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The impact of herbicides on weed control and physiological traits in wheat (*Triticum aestivum* L.)

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Abstract

Objective: This study aimed to evaluate the impact of new and commonly used herbicides on weed control and physiological traits in wheat (*Triticum aestivum* L.).

Methods: The experiment was performed as a randomized complete block design with four replications at the Agricultural and Natural Resources Research Center of Moghan during the 2022-2023 growing season. The wheat variety used was Chamran, a winter-type cultivar. The herbicides included 2-methyl-4-chlorophenoxyacetic acid (MCPA) + Furosulam (WP 42%) at rates of 300, 400, 500, 600, and 700 g/ha, Fluorosulam (Florex WP 10%), 2, 4-D + MCPA (U46 Combi Fluid 67.5% SL), Bromoxynil + MCPA (Bromicide 40% EC), Bromoxynil + 2,4-D (Buctrile Univeral 56% EC), Bentazone + Dichlorprop (Basagaran DP 56.6% SL). A hand-weeded treatment and a weedy check treatment served as controls.

Results: The analysis of variance of the data showed a significant difference between treatments in terms of density and biomass for weeds, and plant height, number of spikes, biomass, grain yield, chlorophyll index (SPAD), proline, and catalase enzyme activity for wheat. The use of 600 and 700 g/ha of MCPA + Fluorosulam, U46 CombiFloid, Bacteril Universal, Bromacid, and Basagran DP herbicides had a favorable effect on the weed control, and resulted in a 10% to 25% increase in wheat grain yield. The results showed that the highest chlorophyll content of wheat was associated with treatments of Florex, U46 Combi Fluid, Buctrile Univeral, and Bromicide. But increasing the rate of MCPA + Furosulam decreased the chlorophyll content in wheat. Also, increasing the rate of MCPA + Furosulam increased the proline content and activity of catalase enzyme in wheat.

Conclusion: In summary, the results indicated that treatments with a higher weed control shifted the competitive conditions towards the cultivated crop, leading to an increase in leaf weight and photosynthetic capacity, ultimately resulting in increased wheat grain yield. Therefore, it seems that the use of 600 g/ha of MCPA + Fluorosulam herbicide in alternation with other permitted herbicides can have an effective role in controlling weeds and increasing wheat yield.

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Introduction

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops (Paudel *et al*. 2024). Weeds are one of the important factors reducing wheat yield, and the use of herbicides is the most important method of controlling weeds in wheat fields in Iran (Minbashi Moeini *et al*. 2023). Broad-leaf weeds are becoming a problem in wheat production in areas where grassy herbicides (Clodinafop-Propargyl, Fenoxaprop-P-ethyl, and pinoxaden), without supplementing with broad-leaf weed herbicides, are used continuously. Under this situation, farmers mostly depend on 2,4-D, which is not always very effective against these weeds. For the control of broad-leaf weeds in wheat, three major herbicides used in Iran are tribenuron-methyl, 2,4-D, and 2,4-D + 2-methyl-4-chlorophenoxyacetic acid (MCPA) (U46 CombiFloid) (Nourbakhsh 2023). Generally, a herbicide is more effective against some of the weeds and less effective or not effective against others. Also, some of the post-emergent contact herbicides are less effective on weeds having an advanced stage, as well as being unable to control the subsequent weeds emerging after application due to their lack of residual activity in soil (Lyon *et al*. 2007; Willis *et al*. 2007). Also, continuous use of herbicides with a similar mode of action may create persistent and herbicide-resistant weeds (Ayana 2022). Therefore, it is necessary to evaluate new herbicides against different weeds in wheat.

