

Comparative Efficacy of the Weed Management Practices on Grain and Straw Yields of Wheat

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ABSTRACT

Wheat is central to Afghanistan's food security. It accounts for 76 percent of the annual grain cereal harvest and 57 percent of the country's total food crop production. Several factors, such as low-yielding varieties, low soil fertility, low-quality agrochemicals, widespread pest and disease infestations, and widespread distribution of weeds, are the leading causes of low wheat productivity in the country. The current study was conducted at the Student Research farm of the Faculty of Agriculture at Kabul University to determine the overall effects of weeds on wheat grain and straw yields and to evaluate and compare different weed management practices in the wheat field. After applying the weed management practices, among the treatments, T₁, T₃, and T₄ showed only 8.3, 5, and 2.3 percent weed populations, respectively, compared to the untreated control. Regarding grain and straw yields, mechanical control (hand weeding) ranked first with a grain yield of 4,867 kg/ha, followed by T₁ (4,580 kg/ha), T₃ (4,513 kg/ha), T₂ (4,133 kg/ha), and T₅ (3,416 kg/ha), respectively. The difference in straw yield among the treatments was not significant; however, mechanical control ranked first (7,103 kg/ha), followed by T₁ (6,783 kg/ha), T₃ (6,700 kg/ha), T₂ (6,207 kg/ha), and T₅ (5,280 kg/ha), respectively. The study findings concluded that by eliminating weeds, wheat grain and straw yields could be increased by an average of 30 and 26 percent, respectively. As broad-leaved weeds are widely distributed in the wheat fields, applying relative herbicides such as 2,4-D is more effective and recommended for all cultivation methods.

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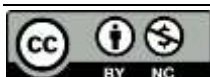
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Introduction

The wheat plant belongs to the family of Gramineae and the tribe of Hordea. The term wheat is commonly used for the cultivated species of Triticum. Only three species of wheat plants are commercially important: bread wheat (*Triticum aestivum* L.), durum wheat

(*Triticum turgidum* L.), and emmer wheat (*Triticum compactum*). However, wheat cultivation is restricted almost entirely to the tetraploid durum wheat (*Triticum turgidum* L.) and hexaploid wheat (*Triticum aestivum* L.). From the two mentioned species, the bread wheat is the most grown type of wheat throughout the world. The vast majority of varieties belong to this wheat type, which shows great diversity in agroecological adaptation and utilization. Wheat is a vital grain food component among cereal crops; globally, it is the most essential food grain and ranks second in total production of cereal crops after maize (Gebeyehu, 2020).

Wheat is the staple food in the Afghan food basket and is central to food security in Afghanistan. Wheat is more or less cultivated in all 34 provinces of Afghanistan by subsistence farmers as a staple food crop to feed their families. In contrast, in some regions where abundant water resources are available for irrigation, wheat is cultivated in relatively large areas where the surplus wheat is supplied to local large-scale wheat flour mills and local markets. Due to the poor backing quality of the local wheat varieties, the flour mills mix either the imported wheat or flour to improve the quality of the domestic wheat flour.

From a nutritional perspective, wheat is superior to rice due to its higher protein content. Wheat grain is rich in nutritional value, containing 12% protein, 1.72% fat, 69.60% carbohydrates, and 27.20% minerals. Wheat flour supplies 57% of the total caloric intake from food items in Afghanistan. Afghans consume wheat with every meal, resulting in the world's highest annual per capita wheat consumption of 180 kg (FAO, 2013). Before the conflicts, Afghanistan was self-sufficient in cereal production and even a small exporter in some years. However, today, mainly due to population growth, stagnant yields, and a shrinkage of the irrigated area, the country imports an average of 1.2 million metric tons of cereal per year (with imports fluctuating widely based on domestic production).

