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SCREENING OF HERBICIDES FOR EFFICIENT CONTROL OF BROADLEAF WEEDS IN WHEAT (*Triticum aestivum* L.)

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ABSTRACT

Broadleaf weeds constitute major proportion of weed flora in wheat. A field study to find out suitable herbicides for controlling broadleaf weeds in wheat crop was conducted during winter, 2014. Ten premixed herbicides viz., bromoxynil + MCPA at 450 g a.i. ha^{-1}, fluroxypyr + clopyralid + tribenuron at 330 g a.i. ha^{-1}, fluroxypyr + MCPA at 450 g a.i. ha^{-1}, bromoxynil + MCPA + tribenuron methyl at 475 g a.i. ha^{-1}, fluroxypyr + MCPA at 375 g a.i. ha^{-1}, fluroxypyrmethyl + MCPA at 144 g a.i. ha^{-1}, clopyralid at 525 g a.i. ha^{-1}, tribenuron + fluroxypyr at 140 g a.i. ha^{-1}, triasulfuron at 30 g a.i. ha^{-1} were applied 25 days after sowing (DAS) (1st irrigation). A weedy control was also kept for comparison. The highest weed control was given by bromoxynil + MCPA at 450 g a.i. ha^{-1}, triasulfuron at 30 g a.i. ha^{-1}, and fluroxypyr + MCPA at 450 g a.i. ha^{-1} as they gave highest values of weed control efficiencies (81.3, 81.2 and 79.7%) and herbicide efficiency indices (3.31, 3.27 and 3.25), respectively. Fluroxypyr + MCPA at 450 g a.i. ha^{-1} produced the highest grain yield (4.07 t ha^{-1}) of wheat which was followed by triasulfuron at 30 g a.i. ha^{-1} (3.97 t ha^{-1}) and bromoxynil + MCPA at 450 g a.i. ha^{-1} (3.95 t ha^{-1}). The improvement in grain yield of wheat by herbicides seem to be resulted due to better weed control as grain yield showed significant negative relationship with total weed density (R^2=0.68) and total weed biomass (R^2=0.85). Regression analysis also revealed a significant positive dependence of grain yield on number of tillers m^{-2} (R^2=0.93), spike length (R^2=0.91), grains spike^{-1} (R^2=0.83) and grain weight (R^2=0.95). It is concluded that fluroxypyr + MCPA, triasulfuron and bromoxynil + MCPA are the best herbicides for the control of broadleaf weeds like Chenopodium album, Chenopodium murale, Convolvulus arvensis, Euphrobia helioscopia and Fumaria indica in wheat.

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Key words: Broadleaf weeds, grain yield, herbicides, *Triticum aestivum*, yield components.

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INTRODUCTION

More than 35% of the world population subsists on wheat (*Triticum aestivum* L.) for its staple food and it is also the top ranked cereal in most of the developing countries including Pakistan. It contributes 2.2% to the gross domestic production of the country. Wheat is grown over an area of 9.18 million hectare which gives 25.48 million tones grain production (Economic Survey of Pakistan, 2014-15). The average grain yield therefore lies around 2797 kg per hectare. Despite among seven leading wheat producers of the world, average grain yield of Pakistan is very much lower than that of global average yield of wheat (Food and Agriculture Organization, 2013). In-spite of wider adoption of promising varieties by wheat growers, the lower yield in Pakistan is due to be some agronomic factors. These factors include late sowing, inadequate irrigation and fertilization and weed infestation. Wheat crop in Pakistani Punjab is infested majorly with *Avena fatua, Chenopodium album, Cirsium arvense, Convolvulus arvensis, Coronopus didymus, Cynodon dactylon, Dichanthium annulatum, Melilotus indica, Phalaris minor, Polygonum plebejum, Polypogon fugax, Rumex dentatus* and *Spergula arvensis* weeds (Waheed *et al.*, 2009). Wheat grain yield losses due to presence of these weeds were estimated to be 20 to 30% (Marwat *et al.*, 2006). These losses can be reduced by effective control of these weeds.

Herbicidal weed control is considered most effective and economical method in wheat (Ashiq *et al.* 2003). According to an estimate, about 63% of herbicides amounting to be of 2.2 billion rupees are being used in wheat crop every year in Pakistan. Although monocot grassy weeds are considered more serious in wheat than dicot weeds, some of the dicot weeds have developed resistance against herbicides most prevalently used in Pakistan since many years (Haleemi, 1994). It is also true that most of the dicot herbicides do not give a 100% control of all broadleaf weeds (Zimdahl, 1993). This is due to differential phytotoxic action of herbicides against a range of broadleaf weeds (Ashiq *et al.*, 2007). That is why, since few years, a broad range of herbicidal compounds have continuously been introduced in the country and tested for their efficacy against diverse weed flora in wheat (Hassan *et al*., 2003; Ashiq *et al.*, 2007). During last decade, isoproturon and bromoxynil + MCPA were mostly used by