Acetolactate synthase (ALS), also called acetohydroxyacid synthase (AHAS), is a key enzyme involved in the biosynthesis of branched-chain amino acids (leucine, isoleucine, and valine) in plants. ALS-inhibiting herbicides inhibit the formation of both acetohydroxybutyrate and acetolactate and cause starvation of branched-chain amino acids, followed by the death of susceptible plants (McCourt and Duggleby 2006; Powles and Yu 2010; Dayan *et a*l. 2015). ALS-inhibiting herbicides have been widely used since their release in the 1980s due to their broad weed control spectrum, high herbicidal activity at very low rates, low toxicity to non-target organisms, and wide crop selectivity (Yu and Powles 2014); however, they are prone to resistance evolution as the result of target-site mutations (Powles and Yu 2010; Xu *et al*. 2015). To overcome the shortfall of sulfonylurea herbicides (Jabusch and Tjeerdema 2008), a new group of ALS inhibitors, triazolopyridine sulfonamide, has been marketed. Florasulam (N-[2,6-difluorophenyl]-8- fluoro-5-methoxy [1, 2 ,4] triazolo [1, 5-c] pyrimidine-2-sulfonamide) was introduced to replace tribenuron-methyl for dicot weed control in winter wheat fields after some broadleaf weeds evolved high resistance to tribenuron-methyl (Deng *et al*. 2015; Xu *et al*. 2015; Zhang *et al*. 2017; Wang *et al*. 2019).

Florasulam is highly selective toward wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), and turf, but it is particularly active on cleavers (*Galium aparine* L.), chickweed [*Stellaria media* (L) Vill.], pineapple weed (*Matricaria* spp.), wild buckwheat (*Polygonum convolvulus* L.), and many Cruciferae at very low application rates (Jackson *et al*. 2000; Daniau and Prove 2001; Deboer *et al*. 2006). The tolerance of wheat to this chemical family is due to its conjugation with glucose. Crops that can be sown in the same year, treated with Fluorosulam, are cereals, oilseed rape, field beans, grass, and vegetable brassicas as transplants. But, oilseed rape, field beans, grass, linseed, peas, sugar beet, potatoes, maize, clover (for use in grass/clover mixtures), carrots, and vegetable brassicas should not be planted in the field for up to one year after using this herbicide (Anonymous 2018). To broaden the spectrum of weed kill and to provide long-term residual weed control, the use of a herbicide mixture is advisable. Herbicide mixture, besides providing control of complex weed flora, will also help in managing and delaying the herbicide resistance problem. Also, tank mix combinations or ready mixtures are advantageous over sequential application due to savings in application timing and cost (Deepesh *et al*. 2020). Florasulam herbicide is commonly used as a mixture with other herbicides having different modes of action (Jabusch and Tjeerdema 2008). Together with florasulam, it can provide a new option for controlling broadleaf weeds in food and forage crops. Overall, due to the low number and diversity of registered herbicides for weed control in wheat in Iran, this research aimed to evaluate the effectiveness of new and commonly used herbicides on annual broadleaf weeds in wheat fields.

Materials and Methods

The experiment was conducted in 2022-2023 using a randomized complete block design with 11 treatments and four replications at the Agricultural and Natural Resources Research Center of Moghan, Iran. The details of the experimental treatments are provided in Table 1.

To conduct the experiment, a field with a significant history of weed infestation was selected in the autumn of 2022. After preparing the land and seedbed, ready-made plots were cultivated. Each experimental plot had dimensions of approximately 8 × 10 meters (8 rows, spaced 30 centimeters apart, with a length of 10 meters). Each plot was divided into two parts in length, in which the upper part of the plot was left unsprayed and considered as the control, while the lower part was treated with the herbicide. Post-emergence herbicides were applied at the wheat tillering stage (Zadoks 20,

Table 1. Characteristics of the experimental treatments.