According to the National Statistics and Information Authority of Afghanistan, wheat was cultivated on 2,534,000 hectares (ha) of land (irrigated wheat:1,566,000 ha and rain-fed:968,000 ha), and the total production was 4,890,000 MT (Irrigated:4,089,000 MT and Rain-fed:801,000 MT). The average national wheat productivity of irrigated wheat was about 2.6, and the rain-fed wheat was about 0.83 MT/ha with an overall average of 1.93 MT/ha (NSIA, 2020).

The country's Wheat productivity is much lower than that of neighboring countries, e.g., Pakistan, Iran, and Uzbekistan. Several factors, such as low-yielding varieties, low soil fertility, low-quality agrochemicals, wide spread of pests and diseases, and wide distribution of weeds, are the country's leading causes of low productivity. Weeds are hidden enemies of crops, and severe weed infestation is one of the significant constraints of low wheat production worldwide. Weeds compete with crop plants for nutrients, solar radiation, water, carbon dioxide, space, and many other growth factors. The number of weed species in wheat fields varied from country to country, and up to 45 weed species have been reported in Pakistan, 33 in Iran, 90 in India, and 73 in Bangladesh (Islam *et al.*, 2023).

Weeds cause yield reduction of up to 15-50 percent depending on weed density and flora (Jat *et al.*, 2003). According to the JDA (2013) report, more than 30% of wheat yield losses are

recorded in northern Afghanistan due to the spread of weeds. Similarly, about a 58% wheat yield increase is reported by USAID (2016) through an assessment of the impact of weed control on wheat yield. To some extent, most farmers in Afghanistan know the importance of weeds and their management in all types of crops, including wheat. At the same time, proper herbicide selection, adequate dosage, and application timing remain the key to checking weed populations and improving crop yields.

When weeds remained uncontrolled, it caused an average of about 48% reduction of wheat grain compared to weed-free conditions. Herbicides effectively controlled weeds in closely spaced crops such as wheat, where manual or mechanical weeding is difficult. Among the different weed management practices, chemical control of weeds is preferred due to less labor requirement and no economic losses due to mechanical damage to the wheat crops during the manual weeding process (Shivran *et al.*, 2020).

Additionally, weeds seriously affect the wheat flour quality (color, taste, and backing property) as wheat is harvested and floured with seeds of different weeds. The findings of the above studies/reports indicate that weed management/control will result in increased wheat yield. Considering all the above facts, an attempt was made to determine the efficacy of different weed management practices, including mechanical control (hand weeding) and application of herbicides against complex weed flora, to improve wheat productivity in Afghanistan.

Materials and Methods

This study was conducted on an improved winter wheat variety, "Moqavim-09," on a student research farm of the Faculty of Agriculture, Kabul University, to evaluate different weed management methods. The material used in the research were Urea and DAP fertilizers as standard inputs being applied in wheat fields, 2,4-D or 2,4-Dichlorophenoxyacetic acid; the broad-leaved herbicide, Qadri Puma or Fenoxaprop-p-ethyl and mechanical control or hand weeding. The experiment was designed in five treatments: T₁-2,4-D, T₂-Qadri Puma, T₃-2,4-D+Qadri Puma, T₄-Mechanical control, or hand weeding and T₅-untreated or check each replicated trice in RCBD design layout. A total of 15 plots, each with 6 square meters (2 x 3 meters), were considered.

Improved wheat seed (Moqavim-09) was obtained from ARIA (Agriculture Research Institute of Afghanistan). At the same time, herbicides, fertilizers (DAP and Urea), and other necessary farm and lab tools and equipment were supplied by the GRAIN project. After land preparation and plot layout, the basal fertilizer application (a split of Urea fertilizer at 50gr/plot and total DAP fertilizer at 120gr/plot) was applied in the field and appropriately mixed with soil, and then wheat seeds were planted in rows at 72gr/plot in the second week of November 2018. The field was irrigated immediately after planting.