Pakistani wheat growers due to their highest weed control (Marwat *et al.*, 2008). But the excessive application of isoproturon alone or combination with other compounds resulted in development of resistant broadleaf weed flora as *Lathyrus aphaca*, *Convolvulus arvensis* and *Galium aparine* (Haleemi, 1995). With the introduction of some new compounds during recent years, some new weed killers of wheat which have been very much popularized in Pakistan among farming community. These include carfentrazone ethyl (Khan *et al.*, 2004), fluroxypyr (Ashiq *et al.,* 2007); and triasulfuron, and pinoxaden (Hussain *et al.*, 2013). These herbicides are now being widely used alone or in mixture with other herbicides for the control of broadleaf weeds.

The efficacy of a herbicide sometimes alters by mixing it with other herbicides or changing its formulation, concentration or dose. These factors should therefore be kept under consideration while testing it against a specific weed species. Moreover, screening studies should be aimed at a certain weed species or a group of weed species with similar morphological characteristics. Therefore, there is a need for continuous testing and evaluation of new herbicidal compounds available in different formulations, mixtures and concentrations for their performance against various weeds which are prevalent in wheat. Studies have been therefore planned for testing the efficacy of new herbicides in comparison with that of older one for effective control of broadleaf weeds in wheat.

MATERIALS AND METHODS

A field study was carried out at Research Area, Plant Physiology Section, Ayub Agriculture Research Institute, Faisalabad, Pakistan in the winter season 2013-14. The meteorological data of the experimental site during the crop season were depicted in Figure 1. The herbicide treatments were bromoxynil+ MCPA at 450 g a.i. ha^{-1} (Standard), fluroxypyr + MCPA at 450 g a.i. ha^{-1}**,** fluroxypyr + clopyralid + tribenuron at 330 g a.i. ha^{-1}**,** bromoxynil+ MCPA + tribenuron methyl at 475 g a.i. ha^{-1}, fluroxypyr + MCPA at 375g a.i. ha^{-1}, fluroxypyr methyl + MCPA at 144 g a.i. ha^{-1}**,** clopyralid at 525 g a.i. ha^{-1}**,** tribenuron + fluroxypyr at 140g a.i. ha^{-1}, triasulfuron at 30 g a.i. ha^{-1} (Table-1). A weedy check was receiving no weed control was retained as control. Crop was sown on November 12, 2014. The randomized complete block design was employed and each treatment was repeated thrice. The net plot size was 8 m × 2 m. Wheat variety Punjab-2011 was used. The field selected for experiment was heavily infested with weeds during the previous year. The broadleaf weeds present in natural abundance during the study year were shown in Table 2. All the narrow leaf weeds that appeared during the crop season were removed manually by hand pulling to avoid their interference. All the herbicides were sprayed 25 days after sowing with first irrigation with second irrigation. Data on total weed density were recorded at 15 days after herbicide application by counting weeds from an area of 1 m^2 at two different places selected at random within each plot and then taking their average. Total weed biomass was obtained at crop harvest by taking above ground portion of weeds, drying initially in sun for two days and then in electric oven at 70^{o}C for 48 hours.

Weed control efficiency of each herbicide was calculated by the following formula as described by Main *et al.* (2007):

$$WCE\ (\%) = \frac{WDc - WDt}{WDc} \times 100$$

Where,
WCE = Weed control efficiency (%)
WDc = Weed dry biomass in weedy check
WDt = Weed dry biomass in herbicide treatment

Herbicide efficiency index was calculated by the formula of Misra and Misra (1997) as under:

$$HEI = \frac{(Yt - Yc)}{Yc} \times 100 \ / \ \frac{\mathrm{WDt}}{\mathrm{WDc}} \times 100$$

Where,
HEI = Herbicide efficiency index
Yt = Grain yield of herbicide treatment
Yc = Grain yield of weedy check
WDc = Weed dry biomass in weedy check
WDt = Weed dry biomass in herbicide treatment

Nitrogen, phosphorus and potassium were applied at 160-120-60 kg ha^{-1}, respectively. All P and K along with 1/3rd of N were applied at sowing. The remaining N was applied at tillering and booting growth stages. All other agronomic practices were kept uniform. Observations on wheat crop parameters likenumber of tiller per m^2,plant height,spike length, spikelets per spike, grain per spike,1000 grain weight, biological yield, harvest index, and grain yield were observed at harvest using standard procedures.

Data collected were statistically analyzed following Fischer's analysis of variance technique and means were compared by least significant difference test at 5% probability (Steel *et al.,* 1997). Computer software Statistix 8.1 was used for statistical analysis whereas figures were prepared on Excel sheets.