Treatment	Commercial name	Common name	Dosage
1	-	MCPA 40.8% + fluorosulam 1.2%	300 g/ha
2	-	MCPA 40.8% + fluorosulam 1.2%	400 g/ha
3	-	MCPA 40.8% + fluorosulam 1.2%	500 g/ha
4	-	MCPA 40.8% + fluorosulam 1.2%	600 g/ha
5	-	MCPA 40.8% + fluorosulam 1.2%	700 g/ha
6	Florex® WP 10%	fluorosulam	85 g/ha
7	U46 Combi Fluid® 67.5% SL	2. 4, D (360 g. L^{-1}) + MCPA (315 g. L^{-1})	2 L/ha
8	Buctrile Univeral® 56% EC	Bromoxynil (200 g. L^{-1}) + 2. 4, D (360 g. L^{-1})	1.5 L/ha
9	Bromicide 40% EC	Bromoxynil (200 g. L^{-1}) + MCPA (200 g. L^{-1})	1.5 L/ha
10	Basagran DP® 56.6% SL	Bentazone (333 g. L^{-1}) + Dichlorprop-P (233 g. L^{-1})	2 L/ha
11	Hand weeding	-	-

Zadoks *et al.* 1974). All herbicides were sprayed with a backpack sprayer equipped with a flooding nozzle and calibrated to deliver 300 L/ha of spray solution at a pressure of 250 kPa. To control narrow leaf weeds in all experimental herbicide treatments, the herbicide clodinafop-propagrgyl (TOPIK) was used at 1 L/ha one week after applying the treatments. Throughout the growth period, all weeds present in the control plots were manually removed. The percent weed density and their biomass were measured 30 days after treatment. Two quadrates (each with an area of 1 m^2) were dropped in the treated and untreated halves of each plot. Then, to determine the biomass of weeds, they were placed in an oven at a temperature of 72 ºC for 48 hours. The reduction was calculated by dividing the weed density and biomass in the treated half by the weed density and biomass in the untreated half and then multiplying by 100.

Leaf chlorophyll was measured by a non-destructive method with a SPAD-502 chlorophyll-meter (Konica, Minolta). It should be noted that SPAD does not specify chlorophyll content; rather, it is an estimation of chlorophyll concentration. SPAD has a strong correlation with leaf chlorophyll content (Hoel and Solhaug 1998). To measure the proline content and catalase activity, three biological replications from the most recent fully developed leaves of three different plants were acquired for each duplicate section in each plot. Proline content of the fresh leaves was measured using the procedure described by Bates *et al*. (1973). Catalase activity was measured by the method of Karo and Mishra (1976). During the ripening of the grain in wheat (Zadoks 99, Zadoks *et al*. 1974), grain yield in an area of 5 m^2 was determined.

Arcsine transformation was used on percent weed control data when needed to mitigate the skewness of the data and meet the requirements of normality for the analysis. The means were compared using Duncan's multiple range test at a significant level of 5%. The data were analyzed using SAS 9.4 software.

Results and Discussion

The dominant broadleaf weed species in the wheat field are shown in Table 2. Since the spectrum of weeds varied in different plots, only the data related to the dominant weeds were separately subjected to statistical analysis, and the results were examined as the total of broadleaf weeds.

Table 2. The dominant weed species composition in the wheat field.

Common name	Scientific name	Family	Presence
Wild mustard	*Sinapis arvensis* L.	Brassicaceae	+++
Shepherd's purse	*Capsella bursa-pastoris*	Brassicaceae	+++
Chickweed	*Stellaria media* L.	Caryophyllaceae	++
Flixweed	*Descurainia sophia* L.	Brassicaceae	+++
Iberian knapweed	*Centaurea iberica* Trevir. ex Spreng	Asteraceae	+
Cowcockle	*Vaccaria grandiflora* (Fisch. ex DC.)	Caryophyllaceae	+
False jagged-ckickweed	*Lepyrodiclis holosteoides*	Caryophylaceae	+

$^{+++}$Dominant presence; $^{+}$Inferior presence.

Effect of herbicide treatments on the density and biomass of weeds

The results of the analysis of variance showed that there was a significant difference between the herbicide treatments in terms of the percentage reduction in density and biomass of wild mustard, shepherd's purse, chickweed, flixweed, and total weeds (data not shown). Based on the results obtained from the density of weeds, controlling the weeds with 600 and 700 g/ha of MCPA + Fluorosulam, Bromicide, and Basagran DP was satisfactory, with over 88% effectiveness (Tables 3 and 4). Observing the percentage reduction in weed density, the Florex with 85 g/ha was poor in controlling the weeds, resulting in a 73% reduction in weed density (Table 4).