The second split of Urea at 50gr/plot was applied on 2nd week of April with second irrigation, and three days after irrigation, 1st hand-weeding and spray of herbicides; 2,4-D@1 ml/litter and Qadri Puma at 0.15 ml/litter was applied to respected treatment. After 20 days,

the 3rd split of Urea at 50gr/plot was used, and the field was irrigated for the third time; similarly, after three days, second-hand weeding was conducted, and the second spray of the herbicide at the same dose was applied on wheat fields.

The field was irrigated six times till the end of the growing season. From the beginning of the research, pre-harvest data was collected, such as percentage of germination or plant stand, weed population after each treatment, number of tillers per square meter, plant height and types of weeds found in wheat fields. Eventually, the crop was harvested by the end of July 2019 using a square-meter sampling method, leaving borders in each field for post-harvest data collection.

After properly threshing the harvested samples, data such as spike length, number of spikelets per spike, number of grains per spike, the weight of 1,000 grains, and total grain and straw yields of one square meter were recorded. Then, all the data (preharvest and post-harvest) was screened and cross-checked for further analysis. Research data was statically analyzed using STAR software, and then the resulting data were tabulated and graphed to interpret the results.

Results

Weed Population Density

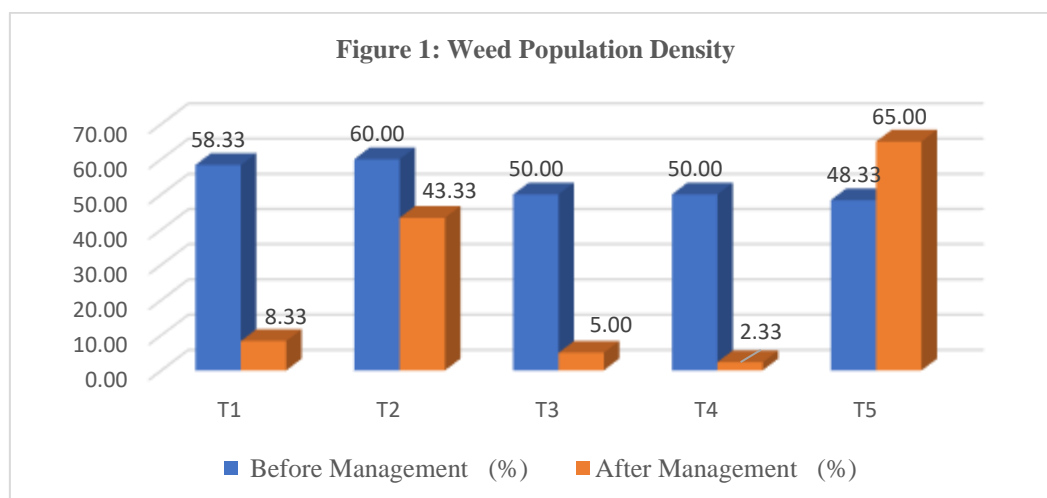
The weed population density was determined twice during the study; the first weed population determination was conducted before the treatment was applied to better analyze the effects of weed management practices in the study. A random sample of one square meter was taken from each treatment, the number of plants (wheat and weed) was counted, and the data was converted to percentages. Similarly, the second weed population density was determined four weeks after the treatments, and for calculation, the same method was applied as described above. Based on the study findings, the average weed population density before the application of the treatment was 53.3%, and there was no significant difference in weed population density among the plots of different treatments (Table 1).

Table 1: Weed Population Density

Treatment	Before Management (%)	After Management (%)
T1: 2,4-D	58.3	8.3 c
T2: Qadri Puma	60.0	43.3 b
T3: 2,4-D + Qadri Puma	50.0	5.0 c
T4: Mechanical Control (Hand Weeding)	50.0	2.3 c
T5: Untreated (Check)	48.3	65.0 a
F-test	NS	HS**
LSD		6.072
CV	11.67	13

There was a highly significant difference in weed population density after the treatment application among the treatments compared to untreated checks. There was no significant difference in weed population density between T1, T3, and T4, while there was a significant

difference between T2 and the rest of the treatments compared to the untreated check (Table 1 and Figure 1).