RESULTS AND DISCUSSION

Weed control efficiency and herbicide efficiency index

Data related to total weed density, biomass and weed control efficiency have been presented in Table-3. Data indicated that weed density 15 days after herbicide application and total weed biomass at harvest significantly differed among different herbicide treatment. The quickest phytotoxic action against all broadleaf weeds was shown by fluroxypyr + MCPA at 450 g a.i. ha^{-1} , bromoxynil+ MCPA at 450 g a.i. ha^{-1} and triasulfuron at 30 g a.i. ha^{-1} as they left significantly the lowest weed densities of 4, 5 and 6.76 weeds per m^{-2}, respectively in wheat after 25 days of their spray. Contrastingly, the highest weed density was recorded with fluroxypyr methyl+ MCPA at 144 g a.i. ha^{-1} (30.67 m^{-2}) and tribenuron + fluroxypyr at 140 g a.i. ha^{-1} (31.67 m^{-2}). Regarding total weed biomass at harvest, all herbicides except fluroxypyr methyl + MCPA at 144 g a.i. ha^{-1}, clopyralid at 525 g a.i. ha^{-1}, and tribenuron + fluroxypyr at 140 g a.i. ha^{-1} could be ranked at first position by producing significantly the lower weed biomass. Decline in weed density and biomass of broadleaf weeds in wheat to various degrees in response various herbicidal treatments as compared to weedy check was attributed to their differential phytotoxic effects against different broadleaf weeds. Significant reduction in density and biomass of diverse broadleaf weed flora by application of fluroxypyr + MCPA, bromoxynil+ MCPA and triasulfuron + terbutryn herbicides compared with weedy check in wheat was also reported by Abbas *et al.* (2009).

A comparison of herbicide efficiency index (HEI) and weed control efficiency (WCE) of herbicides used for against broadleaf weeds of wheat have been given in Figure 2 and Table 3, respectively. Among all herbicides, the highest WCE (81.3 and 81.2%) have been shown by bromoxynil+ MCPA at 450 g a.i. ha^{-1} and triasulfuron at 30 g a.i. ha^{-1}, respectively. However, the herbicide fluroxypyr + MCPA at 450 g a.i. ha^{-1} could be ranked at second position in this regard. Ashiq*et al.* (2007) also recorded the highest WCE of bromoxynil+ MCPA against broadleaf weeds *Chenopodium album, C. murale, Fumaria indica* and *Convolvulus arvensis* in wheat. Herbicide efficiency index represents the crop yield enhancing performance of a herbicide as a result of efficient weed control. It shows weed-killing potential of herbicide along with its crop phyto-toxicity behavior. Regarding this parameter, the highest HEI (3.31) was achieved by triasulfuron at 30 g a.i. per ha which was followed by bromoxynil+ MCPA at 450 g a.i. per ha^{-1} and fluroxypyr + MCPA at 450 g a.i. per ha which gave HEI’s of 3.27 and 3.25, respectively. The highest performance of triasulfuron at 30 g a.i. ha^{-1} in terms of HEI compared with all other herbicides showed its better weed control potential along with lesser phytotoxic effects on wheat crop. The highest HEI by urea based herbicide isoproturon +

Carfentrazone ethyl at 1000 g a.i. per ha compared with all other herbicides was also mentioned by Khaliq *et al.* (2014).

Crop growth, yield and yield component

Number of spike-bearing tillers per m^2, plant height, spike length, and spikelets per spike at maturity indicate vegetative growth pattern of a cereal crop. Data of number tillers per m^2, plant height, spike length and spikelets per spike of wheat as influenced by various herbicide treatments are presented in Table-4. Data reflected that all of these growth traits except plant height were significantly enhanced by various herbicides in comparison with weedy check. Among herbicides, bromoxynil+ MCPA at 450 g a.i. ha^{-1}, fluroxypyr + MCPA at 450 g a.i. ha^{-1}, fluroxypyr + clopyralid + tribenuron at 330 g a.i. ha^{-1}, bromoxynil+ MCPA + tribenuron methyl at 475 g a.i. ha^{-1}, fluroxypyr + MCPA at 375 g a.i. ha^{-1}, triasulfuron at 30 g a.i. ha^{-1}produced significant increase in spike lengthand number of tillers per plant of wheat over weedy check. However, significantly the higher number of spikelets per spike of wheat was recorded with bromoxynil+ MCPA at 450 g a.i. ha^{-1} (17.0), triasulfuron at 30 g a.i. ha^{-1} (16.86), and fluroxypyr + MCPA at 375 g a.i. ha^{-1} (15.63). The enhancement in growth of wheat to variable levels by different herbicides than weedy check might be the result of their differential weed control that minimized weed competitive effects during vegetative growth of crop. Our results are in agreement with those of Yasine*et al.* (2013) who also noticed that triasulfuron + terbutryn, fluroxypyr + MCPA, and bromoxynil+ MCPA gave maximum spikelets per spike of wheat compared with other herbicides on account of better control of broadleaf weeds. The significant incline in number of tillers m^{-2} of wheat due to improved vegetative growth by better weed control (Khan *et al.* 2016) in response to various post-emergence herbicides was also reported by Marwat *et al.* (2008).

