 2007-08 and 2008-09. Dera Ismail Khan (31º 49˙ N, 70° 55˙ E) is the southern district of the North West Frontier Province of Pakistan. Its elevation ranges from 121 to 210 m above sea level with hot and dry in summer and moderate spells of rain during the monsoon season. The soil was silty clay loam with a pH of 7.8 and the content of organic matter was < 1%. The experimental site was massive, cloddy, sticky, plastic, and strongly calcareous in nature. Weather data were collected from the meteorological station, D.I. Khan located near the experimental site. Total seasonal precipitation for the crop growing season was 87.8 mm in 2007-08, and 131.6 mm in 2008-09. Monthly precipitation, maximum and minimum temperatures for the two seasons are presented in Table-1. Total rainfall in the second growing season was sufficiently higher than the first growing season. Average air temperature during first growing season was higher than the second growing season.

Wheat variety "Nasir-2000" was planted in the standing stubbles of rice with zero tillage drill (ZT method) on October 29, 2007 and November 3, 2008. Wheat sowing was accomplished with one pass of rotavator followed by drilling machine in reduced tillage (RT) method, while several cultivator operations in addition to disk plough, rotavator and drilling machine were used in conventional tillage (CT). Three tillage practices (ZT, RT, and CT) and five herbicidal treatments (Table-2) viz. 2,4-D, Puma super, 2,4-D + Puma super, Affinity, and control (weedy check) were assigned in randomized complete block design with split plots arrangement and four replications. Tillage (T) was allotted to main plots, while herbicides (H) were applied to subplots. A uniform seed rate of 120 kg ha^{-1} was used for the whole experiment. The size of sub plot was 5 x 1.8 m having 6 rows 5 m long and 0.3 m apart. A standard dose of 120:60 kg N: P ha^{-1} was used in the form of Urea and triple super phosphate (TSP). All the phosphorous and half of the nitrogen were applied with sowing, while remaining half of the nitrogen was applied in two splits i.e. at the first and second irrigation. The crops

Table-1. Average air temperature and rainfall of experimental area during the years 2007-08 and 2008-09 crop growing seasons

Month	2007-2008				2008-2009			
	Temp. °C			Rainfall (mm)	Temp. °C			Rainfall (mm)
	Max	Min	Aver.		Max	Min	Aver.	
October	34.2	17.1	25.7	0.0	33.9	20.0	27.0	0.0
November	26.5	13.1	19.8	1.1	28.9	10.9	19.9	0.0
December	21.4	6.8	14.1	1.4	23	6.7	14.9	17.3
January	18.3	4.1	11.2	5.2	21.4	6.0	13.7	7.6
February	22.1	6.8	14.5	24.2	23.7	9.2	16.5	25.0
March	31.4	15.4	23.4	1.8	28.0	13.4	20.7	36.6
April	33.1	18.9	26.0	37.2	33.2	18.4	25.8	21.1
May	39.1	24.2	31.7	16.9	37	23	30	24.0
Total rainfall				87.8				131.6

Source: Meteorological Station D.I.Khan

Table-2. Detail of herbicidal treatments used in the experiment

S.N	Trade Name	Common Name	Spectrum of activity	Dose kg/L ha^{-1}
1	2,4-D ester	2,4-dichlorophenoxy acetic acid	Broad leaf killer	1.25 L
2	Puma super 75 EW	fenoxaprop-p-ethyl	Grass killer	1.25 L
3	2,4-D ester + Puma super 75 EW	_	Broad spectrum	1.25 L +1.25 L
4	Affinity 50 WDG	carfentazone ethyl ester + isoproturon	Broad spectrum	2.00 kg
5	Weedy Check	_	_	_

were harvested on May 16, 2008 and May 20, 2009 during 2 years of experiments.

Data were recorded on weed density m^{-2} before and after herbicidal application, dry weeds biomass (DWB g m^{-2}) and grain yield of wheat. Weed density m^{-2} was recorded 30 days after sowing before herbicidal spray. A square quadrate of $1m^2$ was randomly thrown thrice in each treatment and average weed counts m^{-2} was recorded. Thirty days after herbicide's spray, weed density m^{-2} was again recorded. Relative weed density m^{-2} was calculated by dividing weed counts m^{-2} of each species by total weed density and multiplied by 100. For DWB, weeds were harvested at above ground level at crop physiological maturity from 1 m^2 area from each sub plot, bagged each separately and weeds samples were oven dried at 60°C for 72 hours. The oven dried weeds were weighed for recording DWB (g m^{-2}). For recording grain yield, four central rows were harvested at maturity from each subplot, tied in to bundles, sun dried, threshed and the grains obtained were weighed with electronic balance and finally converted into kg ha^{-1}.

