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Research Article
Effect of Herbicides on the Density of Broad Leaf Weeds and their Effect on the Growth and Yield Components of Wheat (*Triticum aestivum* L.)

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Abstract

Objective: The aim of the study was to determine the effects of different herbicides on broadleaf weed density and growth as well as the growth and yield components of wheat. It also examined the effects of weed control (by herbicides and hand weeding) on the growth and yield of wheat, the economic benefits of weed control and aspects of environmental safety. **Materials and Methods:** This experiment was carried out at the Mullah Ghulam Agriculture Research Centre, Afghanistan. Four different types of herbicides namely, methyl chlorophenoxy acetic acid (MCPA) (Agroxone® at 25 1 L ha^{-1}), triasulfuron (Amber® at g a.i kg^{-1}), tribenuron methyl (Express® 25 g a.i kg^{-1}) and pyroxsulam (Merit® at 240 g a.i kg^{-1}) were tested. The manufacturers' recommended dosage for triasulfuron was applied at the rate of 120 L ha^{-1}. The other three post-emergence herbicides were applied at the rate of 350 L ha^{-1}. The herbicides were applied individually at 25 days after sowing (DAS). In another treatment, the weeds were hand weeded at 25, 50 and 75 DAS, while the control plots and were left unweeded. The data was analyzed using SPSS, one-way ANOVA and the Duncan's test for comparison of means. **Results:** The results showed that the highest grain yield (2936 kg ha^{-1}) was obtained from the hand weeded plots, where yields were significantly higher ($p \leq 0.05$) than those of the other treatments. The lowest grain yield of wheat (1855.75 kg ha^{-1}) was obtained from the unweeded plots. It was observed that the population density of the broad leaf weeds was lower in the hand weeded plots than that in the other treatment plots. It was observed that tribenuron methyl effectively controlled the weed density of *Amaranthus bouchonii, Convolvulus arvensis, Acroptilon repense* and *Polygonum aviculare* at 30 DAS. **Conclusion:** The study showed that the significantly higher hand weeding treatment followed by treatments with MCPA and triasulfuron herbicides were more effective in case of yield components of wheat and also decreased the population of broad leaf weeds.

Key words: Weed, weed management, herbicides, *Triticum aestivum*, grain yield

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important crops cultivated throughout Afghanistan. The annual production is 5.10 million metric tons, from an area of approximately 2.55 million hectares, with an average yield of 2.00 metric t ha^{-1} [1]. Wheat is classified as spring or winter wheat whereby the winter wheat is the more common crop and is traditionally referred to by the season during which the crop is grown[2]. The crop can be cultivated between the latitudes of 30-60° N and 27-40° S. The optimum temperature for cultivation is around 25°C, with minimum and maximum growth temperatures of 3-4°C and 30-32°C, respectively[3]. Wheat is adaptable to a wide range of moisture conditions ranging from xerophytic to littoral. Although about three-fourths of the land area where wheat is grown receives an average annual precipitation between 375 and 875 mm, the crop can be grown at locations where precipitation ranges from 250-1,750 mm[4]. Weeds are undesirable plants, which infest different crops and inflict negative effects on crop yield due to competition for water, nutrients, space and/or light[5]. Basically, a weed is considered a pest in agriculture because it causes damage to the main crop. Weeds reduce the quality as well as the quantity of the cultivated crop yield if left uncontrolled[6]. There are many reports on the inhibitory effects of weeds on various crop plants[7]. Weeds are unwanted plants and act as a reservoir for a multitude of pests and diseases, which use them as alternate hosts for survival and shelter during the off season[8]. Weeds can be the cause of various diseases in crops.