Table-5 contains the data pertaining to grain yield and yield linked traits of wheat as affected by various herbicide treatments. Data revealed that highest 1000 grain weight (37.26 g) and number of grains (50.26) were observed with herbicide treatment triasulfuron at 30 g a.i. ha^{-1}. However, this treatment remained statistically at par with bromoxynil+ MCPA at 450 g a.i. ha^{-1}, fluroxypyr + MCPA at 450 g a.i. ha^{-1}, fluroxypyr + clopyralid + tribenuron at 330 g a.i. ha^{-1}, and fluroxypyr + MCPA at 375 g a.i. ha^{-1} with respect to 1000 grain weight and grains per spike. Contrastingly, the minimum weight of 1000 grains (31.57 g) and grains per spike (36.46) was recorded with weedy check where no weed control was employed. Enhancement in number of grains, and grain weight of wheat by herbicides in comparison with weedy check was probably the result of less competition by weeds that produced suitable conditions for crop during grain formation and grain filling stages. Hussain *et al.* (2013) also concluded noted an increase in number of grains per spike of wheat by post-emergence application of bromoxynil+MCPA and triasulfuron herbicides as a consequence of better weed control.

Grain yield of wheat, the overall resultant of various underlying yield contributing traits, also showed significant enhancement in response to herbicide treatments than weedy check receiving no herbicide (Table 5). The maximum grain yield (4.07 t ha^{-1}) of wheat was harvested from plots treated with fluroxypyr + MCPA at 450 g a.i. ha^{-1} which did not differ significantly from grain yields recorded with triasulfuron at 30 g a.i. ha^{-1} (3.97 t ha^{-1}) and bromoxynil+ MCPA at 450 g a.i. ha^{-1} (3.95 5 t ha^{-1}). Increase in yield by herbicide application seems to be the result of decrease in total weed density and biomass which minimized the competitive effect of weeds with crop. Regression analysis showed a significant moderate to strong negative relationship of grain yield with total weed density (R^2=0.69) and total weed biomass (R^2= 0.85) (Figure-3). The reduced weed interference with wheat crop due to herbicide application promoted its growth that resulted in enhancement in yield contributing traits which increased grain yield. The relationship of wheat grain yield with its growth traits was depicted in Figure 4 which showed significant positive dependence of grain yield on plant height (R^2=0.4), spike length (R^2=0.91) and number of spikelets per spike (R^2=0.95). Grain yield of wheat was significantly and positively influenced by its underlying components viz., number of tillers per m2 (R^2=0.93), grains per spike (R^2=0.83) and grain weight (R^2=0.95) strongly as revealed by their regression analyses (Figure 5). The improvement in grain yield of wheat ranging from 506 to 1983% over weedy check as a result of enhancement in number of grains per spike by spraying triasulfuron and bromoxynil+MCPA was also documented by Hussain *et al.* (2013). Data concerned with harvest index (HI) of wheat are shown in Table 5 which revealed that significantly the highest values of HI (43.3%) and 39.36%) were calculated from wheat harvested from plots spayed with triasulfuron at 30 g a.i. ha^{-1} and fluroxypyr + MCPA at 450 g a.i. ha^{-1}, respectively. In contrast, clopyralid at 525 g a.i. ha^{-1} produced the lowest HI (33.16%).

CONCLUSION

The best weed control strategy in wheat field with broadleaf weed flora dominated by *Chenopodium album*, *C. murale*, *Convolvulus arvensis, Euphrobia helioscopia* and *Fumaria indica* is the use of post-emergence application of fluroxypyr + MCPA at 450 g a.i. ha^{-1}, triasulfuron at 30 g a.i. ha^{-1} and bromoxynil+ MCPA at 450 g a.i. ha^{-1}. However, according to authors' visual observations fluroxypyr + MCPA and bromoxynil+ MCPA were more effective against *Chenopodium* *murale, Chenopodium album* and *Euphrobia helioscopia* but weak against the *Convolvulus arvensis* and *Fumaria indica.*

Table-1. Herbicide treatments used for controlling broadleaf weeds in wheat

Common name	Trade name	Dose (a.i. ha^{-1})
Bromoxynil+ MCPA	Buctril super 60EC	450 g
Fluroxypyr + MCPA	Starane-M 60EC	450 g
Fluroxypyr + clopyralid + tribenuron	Gold mix 66WDG	330 g
Bromoxynil+ MCPA + tribenuron methyl	Weed away 38EC	475 g
Fluroxypyr + MCPA	Sprint 50EC	375g
Fluroxypyr methyl + MCPA	Flock 20.5SC	144 g
Clopyralid	Tanical 75WDG	525g
Tribenuron + fluroxypyr	Timber 20WP	140g
Triasulfuron	Logran 75WP	30g

