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Effect of Herbicides Application on Weed Growth and Subsequent Important on Yield of Three Wheat Varieties

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Abstract

This field experiment aimed to study the positive effect of some herbicides (Atlantis, Tonic + 2.4 D, Granstar + Tonic, and control, on weed plants to improve the growth and yield of three wheat varieties (Hasad, Wafia, and Rezan) under the rain-fed condition of both locations. The experiment was laid out in a randomized complete block design, arranged according to a split plot with three replicates. At the Grdjan location, herbicide treatment caused a significant reduction in the number of weeds at sampling (100 DAS) compared with the control treatment by 87.98%. While, at the Qaladze location, the reduction values in the number of weeds by herbicides at sampling (120 DAS) was 60.77%. At the Grdjan location, herbicide treatment significantly decreased flag leaf area as compared with the control treatment. However, at the Qaladze location herbicides significantly increased, plant height and a number of grains spike^{-1}, whereas significantly reduced the flag leaf area biological yield and wheat grain yield, compared with the control treatment. At the Grdjan and Qaladze locations, the Rezan variety surpassed the Hasad and Wafia varieties in plant height, spike length, number of grains spike^{-1}, 1000-grain weight, wheat grain yield and biological yield. The interaction among Granstar + Tonic application with the Rezan variety increased plant height and wheat grain yield at the Qaladze location. The interaction among Tonic + 2.4 D treatment with Rezan increased the number of grains spike^{-1} 1000-grain weight and harvest index.

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Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop in the world and is a major source of nourishment (Kamrozzaman *et al.*, 2015). It is a staple food of millions of people. It provides 20% of the food calories needed by the world's expanding population. Protein and carbohydrates are two of wheat's primary nutrients. Due to its simpler cultivation, better nutrient content, and ecological suitability, wheat is regarded as the king of all cereal crops (Sultana *et al.*, 2012). Wheat production is influenced by a number of variables, including variety and effective agronomic techniques. To produce wheat with a good yield, varieties are crucial. Different types react differently to the environment during the growing season according to their genotypic characteristics, input requirements, growth processes, and other factors (Sullieva and G'Zokirov, 2020; Sultana *et al.*, 2012). High-yielding cultivars' widespread use resulted in a simplifying of sowing arrangements and a significant loss of biodiversity (Divéky-Ertsey *et al.*, 2022; Pankou *et al.*, 2021). The potential to use herbicide rates lower than advised while still achieving sufficient weed control and a satisfactory crop yield is increased by the competitiveness of the crop variety and

meteorological factors. Additionally, using competitive crops or cultivars in conjunction with lower herbicide applications could significantly improve successful weed control (Travlos, 2012). Furthermore, several different compounds are being utilized to reduce these losses. There are, however, some negative side effects associated with these chemical applications (Rasul, 2023). When weed abundance is constrained, modern cultivars with minimal competitive abilities generate great yields in a monoculture. However, under weedy environments, the weak competitive ability means that current crop cultivars may have a very limited ability to control weeds and hence withstand weed invasion (Wu, *et al.,* 2021). Integrated Weed Management (IWM) techniques have centered on the use of competitive cultivars with improved above-ground crop competitiveness in conjunction with chemical control techniques and cultural practices like higher seeding rates, closer spacing between rows, different row orientations, crop rotation, and delayed seeding (Mwendwa *et al.,* 2020).

Weeds are the largest source of crop yield loss globally (Wu *et al.,* 2021). Among the most significant issues in agricultural output is weed growth. They are uninvited plants from semi-domesticated or wild species that are present in food crops against the will of the occupants and cause production reductions (Petrova *et al.,* 2015). Weeds compete with wheat plants for moisture, light, nutrients, and other development demands, which makes them one of the most important factors that negatively affect the production of the wheat crop (Asad *et al.,* 2017). Wheat production might be raised by using effective weed management techniques throughout the plant's prime growth season. The efficiency of weed management is influenced by weed control technique, weeding frequency, and crop and weed types (Kamrozzaman *et al.,* 2015). Weeds can cause a crop's production to decrease by 10 to 40% depending on the kind and severity of the weed infestation in the crop if they are not managed at crucial growth phases (Khan *et al.,* 2020).