The data across two years of the experiment was statistically analyzed using analysis of variance techniques appropriate for split plot treatment arrangement in randomized complete block design (Steel and Torrie, 1980). When the F values were significant for main and interaction effects, means were compared using LSD test at 0.05 level of probability.

RESULTS AND DISCUSSION

Weed density (m^{-2}) before spray

The weed species infesting the experiment were *Phalaris minor*, *Rumex dentatus*, *Medicago denticulata*, *Melilotus indica*, *Chenopodium album*, *Convolvulus arvensis*, *Malva perviflora*, *Avena fatua*, and *Cyperus rotundus* (Table-3). The data recorded on weed density before application of herbicides revealed that maximum weeds density m^{-2} (113.6) was recorded in 2008-09 while minimum weeds density m^{-2} (62.2) was recorded in 2007-08 (Table-3). Conventional tillage (CT) had the maximum weeds density m^{-2} of 79.5 and 152.0 in 2007-08 and 2008-09, respectively, while zero tillage (ZT) had the minimum weeds density m^{-2} of 35.0 and 77.6 in 2007-08 and 2008-09, respectively. However, reduced tillage (RT) showed intermediate result by recording 72 and 111.2 weeds m^{-2} in 2007-08 and 2008-09, respectively. Mean values for tillage revealed that tillage treatments significantly affected weed density m^{-2}.

Maximum weed density m^{-2} (115.7) was recorded in CT, while minimum weed density m^{-2} (56.3) was recorded in ZT.

Table-3. Weed density (m^{-2}) before herbicide spray in wheat as affected by year and tillage

Tillage	2007-08	2008-09	Mean
Zero Tillage	35.0	77.6	56.3 b
Reduced Tillage	72.0	111.2	91.6 ab
Conventional Tillage	79.5	152.0	115.7 a
Mean	62.2 b	113.6 a	

LSD value for tillage at P < 0.05 (Average for years) = 37.2

Means followed by same letter (s) or no letter in each category are not significantly different (P≤ 0.05) using LSD test (This definition will apply to all other data tables).

Relative weed density (%)

Phalaris minor had the maximum infestation of 36.8 and 45.4 % during 2007-08 and 2008-09, respectively. *Rumex dentatus* was the next major weed infesting the crop with 25.8 and 32.4 % during 2007-08 and 2008-09, respectively (Table-4). Infestation % age for *Medicago denticulata*, *Melilotus indica*, and *Chenopodium album* was 21.8, 9.4 and 4.3 % in 2007-08 while 13.2, 3.9, and 2.8 % in 2008-09, respectively. The rest of the weeds were of little importance having negligible weeds infestation. Mean values for tillage revealed that *P. minor* had minimum infestation (37.6 %) under ZT. The probable reason for lower *P. minor* population in ZT compared to RT or CT might be the soil strength and hard compact surface in the former in addition to the allelopathic effects of rice residues and broad leaved weeds on *P. minor* as reported by Om et al. (2003). However, *R. dentatus* was significantly higher (33.7 %) under ZT compared to RT (24.3 %) and CT (29.4 %). Weed seedling emergence was greater for some weeds with ZT compared to CT (Mohler (1993). This differential response may be attributed to seeds enclosed within spikelet thereby protecting from environmental conditions on the soil surface. This might have happened in case of *R. dentatus* where seed is covered with perianth and might protect it from environmental variation on the surface and causing higher infestation under ZT (Chhokar *et al.*, 2007). However, if seed formation is prevented then weed infestation in ZT will be lower than CT. There is rapid loss of viability on the soil surface in ZT compared to CT where seeds are buried in the soil and prevented from environmental hazards.

Table-4. Relative weed density (%) before spray in wheat as affected by year and tillage

Weed species	Tillage	2007-08	2008-09	Mean
P. minor	ZT	33.4	41.8	37.6
	RT	43.2	44.2	43.7
	CT	33.8	50.2	42.0
	Mean	36.8	45.4	
	CV % = 23.7			
R. dentatus	ZT	24.8 b	42.5 a	33.7 a
	RT	23.6 b	24.9 b	24.3 b
	CT	29.0 b	29.8 b	29.4 ab
	Mean	25.8	32.4	
	CV % = 22.9			
LSD value for tillage at P < 0.05 (Average for years) = 7.3				
LSD value for years x tillage at P < 0.05 = 10.3				
M. denticulata	ZT	24.8	9.8	17.3
	RT	18.0	19.1	18.5
	CT	22.4	10.8	16.6
	Mean	21.8	13.2	
	CV % = 36.9			
M. indica	ZT	9.8	2.9	6.4
	RT	10.7	4.1	7.4
	CT	7.9	4.8	6.3
	Mean	9.4 a	3.9 b	
	CV % = 53.8			
C. album	ZT	5.5	2.3	3.9
	RT	2.5	2.5	2.5
	CT	4.7	3.8	4.2
	Mean	4.3	2.8	
	CV % = 69.4			