Weed competition has been reported to reduce straw yield by 13-38% and grain yield by 25-47%[9]. It has been estimated that globally yield reduction in wheat due to weeds is 13.1%[10]. It should be noted that broadleaf weeds are very significant in the wheat crops of Afghanistan. Therefore, the present study focussed more on broadleaf weeds than on grassy weeds. The major broadleaf weeds observed in the experimental plots were as follows: *Amaranthus bouchonii, Chenopodium album, Convolvulus arvensis, Acroptilon repense, Polygonum aviculare, Salsola kali, Sonchus asper, Malva sylvestris* and *Sinapis arvensis.*

Since weeds as reported earlier, are a very important pest in wheat, it is very crucial to find the best approach for weed management. It should be noted that different localities may have different weed composition and different weather conditions. An approach for good weed management at one location might be slightly different to that for another location even when the crops grown are the same. In the present study, 4 different herbicides were used to control broadleaf weeds. These 4 types of herbicides, commonly used by farmers are as follows: MCPA, tribenuron methyl, trisulfuron and pyroxsulam. Trisulfuron methyl is classified as a pre-emergence herbicide, while the other three are post-emergence herbicides. These herbicides can effectively control broadleaf weeds in the wheat crop. Therefore, it is important to know and select a compound that is effective in controlling broadleaf weeds in wheat in order to reduce the operational cost of weed management. The study constitutes relatively new work done in Afghanistan to help farmers and researchers decide on the best method of weed control that can be both beneficial to the wheat crop as well as be more effective in controlling of weeds. The objective of the present study was to investigate the effectiveness of the different methods of weed management on the yield of wheat.

MATERIALS AND METHODS

Experimental site: The experiment was conducted at the Mullah Qullam Research Centre of the Agricultural Department, Bamyan Province, Afghanistan during 2013. The experimental site was located at latitude 34, 83, longitude 67, 78 and altitude 2524 m. The experiment was conducted under field conditions during the winter wheat growing season. Twenty four plots of size 3 m×2 m (6 m^2) each were used. The wheat variety selected for use was Muqawim 09 (*Triticum aestivum* L.) which was developed in 2009[11]. The pedigree of this variety is OASIS/SKAUZ//4*BCN/3/2*PASTOR. Its gluten quality is so high (strong) that it can be used to correct the baking quality of other varieties with inferior gluten content[12].

Four different types of herbicides were tested in the present study namely, MCPA (Agroxone® 600 mL a.i L^{-1}), Triasulfuron (Amber®750 g a.i kg^{-1}), tribenuron methyl (Express® 750 g a.i kg^{-1}) and pyroxsulam (Merit® at 130 g a.i kg^{-1}). There were 6 treatments namely, hand weeding, MCPA (1 L ha^{-1}), trisulfuron (25 g kg^{-1}), tribenuron methyl (25 g kg^{-1}), pyroxsulam (240 g kg^{-}) and the control (unweeded). Each treatment was replicated 4 times. The plots were arranged in a randomized block design (RCBD). The herbicides were sprayed separately (using a knapsack sprayer) at the rate of 350 L ha^{-1} for MCPA, tribenuron methyl and pyroxsulam with the exception of trisulfuron (120 L ha^{-1}). The spraying was done at 20 DAS: MCPA @600 mL a.i L^{-1} (1 L ha^{-1}), tribenuron methyl @ 750 g a.i kg^{-1} (25 g h^{-1} a) and pyroxsulam @130 g a.i kg^{-1} (240 g ha^{-1}). For the pre emergence herbicide trisulfuron the rate was 750 g a.i kg^{-1} (25 g h^{-1}) and it was sprayed at 5 DAS. For the hand weeded plots, the weeds were removed at 25, 50 and 75 DAS. The wheat crop was harvested at 120 DAS.

Fertilizer and irrigation: Animal manure at the local recommended rate of 10 t ha^{-1} was applied prior to sowing of the crop. In addition, one third of the total rate of 110 kg ha^{-1} of nitrogen and the entire quantity of the recommended dosage for P_2O_5 (60 kg ha^{-1}) and K_2O (50 kg ha^{-1}) in the form of urea, diammonium phosphate and potash, respectively were also applied at the time of sowing. The fertilizers were broadcasted and mixed thoroughly with the soil. All plots were irrigated immediately after sowing to facilitate uniform germination. Due to the absence of rain during the plant growth period, irrigation was provided to the crop at weekly intervals. Irrigation was stopped one week prior to harvest of the crop.

The parameters measured were spike length (in cm), number of spikelets/spike, number of spikes m^{-2}, dry weight of husk kg ha^{-1}, number of grains/spike, weight of 1000 grains (g) and grain weight kg ha^{-1}. For assessment of weed density, data was collected on the number of weed species at 30, 60 and 90 DAS (days after sowing) and at the time of harvest.