Among the applied treatments, the best efficacy in controlling the biomass of related weeds was achieved by the use of 600 and 700 g/ha of MCPA + Fluorosulam, Bromicide, and Basagran DP. However, applying 85 g/ha of Florex commercial product was not able to effectively reduce the biomass of these weeds (Tables 3 and 4).

In general, the results showed that the application of MCPA + Fluorosulam herbicide in the early stages of growth, due to the greater sensitivity of weed seedlings to herbicides, had a greater inhibitory effect on weed density and biomass. In such conditions, due to the prevention of early-season interference of weeds with wheat, their competitive effects on the crop were minimized, and the

Table 3. Comparison of herbicides for the density and biomass of weeds.

Treatments	Density				Biomass			
	Wild mustard	Shepherd's purse	Chick-weed	Flix-weed	Wild mustard	Shepherd's purse	Chic-weed	Flix-weed
MCPA + Fluorosulam 300 g/ha	12.25c	4.75d	3.50b	14.25c	23.02d	5.01c	2.57e	6.29c
MCPA + Fluorosulam 400 g/ha	12.50c	5.75d	3.50b	15.00c	23.83cd	5.11c	2.73de	8.97bc
MCPA + Fluorosulam 500 g/ha	13.75c	7.25cd	4.25b	16.50bc	24.38cd	6.89bc	3.28cde	9.37bc
MCPA + Fluorosulam 600 g/ha	13.00bc	7.75bcd	4.50ab	16.50bc	24.69cd	8.24abc	3.76bcd	9.51bc
MCPA + Fluorosulam 700 g/ha	13.00bc	7.75bcd	4.50ab	17.50bc	25.38bcd	8.66ab	4.16abc	10.02abc
Florex 85 g/ha	18.50a	15.50a	6.75a	27.50ab	29.50ab	10.38a	5.14a	13.24ab
U46 Combi Fluid 2 L/ha	13.50bc	8.25bcd	4.75ab	20.00abc	26.13a-d	8.86ab	4.16abc	10.58abc
Buctrile Univeral 1.5 L/ha	13.75bc	11.00abc	4.75ab	20.25abc	26.11a-d	9.13ab	4.39abc	10.67abc
Bromicide 1.5 L/ha	14.25bc	11.25abc	5.25ab	20.50abc	27.34abc	9.43ab	4.50ab	11.44abc
Basagran DP 2 L/ha	15.25b	12.75ab	5.25 ab	27.25ab	29.46ab	9.75ab	4.70ab	11.58ab
Weedy check	19.50a	15.75a	6.75a	30.75a	29.62a	11.43a	5.24a	14.96a

The means with different letters are significantly different, based on Duncan's multiple range test at $p \leq 0.05$.

application of lower amounts of herbicides (even less than 700 g per hectare) had positive results in increasing the crop yield. But, based on the herbicide efficacy, the use of MCPA + Fluorosulam herbicide at rates ranging from 300 to 500 g per hectare, as a post-emergence application at the tillering stage of wheat, showed lower efficacy in weed control, so their use is not recommended.

Effect of herbicide treatments on wheat traits

Data presented in Table 5 showed the effect of weed control treatments on some wheat attributes, such as the plant height, number of spikes, biomass, grain yield, chlorophyll index, proline, and catalase. All herbicidal treatments, except Florex, significantly increased the wheat plant height (data are not shown); however, there were no significant differences among their efficiency (Table 5). Sekhar *et al.* (2024) also showed that the herbicide application increased wheat plant height. However, our results were not in alignment with the findings of Khalil *et al.* (2000), who declared that there was no significant increase in the plant height with the application of herbicides.