Weeds density (m^{-2}) after spray

Weed density m^{-2} was significantly affected by years, tillage, herbicides and tillage x herbicides interaction (Table-5). Maximum weed density m^{-2} (40.7) was recorded in 2008-09 while minimum weed density m^{-2} (28.3) was recorded in 2007-08. The probable reason for higher weeds density m^{-2} in 2008-09 could be higher rain fall and multiplication/dissemination of previous year left over weeds seeds. All herbicidal treatments significantly affected weed density m^{-2}. Maximum weeds density m^{-2} (75.5) was recorded in weedy check followed by 51.8 in 2,4-D, and 34.8 in Puma super. The lowest weed density m^{-2} (3.2) was recorded in Affinity which was statistically comparable to 2,4-D + Puma super (7.2). Years x herbicides interaction also showed significant effect on weed density m^{-2} and maximum weed density m^{-2} (95.0) was recorded in weedy check in 2008-09 while minimum weed density m^{-2} (2.6 and 3.7) were recorded in Affinity treated plots in 2008-09 and 2007-08, respectively. These findings are in agreement with the work of Khalil et al. (1999) who managed weeds significantly in wheat crop with different herbicides. The lowest weeds counts m^{-2} in Affinity could be attributed to its highest phytotoxic effect against diverse flora of weeds. Analogous results were reported by Khan et al. (2004) who reported that Affinity proved to be the best for controlling weeds compared to other herbicidal treatments when applied as post emergence. They reported that herbicidal treatments significantly reduced weed density as herbicides are time saving and economical in comparison to hand weeding or cultural methods.

Mean values for tillage revealed that highest weed density m^{-2} (48.3) was recorded in CT while lowest weed density m^{-2} (22.0) was recorded in ZT which was statistically at par with RT (33.2). The higher weed density m^{-2} in CT may be attributed to its favorable environment for diverse flora of weeds particularly for *P. minor* which was dominant in CT. The hard compact surface in ZT might have created adverse environment for both grassy and broad leaf weeds and hence lowest weed density was recorded therein. These results are in line with the findings of Mehla *et al.*, (2000) and Mann *et al.*, (2004). They reported that the mean grain yield in ZT was higher than CT timely sown wheat. They further reported that 52 % lesser weeds were found in the ZT fields than the crop established with CT. Population of *P. minor* was reduced to nearly one-fourth in ZT plots compared to CT. They ascribed the increase in productivity primarily to enhanced fertilizer- and water-use efficiency and to a significant reduction in weed population. If ZT is practiced with rice residue retention then weed infestation will be lesser. This is because crop residues alter environmental conditions related to weed seed germination, physically impede seedling growth, or inhibit germination and growth by allelopathy (Crutchfield *et al.* 1986).

Tillage x herbicides interaction had also significant effect on weed density m^{-2}. Maximum weed density m^{-2} (112.7) was recorded in CT x weedy check. Lowest weed density m^{-2} (1.9) was recorded in CT x Affinity closely followed by 2.9 in ZT x Affinity. Tillage in combination with herbicide was effective way of controlling weeds in wheat (Acciaresi *et al.* 2003). The results mentioned in Table-5 clearly indicate superiority of ZT / RT over CT and that of Affinity over other herbicidal treatments regarding weeds control strategies. ZT in combination with herbicides drastically reduced *P. minor* population and economically more preferable over traditional tillage practices (Chhokar *et al.* (2007).

Dry weed biomass (g m^{-2})

Statistical analysis of the data revealed that dry weed biomass (DWB) was significantly affected by years, tillage, herbicides, years x tillage and years x herbicides (Table-5). Maximum DWB (180.3 g m^{-2}) was recorded in 2008-09 while minimum DWB (11.7 g m^{-2}) was recorded in 2007-08 (data not shown). The possible reason for higher DWB in 2008-09 could be higher weeds infestation due to rain fall and multiplication / dissemination of the previous year left over weeds seeds. All herbicidal treatments significantly affected DWB. Maximum DWB (220.4 g m^{-2}) was recorded in weedy check (infested with both broad leaf and grassy weeds) followed by 108.9 g m^{-2} in Puma super and 104.2 g m^{-2} in 2,4-D, both being statistically non significant. The lowest DWB (9.5 g m^{-2}) was recorded in Affinity which was statistically comparable to 2, 4-D + Puma super (37.1g m^{-2}). Years x herbicides interaction also occurred for DWB. Maximum DWB (412.6 g m^{-2}) was recorded in weedy check in 2008-09, while minimum DWB (0.9 and 1.6 g m^{-2}) was recorded in 2,4-D + Puma super and in Affinity treated plots in 2007-08. The difference in the DWB in different treatments may be due to variable efficiencies of different herbicides against weed species. Herbicides decreased DWB compared to weedy check (Khan *et al.*, (2003).