Growth Parameters

Growth parameters such as wheat plants' tiller length, spike length, number of spikelets per spike, and number of grains per spike were calculated during the study. Even though, statistically, there was no significant difference between tiller lengths, spike length, and number of grains per spike among the treatments, all the treatments showed considerable differences in the number of spikelets per spike compared to the untreated check, where the least number of spikelets were recorded. Details of the result for the growth parameters of wheat under different treatments are given in Table 2 below.

Table 2: Growth Parameters of Wheat Plant

Treatments	Tiller length(cm)	Spike length(cm)	No. of spikelet/Spike	No. of Grains/Spike
T1: 2,4-D	76.0	6.7	11.9 a	31.3
T2: Qadri Puma	75.8	7.2	12.4 a	30.0
T3: 2,4-D + Qadri Puma	74.3	6.6	11.5 ab	30.9
T4: Mechanical Control (Hand Weeding)	74.7	7.0	11.7 a	28.4
T5: Untreated (Check)	74.8	6.5	10.6 b	26.6
F-test	NS	NS	S*	NS
LSD			0.9774	
CV	3.43	5.61	4.45	8.87

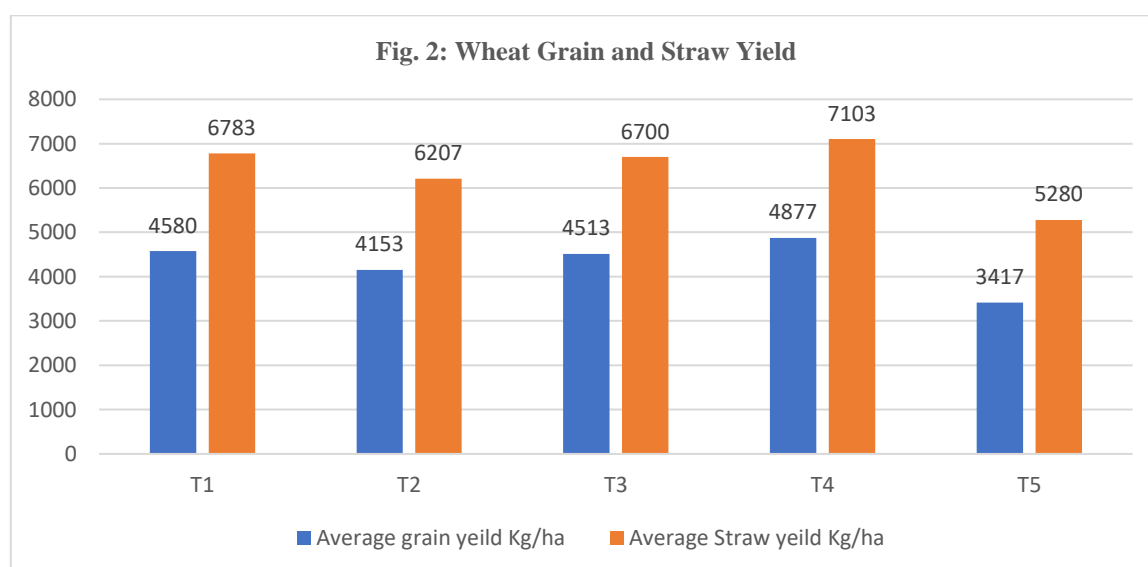
Yield Parameters

Under yield parameters, the weight of 1000 grains, the average grain yield, and the straw yield per plot and hectare were considered for analysis. The results revealed that the weight of 1000 grains in all the treatments was not significant compared to the untreated check; however, a high weight was recorded under T3 and T4, respectively. The average grain yield per plot and ha were also determined, and there was a highly significant difference between the treatments and the not-treated check (Table 3).