The highest number of spikes in wheat was obtained in the hand weeding treatment, which was statistically at par with treatments of 600 and 700 g/ha of MCPA + Fluorosulam, Bromicide, U46 Combi Fluid, and Basagran DP (Table 5). This finding indicates the role of efficacy of the herbicide treatments in controlling weeds, which resulted in decreasing the competition of weeds with the wheat for light and other environmental factors. These results are in harmony with Fenni *et al.* (2002). In their experiment, the maximum number of spikes was obtained with the application of Tribenuron-Methyl 2.7% + Fluroxypyr 13.7% herbicides.

Table 4. Effect of herbicides on the percent reduction in density and biomass of weeds as compared to the control.

Treatments	Density reduction percentage					Biomass reduction percentage				
	Wild mustard	**Shepherd's purse**	**Chic-weed**	**Flix-weed**	**Total**	**Wild mustard**	**Shepherd's purse**	**Chic-weed**	**Flix-weed**	**Total**
MCPA + Fluorosulam 300 g/ha	84.58 b	91.25 a	48.33 b	83.53 ab	76.92 d	81.19 c	79.89 ab	84.45 ab	79.79 ab	81.33 c
MCPA + Fluorosulam 400 g/ha	87.50 ab	92.22 a	53.69 ab	84.22 ab	79.40 cd	84.99 bc	84.54 ab	87.81 ab	82.88 ab	83.64 c
MCPA + Fluorosulam 500 g/ha	89.32 ab	92.31 a	62.91 ab	84.57 ab	82.28 bcd	86.37 abc	87.34 ab	93.08 a	84.83 ab	85.05 bc
MCPA + Fluorosulam 600 g/ha	100.00 a	93.34 a	70.00 ab	84.76 ab	88.59 ab	90.45 ab	93.89 a	95.66 a	92.02 a	93.01 ab
MCPA + Fluorosulam 700 g/ha	100.00 a	93.51 a	77.44a b	92.92 a	90.97 ab	92.74 a	94.93a	98.00 a	95.57 a	95.31 a
Florex 85 g/ ha	84.23 b	72.62 b	56.84 ab	79.87 b	73.39 d	67.52 d	270.28 b	71.86 b	70.56 b	70.05 d
U46 Combi Fluid 2 L/ha	100.00 a	100.00 a	68.33 ab	86.03 ab	87.02 abc	84.62 bc	83.44 ab	85.58a b	80.32 ab	81.33 c
Buctrile Univeral 1.5 L/ha	100.00 a	100.00 a	70.98 ab	90.15 ab	90.28 ab	80.03 c	84.68 ab	90.20 ab	79.65 ab	87.90 abc
Bromicide 1.5 L/ha	100.00 a	100.00 a	79.16 a	92.57 a	92.93 a	82.68 c	85.31 ab	86.69 ab	79.00 ab	93.64 ab
Basagran DP 2 L/ha	100.0 a	100.00 a	74.58 ab	86.80 ab	90.34 ab	92.67 a	89.82 ab	95.26 a	91.74 a	92.37 ab

The means with different letters are significantly different, based on Duncan’s multiple range test at $p \leq 0.05$.

The results of mean comparisons showed that, regardless of the weed-free treatment (hand weeding), the highest wheat biomass was associated with treatments of 600 and 700 g/ha MCPA + Fluorosulam, Bromicide, and Basagran DP (Table 5). This might be due to the increase in plant height relative to the untreated check (Metwally *et al*. 1999). Muhammad *et al*. (2012) reported that post-emergence application of herbicides increased the wheat grain yield and biomass.

The results showed that regardless of the weed-free treatment (hand weeding), the highest wheat grain yield was associated with the treatments of 600 and 700 g/ha MCPA + Fluorosulam, Bromicide, and Basagran DP. The use of these herbicides resulted in a 10% to 25% increase in wheat yield (Table 5). These herbicides performed better in controlling weeds and better utilization of environmental resources for growth and development. On the other hand, the application of 300, 400, and 500 g/ha of MCPA + Fluorosulam and 85 g/ha of Florex showed the lowest efficiency in controlling the weeds and resulted in the least increase in the wheat yield. Nanher *et al*. (2015) indicated that the increased yield attributes of wheat might be due to a lower weed crop-competition and increased nutrients and water uptake by the crop, increased rate of photosynthesis and supply of photosynthates to the metabolic sinks, leading to increased vegetative growth and yield attributes. Shah *et al*. (2018) reported that the maximum grain yield was obtained where minimum weed crop competition for nutrients and water occurred.