Chemical inputs and genetic selection have been heavily utilized in agriculture in industrialized nations since the Second World War (Mamine and Farès, 2020). Herbicides are now the primary tool used in industrialized nations for weed management since weed control is typically seen as necessary for crop productivity. However, farmers are under intense pressure to use fewer pesticides as a result of worries about negative environmental effects. Crop yields and pesticide use were not found to be related. It has been discovered that herbicides are superior to weed killers at controlling uncommon plant species (Gaba *et al.,* 2016). However, farmers still use the old approach of manual weeding, which is expensive, time-consuming, and labor-intensive, to control weeds in wheat fields. Herbicidal weed management techniques are advantageous in that they can reduce labor costs and overhead, making them considered to be cost-effective (Khan *et al.,* 2020; Mustari *et al.,* 2014). Furthermore, Atlantis, a product of Bayer Crop Science, has been registered as a herbicide in Iraq recently to control both broad and narrow annual weeds. It contains iodosulfuron methyl sodium, an active ingredient in the sulfonylurea group (4), and is widely used to control both annual grasses, especially Avena sativa in wheat fields, and broad leaf weeds (Said and Jaff, 2020). 2,4-D herbicide selectively controls many broadleaf plants without harming grass, has short soil residual lives of up to 4 and 6 weeks respectively (Shrivastav, 2023). Herbicide usage is widespread to lessen weed infestation and consequent crop loss in wheat production, which necessitates weed management (Mehmeti *et al.,* 2016). This study aimed to the effect of some herbicide applications on weed growth and subsequent importance on the yield of three wheat varieties.

Materials and Methods

A field study was carried out during the growing season 2021-2022 at two locations; the first was at the experimental fields of the Grdjan Research Station, Agricultural Research Station, and the second; was conducted at the Qaladze Agricultural Research Station, College of

Agricultural Engineering Sciences-University of Raparin, to study the effect of four types of herbicides treatment (Atlantis (400 g ha^{-1}), Tonic (400cm^3/h + 2.4D (500cm^3/h), Granstar (50 g ha^{-1}) + Tonic and unweeded control, on reducing the competitive ability of weed plants. Wheat varieties (*Triticum aestivum* L.) namely; Hasad, Wafia and Rezan during the winter season. Were seeded manually on the 16th and 17th, of December in Grdjan and Qaladze locations respectively at the rate of 120 kg ha^{-1} (300 seeds m^{-2}). Data from all plots were statistically analyzed to evaluate; the number and fresh of weed species above-ground biomass were determined in 1-meter square from each treatment by hand by using quadrate randomly at two growing stages 100 and 120 Days After Sowing (DAS). The dry weights of weeds were recorded after drying in an oven at 70ºc for 48 hours. Yield and yield contributing characters such as plant height (cm), number of tillers $plant^{-1}$, number of tillers m^{-2}, flag leaf area (cm^2), spike length (cm), number of grains $spike^{-1}$,1000- grain weight (g), harvest index , grain and biological yield (g).

Experimental Design and Statistical Analysis

The experimental design was Randomized Complete Block Design (RCBD) in split plots arrangement with three replications. Herbicides treatments (a) were randomly assigned in the main-plots, and varieties applications (b) were placed in the sub-plots. The net size of each sub-plot was 3×1.2 m (3.6 m^2) comprising 4 rows, 3 m long with 50 cm apart and the alleys between each sub-plot were 1 m. Data were statistically analyzed according to the method of Analysis of variance (ANOVA) and combined Analysis of Variance (Co-ANOVA) test by using the computer program SPSS. Comparisons between the two means were carried out by using Least Significant Differences (LSD) at a significant level of 5% after they showed their significance in the general test.

Table 1. Herbicides information

No.	Herbicides	Active ingredient	Use for
1	Atlantis	Mesosulfuron-methyl 3% + Iodosulfuron-methyl sodium 0.6 w/w WDG (3.6 DG)	Herbicide for the control of annual grass and broadleaf weeds in fall – sown or winter wheat and fall - sown triticale
2	Granstar	Contains 750 g/kg Tribenuron-methyl in the form of a water dispersible granule	For control of broadleaf weeds in wheat, barley and oats, and use in conservation tillage
3	2,4-D	*Dimethylamine salt of 2,4-Dichloro-phenoxyacetic acid	For selective broadleaf weed control in certain crops, turf and non-crop areas.
4	Tonic	Metribuzin 70% Wp	Selective herbicide used for control of the various kinds of annual grasses and weeds in sugarcane, vegetables, wheat

Results and Discussion

The statistical analysis of some growth characters presents in Table 2 indicated that the effect of herbicides was significant on the flag leaf area in the Grdjan location only and not significant on the other characters, while in the Qaladze location this effect was highly significant on plant height and flag leaf area and not significant on the other characters. Regarding to varieties effect the differences among varieties were highly significant for plant height and significant for tiller m^2 in the Grdjan location, while in the Qaladze location, it was highly significant for plant height, and tiller m^2 but significant for tiller $plant^{-1}$. Crop cultivars differ in how they grow, and this can have a significant impact on the crop-weed balance. Fast-growing or early canopy-forming varieties that spread out in the early stages are less vulnerable to competition from weeds. Genes for taller wheat are more competitive. The need to create more competitive winter or spring cultivars has also become essential due to the rise in herbicide-resistant weed cases (Chhokar *et al.*, 2012). As the average of both locations differences among varieties were

highly significant for plant height and tiller m^2 but it was significant for tiller $plant^{-1}$ and flag leaf area this maybe connected to the way that herbicides work to eliminate weeds, which allows the crop to profit from the needs of growth and speeds up photosynthesis (Khudur *et al*., 2019)**.** Regarding the interaction effect between herbicides and varieties, it was found that the effect of this interaction was significant for plant height in the Qaladze location and the average of both locations, while it was significant also for tillers $plant^{-1}$ in the average of both locations only and not significant for the rest. Concerning the effect of locations, it was significant for plant height while highly significant for tillers $plant^{-1}$, and not significant for the rest.