Table-2. Broad leaf weeds present in wheat field

Botanical name	Common name	Local name
Convolvulus arvensis	Field bind weed	Lehli
Chenopodium murale	Nettleleaf goosefoot	Krund
Chenopodium album	Lambsquarters	Bathu
Euphrobia helioscopia	Madwoman's milk	Chatridodhak
Fumaria indica	Fumitory	Shahtra

Table-3. Dynamics of broad leaf weeds under various herbicide treatments

Treatment	Total weed density m^{-2} (15 days after treatment)	Total Weed biomass (g m^{-2})	Weed control efficiency (%)
Weedy check (Control)	111.33 a	769.0 a	-
Bromoxynil+MCPA at 450 g a.i. ha^{-1}	5.0 de	144.0 c	81.3
Fluroxypyr+MCPA at 450 g a.i. ha^{-1}	4.0 e	156.3 c	79.7
Fluroxypyr+clopyralid + tribenuron at 330 g a.i. ha^{-1}	8.33 d	161.0 c	79.1
Bromoxynil+MCPA + tribenuron methyl at 475 g a.i. ha^{-1}	9.0 d	171.3 c	77.7
Fluroxypyr+MCPA at 375 g a.i. ha^{-1}	8.33 d	166.3 c	78.4
Fluroxypyrmethyl+MCPA at 144 g a.i. ha^{-1}	30.67 bc	384.3 b	50.0
Clopyralid at 525 g a.i. ha^{-1}	26.67 c	384.3 b	50.0
Tribenuron+fluroxypyr at 140 g a.i. ha^{-1}	31.67 b	358.0 b	53.4
Triasulfuron at 30 g a.i. ha^{-1}	6.67 de	144.3 c	81.2
LSD (at $P \leq 0.05$)	4.088	38.96	-

Table-4. Growth traits of wheat as affected by different herbicide treatments

Treatment	Plant height (cm)	Number of productive tillers m^{-2}	Spike length (cm)	Number of spikelets $spike^{-1}$
Weedy check (Control)	93.00	223.0 b	7.06 c	9.50 e
Bromoxynil+MCPA at 450 g a.i. ha^{-1}	97.07	309.3 a	10.70 ab	17.0 a
Fluroxypyr+MCPA at 450 g a.i. ha^{-1}	98.33	302.2 a	9.56 a	15.56 bc
Fluroxypyr+clopyralid + tribenuron at 330 g a.i. ha^{-1}	92.53	314.3 a	9.40 ab	15.60 bc
Bromoxynil+MCPA + tribenuron methyl at 475 g a.i. ha^{-1}	95.27	307.6 a	9.83 a	15.13 c
Fluroxypyr+MCPA at 375 g a.i. ha^{-1}	98.93	316.0 a	9.63 a	15.63 abc
Fluroxypyrmethyl+MCPA at 144 g a.i. ha^{-1}	91.67	243.0 b	7.93 bc	12.30 d
Clopyralid at 525 g a.i. ha^{-1}	90.86	242.6 b	7.93 bc	11.46 d
Tribenuron+fluroxypyr at 140 g a.i. ha^{-1}	95.53	230.3 b	7.76 c	12.36 d
Triasulfuron at 30 g a.i. ha^{-1}	94.67	304.0 a	10.06 a	16.86 ab
LSD (at $P \leq 0.05$)	NS	29.07	1.503	1.378

Table-5. Grain yield and yield components of wheat as affected by different herbicide treatments

Treatment	Grains per spike	1000-grain weight (g)	Grain yield (t/ha)	Harvest index (%)
Weedy check (Control)	36.46 c	31.57 b	2.45 d	33.74 de
Bromoxynil+MCPA at 450 g a.i. ha^{-1}	48.96 a	36.19 a	3.95 ab	38.77 bc
Fluroxypyr+MCPA at 450 g a.i. ha^{-1}	49.03 a	36.76 a	4.07 a	39.36 ab
Fluroxypyr+clopyralid + tribenuron at 330 g ha^{-1}	48.96 a	36.99 a	3.84 b	37.89 bcd
Bromoxynil+MCPA + tribenuron methyl at 475 g a.i. ha^{-1}	41.60 bc	36.73 a	3.82 b	33.65 de
Fluroxypyr+MCPA at 375 g a.i. ha^{-1}	45.80 ab	35.56 a	3.85 b	36.05 bcde
Fluroxypyrmethyl+MCPA at 144 g a.i. ha^{-1}	35.53 c	33.10 b	2.96 c	35.79 bcde
Clopyralid at 525 g a.i. ha^{-1}	38.36 c	32.41 b	2.86 c	33.16 e
Tribenuron+fluroxypyr at 140 g a.i. ha^{-1}	35.83 c	32.73 b	2.91 c	34.90 cde
Triasulfuron at 30 g ha^{-1}	50.26 a	37.26 a	3.97 ab	43.30 a
LSD (at $P < 0.05$)	6.2282	1.856	0.1923	4.455