Table 5. The effect of the herbicide control of weeds on wheat traits.

Treatments	Plant height (cm)	Number of spikes (per m^2)	Biomass (g/m^2)	Grain yield (g/m^2)	Percentage yield compared to the weedy check	SPAD	Proline content (mg/g fresh weight)	Catalase activity (U/g fresh weigh per min)
MCPA + Fluorosulam 300 g/ha	82.2 ab	104.25 f	320.25 e	108.93 e	111.52 ab	43.74 abc	0.18 g	1.56 ef
MCPA + Fluorosulam 400 g/ha	82.5 ab	118.25 e	347.00 e	124.53 d	112.90 ab	43.11 a-d	0.21 f	1.90 d
MCPA + Fluorosulam 500 g/ha	87.5 ab	138.50 d	386.75 d	130.88 cd	114.87 ab	42.34 bcd	0.23 e	2.23 c
MCPA + Fluorosulam 600 g/ha	89.0 ab	158.25 abc	515.75 ab	164.71 b	124.46 a	41.04 cd	0.31 b	2.40 b
MCPA + Fluorosulam 700 g/ha	91.0 ab	159.35 abc	518.25 ab	171.05 b	124.74 a	38.25 d	0.34 a	3.11 a
Florex 85 g/ha	79.6 b	123.25 e	348.25 e	131.22 cd	110.37 b	45.15 abc	0.16 h	1.46f
U46 Combi Fluid 2 L/ha	82.5 ab	157 abc	503.75 b	139.62 c	113.75 ab	45.46 abc	0.26c	1.66 e
Buctrile Univeral 1.5 L/ha	85.5 ab	156 bc	462.00 c	134.91 cd	116.58 ab	44.38a bc	0.24 de	1.46 f
Bromicide 1.5 L/ha	90.4 ab	161 ab	514.50 ab	174.58 b	122.04 ab	45.47 ab	0.26 c	1.46 f
Basagran DP 2 L/ha	91 ab	160.75 ab	510.50 ab	168.21 b	120.76 ab	43.36 abc	0.26 c	1.63 e
Hand weeding	93.5 a	168.75 a	537.25 a	195.76 a	125.5 a	46.02 a	0.14 i	0.93 g

The means with different letters are significantly different, based on Duncan's multiple range test at $p \leq 0.05$.

Ignoring the weed-free treatment (hand weeding), the highest wheat chlorophyll content (SPAD) was associated with the treatments of Florex 85, U46 Combi Fluid, Buctrile Univeral, Bromicide, and Basagran DP (Table 5). All herbicides resulted in an increase in wheat proline and catalase as compared to the hand weeding treatment (Table 5). Among the applied treatments, Florex 85 showed a lower activity of catalase but higher rates of MCPA + Fluorosulam, which increased the activity of proline and catalase in wheat (Table 5). In an experiment, the interference of weeds and the use of herbicides in plants stimulated the synthesis of antioxidant molecules, including proline, in response to stress (Harre *et al*. 2018). Grigoryuk *et al*. (2016) evaluated the effect of herbicides on the catalase activity in the wheat roots and stems. The herbicides increased the catalase activity in both organs, which was consistent with the results of the present study. Hassannejad and Porheidar Ghafarbi (2018) showed that by increasing the clodinafop-propagrgyl (TOPIK) herbicide, the maximum fluorescence (Fm), variable fluorescence (Fv), efficiency, and/or activity of water-splitting complex at the donor side of photosystem II (Fv/F0), and maximum photochemical efficiency of photosystem II (Fv/Fm) decreased, but minimum fluorescence (F0) increased. In another experiment, by examining Topik, Titos, Equip, Mister, Lumax, Bromicide, and Oltima herbicides on the photosynthetic efficiency of three maize cultivars, only Lumax and Bromicide affected the chlorophyll fluorescence (Porheidar Ghafarbi *et al*. 2017).