Table 3: Yield Parameters of Wheat

Treatments	Avg. weight of 1000 grains (gr)	Avg. Grain yield Kg/plot	Avg. straw yield Kg/Plot	Avg. grain yield Kg/ha	Avg. Straw yield Kg/ha
T1: 2,4-D	49.81	0.46a	0.68	4580.00ab	6783.00
T2: Qadri Puma	49.38	0.42b	0.62	4153.33c	6206.67
T3: 2,4-D + Qadri Puma	51.42	0.45a	0.67	4513.33b	6700.00
T4: Mechanical Control (Hand Weeding)	50.68	0.49a	0.71	4876.67a	7103.33
T5: Untreated (Check)	47.01	0.34c	0.53	3416.67d	5280.00
T-test	NS	HS**	NS	HS**	NS
LSD		0.035		322.53	
CV	4.27	4.29	18.4	3.98	18.26

Among the treatments, mechanical control (T5) ranked first with 0.49 Kg/plot (4876.67 Kg/ha), followed by T1(0.46 Kg/plot or 4580 Kg/ha) and T3(0.45 Kg/plot or 4513.33 Kg/ha) respectively while the lowest grain yield per plot/ha was recorded in T5 (0.34 Kg/plot or 3416.67 Kg/ha). There was no significant difference between straw yield among the treatments; however, mechanical control was ranked first by 7103 Kg/ha, followed by T1(6,783Kg/ha), T3(6,700Kg/ha), T2(6,207Kg/ha) and T5(5,280Kg/ha) respectively (see Table-3 and Figure-2 below for details).

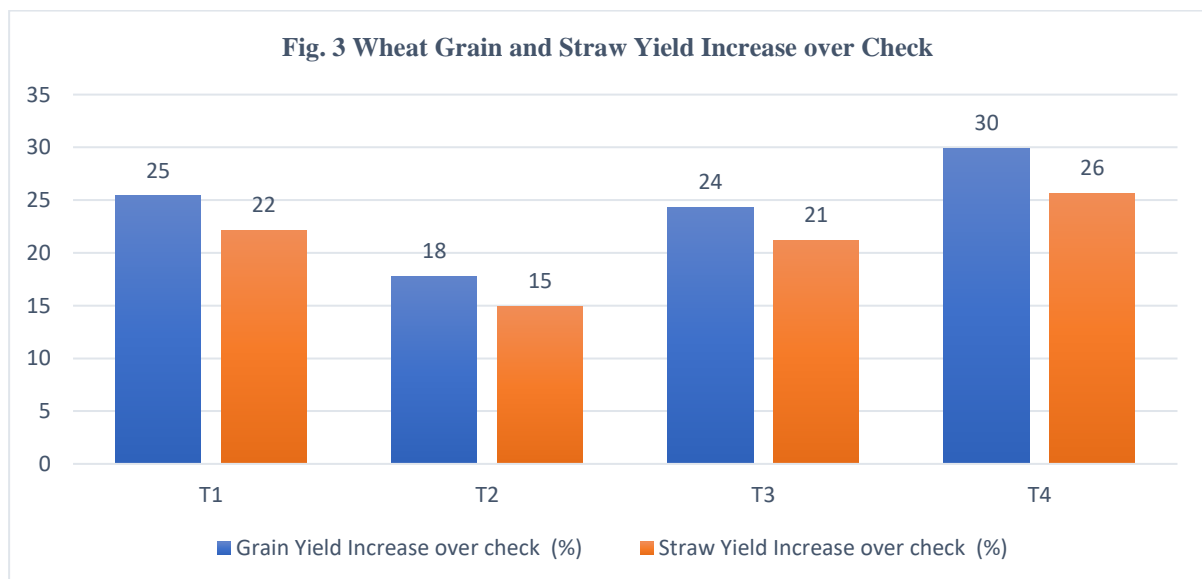


The differences between the wheat grain and straw yield were also calculated for all the treatments against the untreated check, and the results are demonstrated in Table 4 below. On average, there were about 1114.25 Kg/ha of wheat grain yield and 1418.25 Kg/ha wheat straw yield differences compared to an untreated check. Among the treatments, T4 was superior with 1460 Kg/ha, followed by T1 with 1163, T3 with 1097 Kg/ha, and T2 with 737 Kg/ha yield differences over the untreated check. A similar trend in results among treatments was observed regarding the wheat straw yields over the untreated check (Table 4).