Mean values for tillage showed that highest DWB (136.5 g m^{-2}) was recorded in CT while lowest DWB (73.8 g m^{-2}) was recorded in ZT being statistically at par with RT (77.7 g m^{-2}). The higher DWB in CT may be attributed to its suitable growth environment having enough moisture and well prepared land to a sufficient depth for feeding vast flora of weeds particularly *P. minor* and *R. dentatus* which were dominant in CT. The adverse physical environment in ZT might have negative impact on weeds population and growth which ultimately resulted in lowest DWB as reported by Mehla *et al.*, (2000).

Years x tillage interaction significantly affected DWB. Maximum DWB (257.2 g m^{-2}) was recorded in CT in 2008-09, while minimum DWB (7.3 g m^{-2}) was recorded in ZT in 2007-08. The results (Table-5) illustrate that ZT and RT proved better than CT in suppressing weeds growth. Similarly among herbicidal treatments, Affinity and 2,4-D + Puma super both treatments with broad spectrum activities were most effective against broad leaf as well as grassy weeds. However, none of the herbicides showed any response against *Cyperus rotundus* being carried out from rice, though its population was limited in wheat. The prevailing weeds of wheat in rice-wheat cropping systems were *P. minor*, *R. dentatus*, *Medicago denticulata*, *Melilotus indica* and *Chenopodium album*. They provided tough competition to wheat crop in CT method due to soft and deeply ploughed well prepared land, while in ZT these weeds were suppressed in the very early growth stage due to hard compact surface and soil strength. Weeds could hardly emerge from hard compact surface of ZT while the emerged weeds remained under stress, poorly grown up and were effectively controlled by spraying with broad spectrum herbicides such as Affinity or 2,4-D + Puma super which had more phytotoxic effects on weeds compared to other herbicides. However, it was also observed during the course of study that although Affinity was far better in controlling weeds than either of the herbicidal treatments under study including 2,4-D + Puma super, but higher dose than the recommended might result in phytotoxic effect on crop, and Affinity might lose its selectivity in herbicidal action. The higher dose of 2,4-D + Puma super also showed phytotoxic effects against wheat crop, however this treatment even at recommended dose was less economical compared to Affinity. These findings are in agreement with Hassan *et al.*, (2005) and Baghestani *et al.*, (2007). They reported that increasing dose of carfentrazone-ethyl, the herbicide ability to damage weeds increased but this was at the expense of higher wheat injury. The post application of 2,4-D ester and Puma super plus 2,4-D ester premix results in unacceptable injury in winter wheat.

Grain yield (kg ha^{-1})

Statistical analysis of the data revealed that grain yield was significantly affected by years, tillage, herbicides, tillage x herbicides and years x tillage x herbicides interactions (Table-5). Maximum grain yield (5601 kg ha^{-1}) was recorded in 2008-09 while minimum grain yield (5491 kg ha^{-1}) was recorded in 2007-08 (data not shown). The lower yield in 2007-08 may be due to unfavorable solar radiation, precipitation and an increase in minimum temperature resulting in declining yield of wheat. Similar results were reported by Pathak *et al.* (2003). They analyzed weather data and reported negative trends in solar radiation and an increase in minimum temperature resulting in declining trends of potential simulated yield of rice and wheat. Grain yield increased with herbicidal treatments and maximum grain yield (6907 kg ha^{-1}) was recorded in plots treated with Affinity followed by 6348 and 5549 kg ha^{-1} in 2, 4-D + Puma super and 2,4-D alone. Weedy check and treatment with Puma super showed the lowest grain yield of 3766 and 5161 kg ha^{-1}, respectively. Herbicides with broad spectrum activity showed better performance than their alone application. The years x herbicides had also significant effect on grain yield of wheat. Maximum grain yield (6996 kg ha^{-1}) was recorded in plots treated with Affinity in 2008-09 while minimum grain yield (3690 kg ha^{-1}) was recorded in weedy check in 2008-09. Similar results were reported by Baghestani *et al.* (2008); and Chhokar *et al.* (2008). They reported that herbicides significantly increased grain yield in wheat corresponding to their weed control spectrum.