Statistical analysis: The data was analyzed using the program SPSS version 23, one-way ANOVA and the Duncan's test for comparison of means, at $p = 0.05$ level of significance[13].

RESULTS AND DISCUSSION

Effect of herbicides on the growth and yield components of wheat: Statistical analysis of the data indicated that (at $p \leq 0.05$) hand weeding (2936.00 kg ha^{-1}) recorded the highest grain weight that was statistically at par for treatments with the herbicides MCPA, triasulfuron and pyroxsulam. However, the lowest grain weight was recorded for the unweeded check plots where the grain weight were not significantly different from those treated with the tribenuron methyl herbicide. Regarding husk weight there was no significant difference among all the treatments. There were also observed no significant differences among all the treatments on the number of spikes per square meter. The highest 1000 grain weight was recorded for hand weeding (41.83 g) but this was statistically at par with treatments of triasulfuron (38.40 g) and pyroxsulam (37.57 g). The lowest weight for the 1000 grain weight was recorded at the unweeded check plots (33.98 g) and this weight was at par with that from the treatments with MCPA (37.18 g) and tribenuron methyl (35.58 g), respectively. The longest spike length per plant was recorded for the hand weeding plots (9.16 cm) while all other treatments had significantly lower length compared to that of the hand weeding treatment. The MCPA and unweeded check treatments were not statistically different and of the spike length was low compared to that obtained from hand weeding. The number of grains per spike exhibited the same trend as that of the length of the spike per plant (Table 1).

The similar findings were reported by earlier research Hesammi *et al.*[14], Mahmood *et al.*[15], Shehzad *et al.*[16], Hussain *et al.*[17] and Singh *et al.*[18], who reported the effectiveness of herbicide applications having been increased the grain yield of wheat. Cheema *et al.*[19] also reported that the maximum biological yield was recorded in those plots which were treated with a mixture of herbicides while the unweeded check plots had the lowest yields. Amare[20] reported that the highest grain yield (2289.4 kg ha^{-1}) was recorded in the hand weeded plots, followed by those treated with isoproturon @ 1.50 kg ha^{-1} (2177.3 kg ha^{-1}). Singh *et al.*[18] reported that the post emergence herbicide, metsulfuron (@6 g ha^{-1}) and 2, 4-D (@500 g ha^{-1}) when applied at 30-35 DAS controlled weeds effectively. The application of these herbicides increased the efficiency of weed control by 38.1 and 78.3%, respectively. It was also reported that the dry matter accumulation of weeds was reduced by 67.4% and the weed index by 23.5%. The grain yield of wheat increased by 37.8% compared to that obtained following farmer's normal practices.

Effect of herbicides on weed density at the different growth stages of the wheat plant: The major broad leaf weed species observed in the experimental plot were

Table 1: Effect of herbicides on the yield components of spring wheat

Weed management practices	Spike length (cm)	No. of spikelets/ spike	No. of spikes (m^{-2})	Dry weight of husk (kg ha^{-1})	No. of grains/ spike	Weight of 1000 grains (g)	Grain weight (kg ha^{-1})
T_1-Hand weeding	9.16	15.00	53.50	5475.00	38.67	41.83	2936.00
T_2-MCPA, 600 mL a.i L^{-1} (post-emergence)	7.54	13.42	49.50	4550.00	33.33	37.18	2373.75
T_3-Triasulfuron, 750 g a.i kg^{-1} (pre-emergence)	7.13	12.58	48.75	5100.00	31.58	38.40	2406.50
T_4-Tribenuron methyl, 750 g a.i kg^{-1} (post-emergence)	7.04	12.25	46.25	4750.00	32.67	35.58	2031.00
T_5-Pyroxsulam; 130 g a.i kg^{-1} (post-emergence)	7.21	12.50	49.25	5000.00	32.83	37.57	2313.00
T6-Unweeded control	7.46	11.83	44.00	4125.00	30.75	33.98	1855.75
CD ($p \leq 0.05$)	0.00	0.00	0.25	0.02	0.32	0.25	0.07

a.i: Active ingredient, mL: Millilitre, Kg: Kilo gram, No: Number, Ha: Hectare, m^2: Square meter, g: Gram, DAS: Days after sowing, CD: Critical Difference and p: Probability at 5%

Amaranthus bouchonii, *Chenopodium album*, *Convolvulus arvensis*, *Acroptilon repense*, *Polygonum aviculare*, *Salsola kali*, *Sonchus asper*, *Malva sylvestris* and *Sinapis arvensis.* The data on the weed population at the different growth stages, as influenced by the different weed management practices are presented in Table 2-5. At all stages, the density of the broadleaf weeds, according to species, differed significantly for the different methods of weed management at 30, 60, 90 DAS and at harvest.