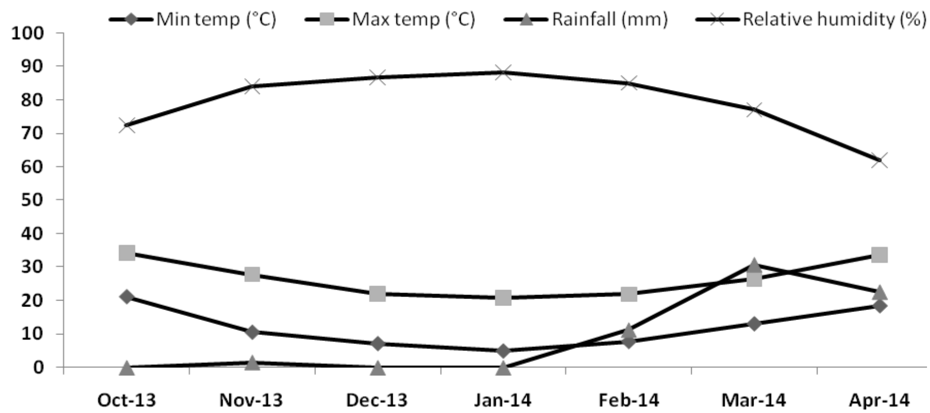

Figure 1. Meteorological data of experimental site during wheat growing season 2013-14

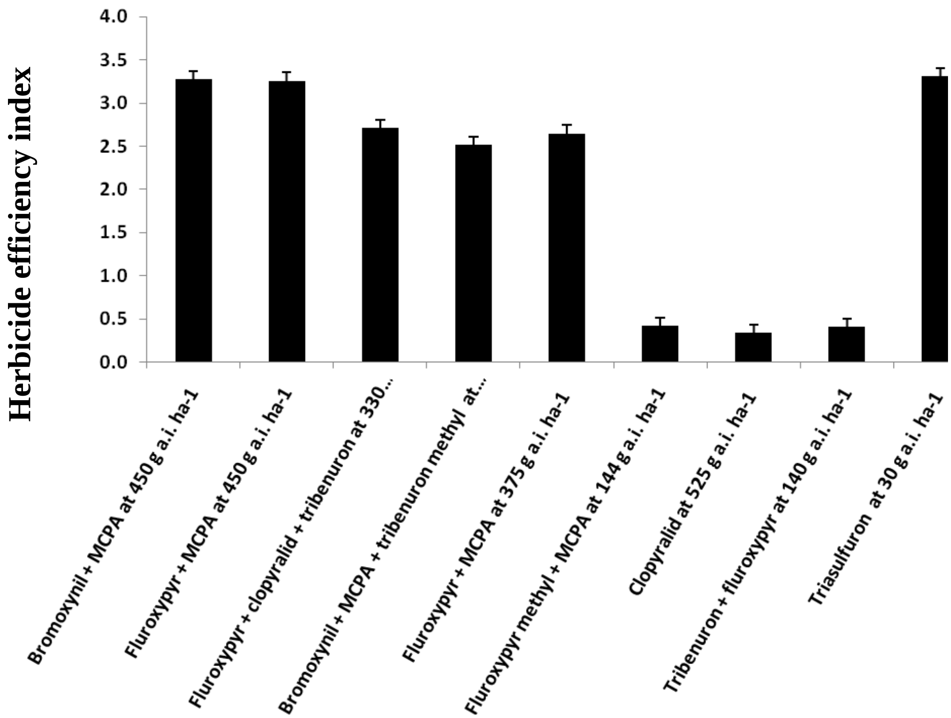

Figure 2. Herbicide efficiency index (HEI) of various herbicide treatments for controlling broadleaf weeds in wheat