Tillage significantly increased grain yield and maximum grain yield (5584 kg ha^{-1}) was recorded in RT, however, it was statistically similar with ZT (5575 kg ha^{-1}). Minimum grain yield was recorded in CT (5479 kg ha^{-1}). The lower yield under CT may be due to higher weed density, leaching of N fertilizer and immobilization due to crop residues incorporation (Mandal *et al.* 2004). The higher yield in ZT and RT is ascribed to reduced weed growth; enhanced fertilizer and water use efficiency and to a significant reduction in weed population; particularly population density of *P. minor*. These results are in line with the findings of Mehla *et al.* (2000); Mari *et al.* (2003) and Erenstein *et al.* (2008). They reported higher productivity for ZT over CT due to early sowing, reduced population of *P. minor* and enhanced water and fertilizer use efficiency and improved fertility level of the soil in the organic matter compared to CT. Years x tillage also showed significant effect on grain yield of wheat. Maximum grain yield (5846 and 5647 kg ha^{-1}) was recorded in RT and ZT, respectively in 2008-09 while minimum grain yield (5310 kg ha^{-1}) was recorded in CT in 2008-09.

Mean values for tillage x herbicides interaction revealed that maximum grain yield was obtained from the interaction of Affinity x CT followed by Affinity x ZT (6929 kg ha^{-1}) while minimum grain yield was obtained from the interaction of CT x weedy check, where no herbicide was applied. The data further revealed that grain yield of weedy check x RT was higher than ZT x weedy check and CT x Weedy check in both years. One of the reasons may be higher density of *M. denticulata* and *Melilotus indica* in RT plots which are leguminous in nature having complementary effects on wheat crop and detrimental effects on other weeds. Banik *et al.* (2007) reported that association of *M. denticulata* with winter wheat controlled weeds, improved soil fertility, saved weeding costs, and increased yield. The observed increase in grain yield of wheat with the use of ZT and herbicides is in agreement with the findings of Chhokar *et al.* (2007). They reported that combination of ZT and herbicides have significantly increased wheat yield in different environments of the world by reducing weeds infestation and resulting in higher grain yield compared to CT. However, the magnitude of increase varied is rather site specific and dependent on the type of tillage and herbicides used. The years x tillage x herbicides interaction was significant. Maximum grain yield was recorded in ZT treated with Affinity in 2008-09. However, it was statically similar with RT x Affinity (6995 kg ha^{-1}), CT x Affinity (6995 kg ha^{-1}) in 2008-09 and with CT x Affinity (6995 kg ha^{-1}) in 2007-08. Minimum grain yield (3497 and 3527 kg ha^{-1}) was recorded in weedy check x ZT and weedy check x CT in 2008-09 (data not shown).

CONCLUSIONS

The following conclusions are drawn from the experiments:

1. The herbicides controlled weeds to a varying level and significantly affected all parameters such as weed density m^{-2}, dry weed biomass, and grain yield. Among the herbicidal treatments, Affinity was the most effective broad-spectrum herbicide which controlled both grassy and broad-leaved weeds and gave the highest grain yield.

2. Tillage significantly affected weed density, dry weed biomass and grain yield. Zero tillage and reduced tillage had minimum weed density m^{-2}, minimum dry weed biomass and maximum grain yield while conventional tillage had maximum weed density m^{-2}, maximum dry weed biomass, and minimum grain yield.

Table-5. Effect of tillage and herbicides on weeds density (m^{-2}) after spray, dry weed biomass and grain yield (average of 2 years).

Tillage	Weed density (m^{-2})	Dry weed biomass ($g\ m^{-2}$)	Grain yield ($kg\ ha^{-1}$)
Zero tillage	22.0 b	73.8 b	5575 a
Reduced tillage	33.2 ab	77.7 b	5584 a
Conventional tillage	48.3 a	136.5 a	5479 b
$LSD_{(0.05)}$ for tillage	15.2	49.2	22.9
Herbicides			
2,4-D	51.8 b	104.2 b	5549 c
Puma super	34.8 c	108.9 b	5161 d
2,4-D + Puma super	7.2 d	37.1c	6348 b
Affinity	3.2 d	9.5 c	6907 a
Weedy check	75.5 a	220.4 a	3766 e
$LSD_{(0.05)}$ for herbicides	14.1	48.0	15.9
Tillage X Herbicides	**	NS	**

* = Significant at $P \leq 0.05$, ** = Significant at $P \leq 0.01$, NS= Non Significant

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