The density of broadleaf weeds in the plot at 30 DAS is shown in Table 1. The highest population of *Amaranthus brouchonii* was observed at the unweeded check plots. The number of *Chenopodium album* plants ranged from 0.75-4.00 where the unweeded check recorded the highest population of *Chenopodium album* (4.00) followed by that from the triasulfuron herbicide (3.00). The hand weeding treatment population (2.50) was not significantly different from that of the pyroxsulam treated plots and the lowest population of *Chenopodium album* was recorded for the MCPA treatment (0.75). The unweeded check plots recorded the highest population of *Convolvulus arvensis* namely, 79.17% and the lowest population of *Convolvulus arvensis* was recorded for the tribenuron methyl treatment plots. The population of *Acroptilon repense* ranged from 0.25-3.25 and the highest number of *Acroptilon repense* plants were recorded for the hand weeded treatment followed by that from the (triasulfuron and treatment plots). Pyroxsulam which were not statistically significant from as the treatment with

Table 2: Effect of herbicides on number of broadleaf weeds (according to species) at 30 days after sowing in spring wheat

	Number of broad leaf weeds							
Weed management practices	Ab	Cha	Ca	Ar	Pa	Sk	Ms	Sa
T_1- Hand Weeding	0.75[b]	2.50[b]	1.75	0.25	2.00	0.00	0.25	0.25
T_2- MCPA, 600 ml a.i L^{-1} (post-emergence)	0.50	0.75	2.00	1.00	2.00	0.50	0.75	0.25
T_3- Triasulfuron, 750 g a.i kg^{-1} (pre-emergence)	0.50	3.00[b]	2.25	1.50	2.75	0.50	0.00	0.00
T_4- Tribenuron methyl, 750 g a.i kg^{-1}, (post-emergence herbicide)	1.00[b]	1.75	1.25	1.50	1.25	0.25	0.50	0.00
T_5- Pyroxsulam, 130 g a.i kg^{-1} (post-emergence herbicide)	1.75	2.00	2.50	1.25	2.00	0.50	0.75	0.00
T6- Unweeded control	4.00	4.00	6.00	3.25	6.25	1.25	1.50	0.50
CD ($p \leq 0.05$)	0.99	0.91	0.09	0.01	0.17	0.00	0.01	0.00

a.i: Active ingredient, mL: Millilitre, m^2: Square meter, DAS: Days after sowing, CD: Critical difference, p: Probability at 5%, BLW: Broad leaf weed, Ab: *amaranthus bouchonii*, Cha: *Chenopodium album*, Ca: Convolvulus arvensis, Ar: *Acroptilon repens*e, Pa: *Polygonum aviculare*, Sk: *Salsola kali*, Ms*: Malva sylvestris* and Sa: *Sonchus asper*

Table 3: Effect of herbicides on number of broadleaf weeds (according to species) at 60 days after sowing in spring wheat

	Number of broad leaf weeds							
Weed management practices	Ab	Cha	Ca	Ar	Pa	Sk	Ms	Sa
T_1- Hand weeding	0.50	2.25	1.00	0.75	2.25	0.00	0.25	0.00
T_2- MCPA, 600 mL a.i L^{-1} (post-emergence)	1.50	3.50	2.00	0.75	3.50	0.75	0.25	0.75
T_3- Triasulfuron, 750 g a.i kg^{-1} (pre-emergence)	1.25	4.00	1.50	1.00	3.50	1.00	0.25	0.00
T_4- Tribenuron methyl, 750 g a.i kg^{-1}, (post-emergence herbicide)	1.00	2.50	1.00	1.25	3.00	0.50	0.25	0.00
T_5- Pyroxsulam, 130 g a.i kg^{-1} (post-emergence herbicide)	1.00	3.00	1.50	1.50	3.50	1.00	0.50	0.00
T6- Unweeded control	4.00	9.00	4.25	4.25	8.00	2.25	1.75	1.50
CD ($p \leq 0.05$)	0.95	0.17	0.63	0.51	0.99	0.04	0.96	0.00