Table 4: What Grain and Straw Yield Differences

Treatments	Avg. grain yield Kg/ha	Difference over check Kg/ha	Increase over check (%)	Avg. Straw yield Kg/ha	Difference over check Kg/ha	Increase over check (%)
T1: 2,4-D	4580	1163	25	6783	1503	22
T2: Qadri Puma	4153	737	18	6207	927	15
T3: 2,4-D + Qadri Puma	4513	1097	24	6700	1420	21
T4: Mechanical Control (Hand Weeding)	4877	1460	30	7103	1823	26
T5: Untreated (Check)	3417			5280		
Average		1114.25	24		1418.25	21

The yield analysis results revealed that, on average, all the treatments showed about 24 percent of wheat grain and 21 percent of wheat straw increase over the untreated check. Among the treatments, T₄ showed the highest percentage increase in grain and straw yield (30 and 26%), followed by T₁ with 25 and 22%, T₃ with 24 and 21% increase, and T₂ with 18 and 15%, respectively (Figure 3).



Discussion

This study studied the efficacy of mechanical control of weeds (hand weeding), broad and narrow leaf herbicides, and application of narrow leaf herbicides. We found that weed management practices significantly affected wheat grain and straw yield in all the treatments. Among the treatments, mechanical control (T₄) ranked first due to eliminating broad and narrow-leaved weeds. Similar results were achieved by Islam et al. (2023), who evaluated different weed management methods on weed population and wheat yield, and they found that mechanical control alone and combined with chemicals significantly affected both weed population density and ultimately increased wheat yield.

Similarly, Tunio, S.D et al. (2002) also studied the effect of different weed management practices on wheat grain and straw yield; among the tested methods, the highest yield was achieved through mechanical control or hand weeding (4,166Kg/ha) that is very close to the yield achieved under our study (4,867Kg/ha). Their study also revealed that all the treated practices significantly affected wheat grain and straw yield. The findings of this research are also in agreement with the findings of Amare Tesfay (2014), who achieved the highest yield with hand weeding (2289.4 Kg/ha) followed by broad-leaved herbicides (2177.3 Kg/ha).

Similar to the finding of this research, Riaz *et al.* in 2006 also reported a significant effect of all the weed management methods tested by them (mechanical, chemical, and their integration) on wheat yield, while the highest wheat grain yield was obtained in chemical (67%) and mechanical control (63%) respectively at 50 days after cultivation. Though mechanical control or hand weeding is labor intensive, which increases the cost of production, it is an environmentally friendly and safe approach for eliminating weeds and increasing the production and productivity of wheat. These findings are also in conformity with the findings of Sing et al. (2013), who applied Metsulfuron and 2,4-D at 6 gr/ha and 500 gr/ha as post-emergence herbicides that resulted in reduced weed populations, weed biomass, and weed index by 78.3%, 67.4% and 23.5% respectively and increased wheat grain yield by 37.8% as compared to the weedy check.