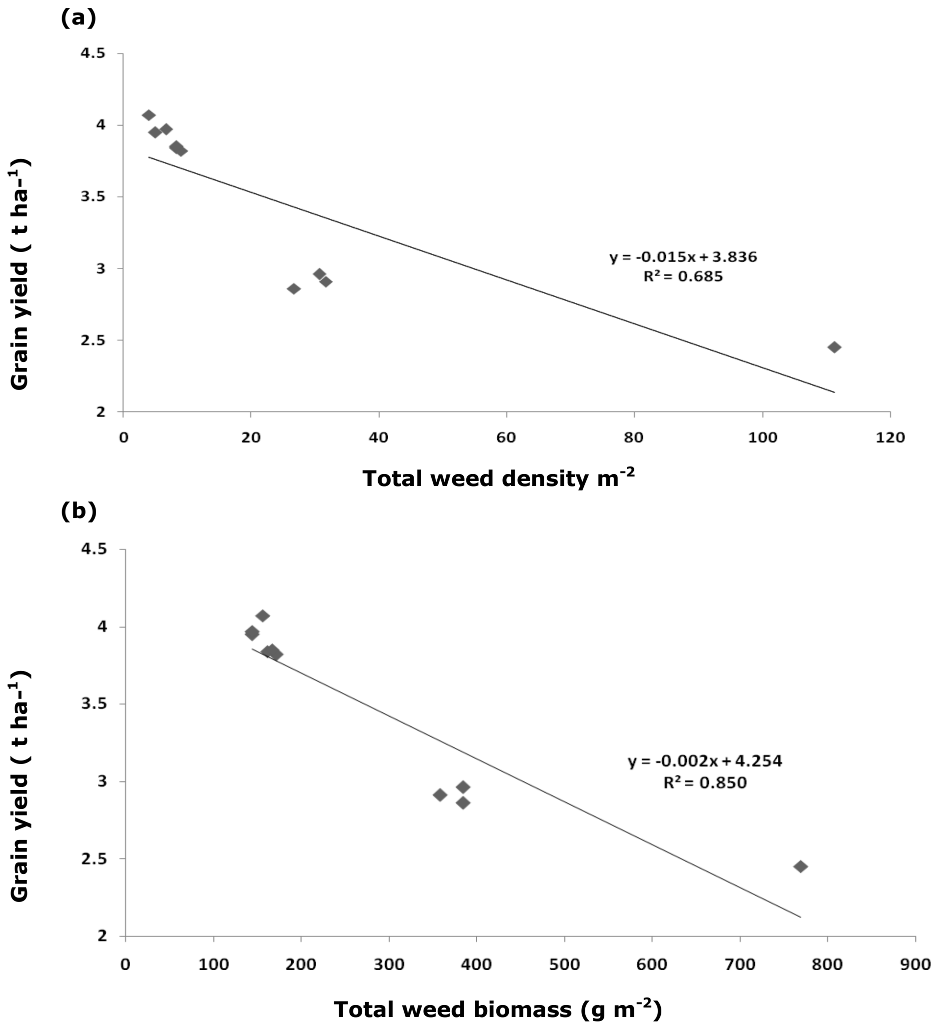

Figure 3. Relationship of wheat grain yield with (a) Total weed density and (b) Total weed biomass