a.i: Active ingredient, mL: Millilitre, m^2: Square meter, DAS: Days after sowing, CD: Critical difference, p: Probability at 5%, BLW: Broad leaf weed, Ab: *Amaranthus bouchonii,* Cha: *Chenopodium album*, Ca: *Convolvulus arvensis*, Ar: *Acroptilon repense*, Pa: *Polygonum aviculare,* Sk: *Salsola kali*, Ms: *Malva sylvestris* and Sa: *Sonchus asper*

Table 4: Effect of herbicides on number of broadleaf weeds (according to species) at 90 days after sowing in spring wheat

	Number of broad leaf weeds							
Weed management practices	Ab	Cha	Ca	Ar	Pa	Sk	Ms	Sa
T_1- Hand weeding	1.25	2.50	1.00	0.50	3.25	0.75	0.75	0.00
T_2- MCPA; 600 ml a.i L^{-1} (post-emergence)	1.50	3.50	2.00	1.50	3.75	1.75	0.75	0.25
T_3- Triasulfuron; 750 g a.i kg^{-1} (pre-emergence)	1.50	4.25	2.25	1.50	4.00	1.25	1.25	0.50
T_4- Tribenuron methyl, 750 g a.i kg^{-1}, (post-emergence herbicide)	0.75	2.75	1.75	1.25	3.25	1.00	0.00	0.25
T_5- Pyroxsulam, 130 g a.i kg^{-1} (post-emergence herbicide)	2.00	4.00	1.75	1.50	4.00	1.25	1.00	0.25
T6- Unweeded control	5.50	11.50	5.75	4.50	10.25	3.25	1.50	1.25
CD ($p \leq 0.05$)	0.67	0.20	0.68	0.45	0.08	0.47	0.22	0.04

a.i: Active ingredient, mL: Millilitre, m^2: Square meter, DAS: Days after sowing, CD: Critical difference, p: Probability at 5%, BLW: Broad leaf weed, Ab: *Amaranthus bouchonii,* Cha: *Chenopodium album*, Ca: *Convolvulus arvensis*, Ar: *Acroptilon repense*, Pa: *Polygonum aviculare,* Sk: *Salsola kali,* Ms: *Malva sylvestris* and Sa: *Sonchus asper*

Table 5: Effect of herbicides on number of broadleaf weeds (according to species) at harvest in spring wheat

	Number of broad leaf weeds							
Weed management practices	Ab	Cha	Ca	Ar	Pa	Sk	Ms	Sa
T_1- Hand Weeding	0.50	2.00	1.25	0.25	2.00	0.75	0.00	0.00
T_2- MCPA; 600 ml a.i L^{-1} (post-emergence)	1.00	2.50	1.75	1.25	2.75	0.75	0.00	0.00
T_3- Triasulfuron, 750 g a.i kg^{-1} (pre-emergence)	0.50	2.75	1.75	1.50	2.25	1.00	0.50	0.50
T_4- Tribenuron methyl, 750 g a.i kg^{-1}, (post-emergence herbicide)	0.75	2.00	1.50	1.00	2.25	0.25	0.25	0.50
T_5- Pyroxsulam, 130 g a.i kg^{-1} (post-emergence herbicide)	1.75	2.75	1.50	2.25	2.25	0.75	0.00	0.50
T6- Unweeded control	4.00	9.75	4.25	3.00	8.00	1.75	1.00	0.75
CD ($p \leq 0.05$)	0.84	0.75	0.26	0.22	0.04	0.99	0.00	0.00

a.i: Active ingredient, mL: Millilitre, m^2: Square meter, DAS: Days after sowing, CD: Critical difference, p: Probability at 5%, BLW: Broad leaf weed, Ab: *Amaranthus bouchonii*, Cha: *Chenopodium album*, Ca: *Convolvulus arvensis*, Ar: *Acroptilon repense*, Pa: *Polygonum aviculare*, Sk: *Salsola kali*, Ms: *Malva sylvestris* and Sa: *Sonchus asper*