The second highest yield (4,600 Kg/ha) was achieved by combining both the broad and narrow-leaved herbicide (2,4-D+ Qadri puma) that reduces weed growth to a maximum extent or eliminates both types of weeds. This finding agrees with the findings of Hossain *et al.* (2009), who evaluated the effects of various herbicides and revealed that the high yield of 3.18MT/ha was obtained from 2,4-D herbicide application @ 1.5 litter per hectare followed by mechanical hand weeding 3.3MT/ha. A similar result (5MT/ha of wheat grain yield) was also achieved by Wara *et al.* (2020), who applied post-emergence herbicide at 23 days after sowing (DAS) plus had weeding at 40 DAS. The results are also in conformity with Shakya (2016), who studied the effect of different chemical herbicides on wheat yield and found all the herbicides effective on wheat yield; however, among the applied herbicides, the highest grain yield was obtained by application of 2,4-D at the rate of 0.5 Kg a.i /ha at 30 days after sowing.

With the application of herbicides that control or manage only weeds with broad leaves (2,4-D), the second highest yield of both grain (4,850Kg/ha) and straw (6783 Kg/ha) was achieved, which indicates that the broad-leaved weeds population is about 35% higher than the narrow-leaved weeds which compete with the main crop for getting the nutrients, water, sunlight and preventing root growth and tillering of wheat. The findings of this study agree with the study conducted by Amare *et al.* (2016), who studied the effect 2,4-D, hand weeding and their combination on weed control and wheat productivity in comparison with un-weeded check, who also achieved highest wheat yield of 3,989Kg/ha by the application of 2,4-D.

The findings of this research on increased wheat grain and straw yield are also confirmatory with the conclusions from Inqilaabi (2022), who studied the effect of herbicides on weed management and grain yield of wheat in Afghanistan by application of 2,4-D @ 1Kg/ha and MCPA@ 1Kg/ha and achieved the highest grain and straw yield (5.07 and 8.23 MT/ha respectively) with application of 2,4-D compared to MCPA. According to him, the higher grain and straw yield achieved is mainly due to better control of weeds and higher weed control efficiency during the early growing stage of the crop that resulted in effective utilization of nutrients, moisture, space, and sunlight that ultimately resulted in better expression of yield components.

Compared to broad-leaved weeds, the narrow-leaved weeds population observed was less during the life of the project or the wheat growing season. Still, the application of narrow-leaved herbicides also positively affected wheat grain and straw yield to some extent compared to untreated checks. Among the treatments, the high yields of wheat grain and straw obtained are in mechanical control, followed by a combination of the narrow and broad leaf herbicide and then the broad leaf alone. This indicates that the complete removal of all types of weeds from the wheat crop field will significantly increase the yields of grain and straw. A similar result was also achieved by combining both kinds of herbicides (broad and narrow leaf herbicides), where both weeds were controlled to some extent but not eliminated. The highest straw yield was achieved in untreated check, and the reason behind that was that the wheat straw and the weeds were harvested collectively.

The best and easiest way of weed management is through mechanical control or hand weeding, which may result in higher grain and straw yields. This method applies well to small farming systems, especially where enough labor is available. In Afghanistan, wheat is mainly traditionally cultivated on broadcasting systems. It is not yet mechanized to be planted by machineries in rows where weeds can easily be removed mechanically. This method will be difficult to apply because of high labor costs and heavy crop damage/losses during the weeding process. Therefore, chemical control remains one of the best methods for weed management in wheat fields.

Conclusion

Based on the research findings and the available literature about weed management practices, all weed management methods significantly affect wheat grain and straw yield. Among them, mechanical control, followed by chemical controls, showed its high effects. Mechanical weed control is one of the easiest and cheapest ways of weed management and requires no specialized knowledge and experience. To some extent, this method is traditionally being adopted by some farmers. Still, it is not widely applied throughout the country due to possible crop damage during the weeding and limited human resources in farming communities. As broad-leaved weeds are commonly distributed in wheat fields in the country, applying relative herbicides such as 2,4-D was more effective and recommended for all types of cultivation methods (broadcasting and row planting) to eliminate weeds in

wheat fields. Weeds can decrease wheat grain and straw yield by 30 and 26 percent, respectively; mechanical and chemical weed management practices are highly recommended to increase wheat productivity and production or decrease wheat yield losses in the country.

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