The results of this experiment indicated that treatments that had a higher percentage of weed density and biomass control shifted the competitive conditions towards the cultivated crop, leading to an increase in photosynthetic capacity, ultimately resulting in increased wheat grain yield. Since old herbicides are widely used in Iran for controlling wheat weeds, this study aimed to replace these herbicides with new ones to mitigate some of the problems associated with herbicide use, such as risks in subsequent crops and environmental pollution. Overall, all applied herbicides showed a significant effect on weed control. Based on the results of this experiment, it can be concluded that MCPA + Fluorosulam, at the rates of 600 to 700 g/ha, was effective in controlling the weeds and increasing wheat grain yield, without significant differences compared to other registered herbicides. Although the use of 700 g/ha of MCPA + Fluorosulam herbicide showed higher efficacy in weed control compared to a rate of 600 g/ha, the difference was not significant. Therefore, the use of 600 g/ha MCPA + Fluorosulam herbicide is recommended for wheat, especially in terms of sustainable weed management and chemical control hazards. On the other hand, the use of MCPA + Fluorosulam herbicide applied at the concentration of 300 to 500 g/ha as a post-emergence application at wheat tillering stage (Zadoks 20), showed lower efficacy in weed control, so their application is not recommended.

Herbicide mixture lowers the selection pressure being imposed by the repeated use of the same herbicide. Therefore, for the broad-spectrum weed killing, the combination of two or three herbicides needs to be tried. These combinations, besides broadening the weed control, reduce the cost of weed control. Florasulam inhibits the acetolactate synthase enzyme in plant leaves or roots that take up the herbicide, following the postemergence application (Krieger *et al*. 2000; Li *et al*. 2013). MCPA works by concentrating in the meristematic tissues where it interferes with protein synthesis, cell division, and ultimately the growth of the plant (EXTOXNET 1996). One solution to broaden the spectrum of Fluorosulam and MCPA herbicides in controlling broadleaf weeds is to mix these (Anonymous 2018). The mixture of MCPA + Fluorosulam herbicides also reduces the required concentration for achieving the desired control level compared to the recommended rates of each herbicide alone (Karkanis *et al*. 2022). It is evident that the use of this herbicide is preferred compared to other herbicides at higher recommended rates, particularly Basagran DP at a rate of 2 L/ha. The herbicide

U46 Combi Fluid (a combination of 360 g/L 2,4-D + 315 g/L MCPA) was effective for controlling broadleaf weeds in wheat fields and provided a wider spectrum of control. This was in agreement with the results of Nezamabadi *et al.* (2025). Additionally, the mixture of two herbicides, Bromoxynil + MCPA (Bromicide), had a desirable effect on weed control. It has also been reported that the mixture of Bromoxynil + MCPA in wheat fields increased the herbicidal spectrum and effectively controlled dominant weeds in the field (Nezamabadi *et al.* 2025). Bentazon + dichlorprop (Basagran DP) controls dicotyledonous weeds in the early and late stages of development (Hofmann and Pallutt 1989). In total, it is recommended to use herbicide combinations, such as MCPA + Fluorosulam, for weed control at the wheat tillering stage (Zadoks 20). Other treatments, such as Bromicide, can be used with more confidence if the emerged weeds in the field match the weeds examined in this experiment.

Conclusion

Based on the results of this experiment, MCPA + Furosulam (WP 42%) at a rate of 600 g/ha of the commercial product at the wheat tillering stage (Zadoks 20) effectively controlled the broadleaf weeds in the wheat field, without negatively affecting wheat plants, and enhanced the grain yield of this crop. Future studies need to be directed towards evaluating the compatibility/suitability between different broad-leaved and grassy herbicides.

Conflict of Interest

The authors declare that they have no conflict and/or competing interests.

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