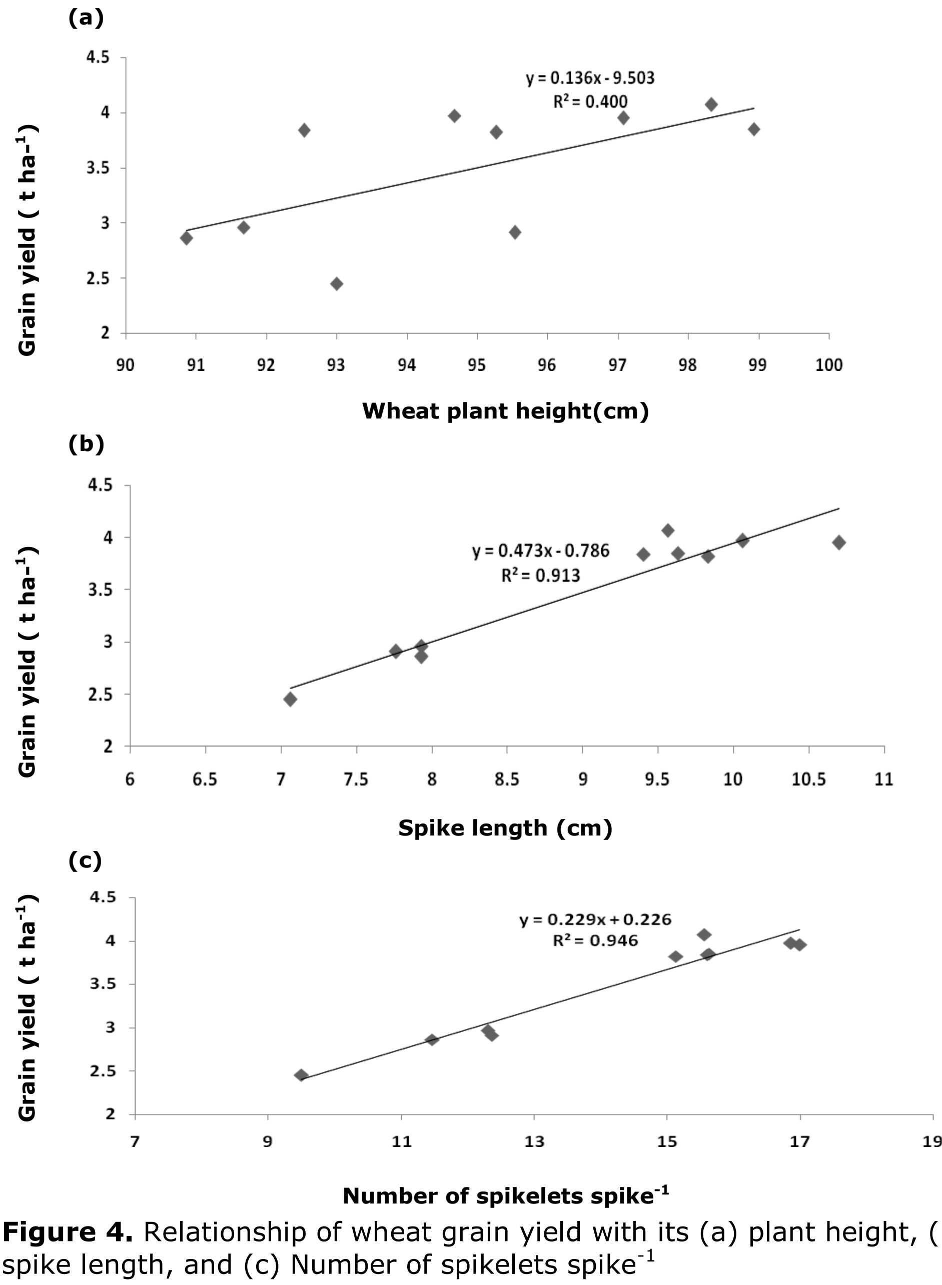

Figure 4. Relationship of wheat grain yield with its (a) plant height, (b) spike length, and (c) Number of spikelets spike^{-1}

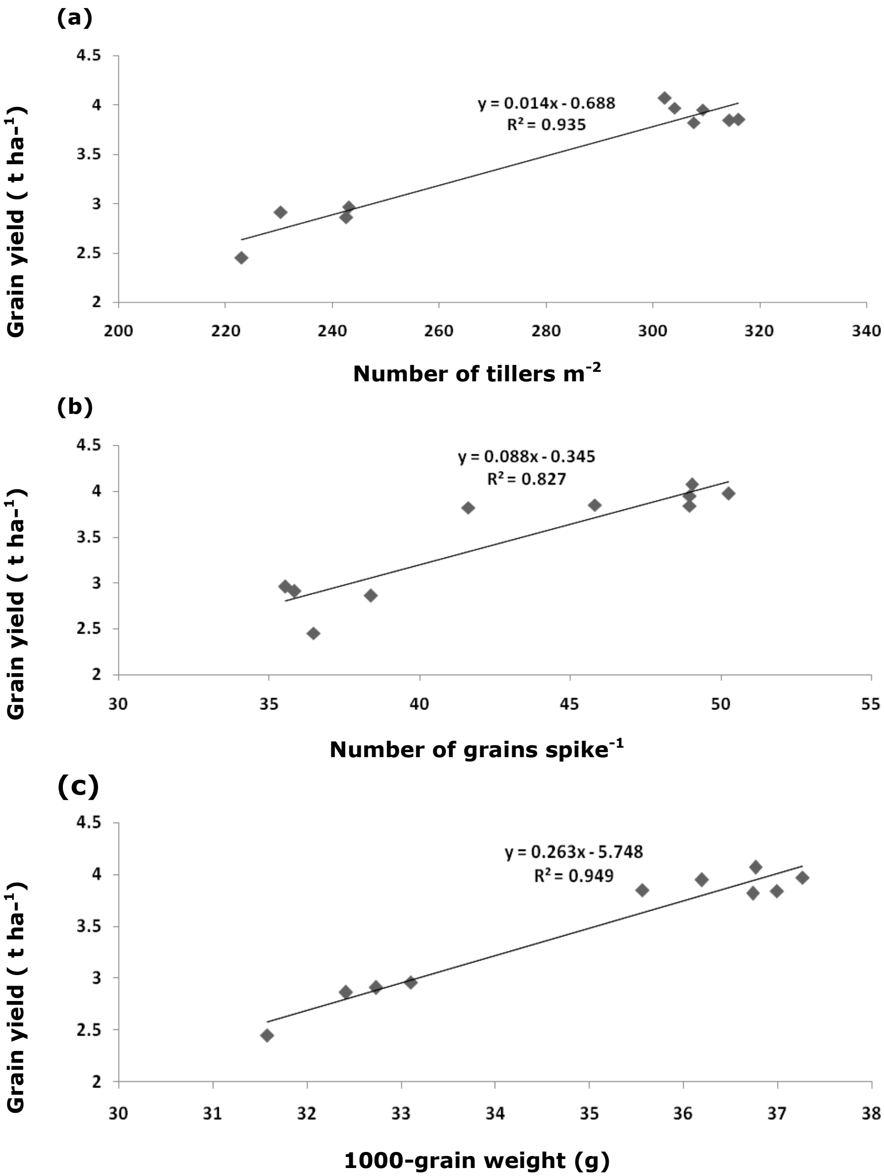

Figure 5. Relationship of wheat grain yield with its (a) tillers plant^{-1}, (b) Grains spike^{-1} and (c) 1000-grain weight

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