MCPA. Unweeded check plots recorded 96% more *Polygonum aviculare* plants compared to that of the hand weeded plots (0.25). The lowest density of *Polygonum aviculare* was recorded for the hand weeding treatment. At 60 DAS the hand weeding and pyroxsulam herbicide treatments were not statistically significant for *Amaranthus bouchonii.* The unweeded check had higher populations of *Amaranthus bouchonii*, *Chenopodium album, Convolvulus arvensis*, *Acroptilon repense, Polygonum aviculare*, *Salsola kali*, *Malva sylvestris* compared to the other treatments. The higher number of weed plants was observed for the unweeded check plots (1.50), followed by the MCPA treated plots (0.75). However, for the other treatments (hand weeding, triasulfuron, tribenuron methyl and the unweeded check) no *Sonchus asper* species were observed. At 90 DAS, the number of weedy plants of *Amaranthus bouchonii* varied from 0.75-5.50, highest number being observed in the unweeded check plots, followed by that from treatments with pyroxsulam, triasulfuron and MCPA herbicides. The lowest number of *Amaranthus bouchonii* weeds was recorded for the tribenuron methyl treatment (0.75). The unweeded check plots had the highest number of *Chenopodium album* plants (11.50), 78.26% higher compared to that of the hand weeded plots (2.50) which had the lowest number the *Chenopodium album* plants*.* The minimum and maximum number of plants of *Acroptilon repense, Polygonum aviculare* and *Salsola kali* were recorded for the hand weeding and unweeded check plots, respectively. In general, at the time of harvest, the plots that were hand weeded had at level of ($p \leq 0.05$) significantly lower number of *Amaranthus bouchonii* plants while the unweeded check plots recorded the highest number of *Amaranthus bouchonii* plants. The unweeded check (control) plot recorded the highest number (9.75) of *Chenopodium album* plants followed by that from the pyroxsulam and triasulfuron treatment for the number of *Chenopodium album* plants (2.75) which were not significant statistically from the other treatments. However, there was no significant difference among the treatments for *Convolvulus arvensis, Polygonum aviculare* and *Malva sylvestris* plants with the exception of the unweeded control treatment*.*

Similarly, Hashim *et al.*[21] reported that maximum weed density was recorded in the unweeded check plots in a herbicide trial on wheat. Chhokar *et al.*[22] also reported similar results and concluded that a mixture of herbicides effectively controlled the weed flora (compared to that of the unweeded check) in a herbicide treatment experiment on wheat. The weeds in the unweeded plots competed with the crop plants for nutrients and other basic necessities. Baghestani *et al.*[23] also obtained similar results and reported that satisfactory weed control was achieved through the use of a mixture of herbicides. Khalil *et al.*[24] reported that there was significant difference in weed density for hand weeding and herbicide treatments. As expected, the lowest weed density was recorded in the hand weeded plots, whereas, the maximum weed density was recorded in the unweeded check plots. However, in plots treated with tribenuron methyl, there was reduction in the number of several weed species, some even to levels lower than that obtained in the hand weeded plots. Currently chemical weed control is preferred because of its better efficiency along with less cost and time involvement. Also, it causes no mechanical damage to the crop such as that which happens during manual weeding. Based on the results obtained it is highly recommended that for future studies on the choice of herbicides in the wheat crop especially triasulfuron and pyroxsulam should be considered.

CONCLUSION

Among all the treatments tested, the hand weeding treatments recorded significantly higher values for the yield components of wheat compared to those of the other treatments namely the pre-emergence and post-emergence herbicides. The hand weeded treatment plots also recorded the lowest density of broadleaf weeds at all growth stages of the wheat plant. In general, triasulfuron herbicide was the most effective of the herbicides tested for control of the broadleaf weeds in the wheat crop. Under field conditions, the use of triasulfuron would cause reduction in weed density more effectively than use of pre-emergence herbicides.

SIGNIFICANCE STATEMENTS

This study showed that the tribenuron methyl was very effective in controlling weeds in wheat. Plants without weed competition enhance grain yields and consequently increase the farmer's income. Those farmers who apply the correct herbicides and at the recommended concentration may get a better yield. According to this study sulfonylurea group of herbicide is more suitable to control weeds in the wheat crops.

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