Table 2. Mean squares of ANOVA components for studied growth characters

S.O.V	df	Plant height	Tiller $Plant^{-1}$	Tiller/m^2	Flag Leaf Area
Grdjan					
Block	2	95.285	0.854	9900.194	21.891
A	3	36.094^{ns}	1.378^{ns}	220.222^{ns}	68.927^{*}
E(a)	6	34.152	3.486	3418.861	7.792
B	2	3250.347^{**}	8.334^{ns}	14432.861^{*}	26.071^{ns}
AB	6	27.995^{ns}	5.872^{ns}	992.083^{ns}	19.025^{ns}
E(b)	16	19.805	2.994	2393.778	24.591
Qaladze					
Block	2	5.520	0.541	3401.688	2.742
A	3	95.605^{**}	0.670^{ns}	3998.563^{ns}	101.140^{**}
E(a)	6	6.685	0.576	1423.910	2.287
B	2	2554.787^{**}	4.575^{*}	5528.688^{**}	42.005^{ns}
AB	6	30.222^{*}	1.432^{ns}	2141.438^{ns}	16.914^{ns}
E(b)	16	7.390	0.820	790.917	13.783
Combined Analysis					
Location	1	599.878^{*}	46.401^{**}	30237.503^{ns}	12.258^{ns}
Block/L(EA)	4	50.403	0.698	6650.941	12.316
A	3	62.499^{ns}	1.531^{ns}	2988.448^{ns}	168.488^{**}
A*L	3	69.199	0.516	1230.337	1.579
E(b)/L	12	20.418	2.031	2421.385	5.040
B	2	5782.813^{**}	8.513^{*}	18749.420^{**}	64.731^{*}
B*L	2	22.321	4.397	1212.128	3.346
AB	6	44.483^{*}	5.833^{*}	2636.712^{ns}	34.334^{ns}
AB*L	6	13.734	1.471	496.809	1.604
E(c)/L	32	13.598	1.907	1592.347	19.187

Data in Table 3 illustrate the effect of herbicides on some growth characters at both locations and their average. It was confirmed that the effect of herbicides was significant on flag leaf area in the Grdjan locations and the average of both locations only, indicating that the control gave the highest value for this character, showing 26.081 and 25.906 cm for the Grdjan location and the average of both locations respectively, while the Granstar + Tonic treatment gave the lowest value for flag leaf area, producing 20.189 and 19.447 cm respectively. These results support the findings (Gopal *et al*., 2017). At the Qaladze location the effect of herbicides was significant for plant height and flag leaf area, regarding to plant height the Tonic + 2.4 D treatment showed the highest value which was 69.467cm, while the Atlantis application gave the lowest value 62.700cm. Concerning to flag leaf area it was found that the Control gave the highest value

25.731cm, while the minimum value was 18.705 showed by the Granstar + Tonic.

Table 3. Effect of herbicides on studied growth characters at both location and their average

Herbicide (A)	Plant height	Tiller Plant^{-1}	Tiller/m^2	Flag Leaf Area
Grdjan				
Atlantis	73.544	6.067	206.556	25.657
Tonic + 2.4 D	71.489	6.533	199.556	22.620
Granstar + Tonic	72.278	5.778	211.444	20.189
Control	76.067	6.600	204.222	26.081
LSD $_{(0.05)}$	NS	NS	NS	3.220
Qaladze				
Atlantis	62.700	4.244	172.333	25.358
Tonic + 2.4 D	69.467	4.778	146.167	21.453
Granstar + Tonic	68.819	4.678	190.667	18.705
Control	69.300	4.856	148.667	25.731
LSD $_{(0.05)}$	2.982	NS	NS	1.744
The average of both location				
Atlantis	68.122	5.156	189.444	25.508
Tonic + 2.4 D	70.478	5.656	172.861	22.036
Granstar + Tonic	70.549	5.228	201.056	19.447
Control	72.683	5.728	176.444	25.906
LSD $_{(0.05)}$	NS	NS	NS	1.631

Data in Table 4 discussed the performance of varieties due to growth characteristics. At the Grdjan location, there were significant effects of varieties on plant height and number of tillers/ m^2 only. The maximum value for plant height was 87.958cm recorded by Rezan, while the lowest value was 55.517cm shown by Wafia. Regarding number of tillers/m^2 the highest value was 245.250 tillers as shown by Wafia, while Rezan gave the minimum number of tillers/m^2 reached 181.750 tillers. Regarding to the Qaladze location the differences among varieties were significant for all characters except flag leaf area. Maximum plant height was 80.858cm showed by Rezan, while the minimum plant height was 51.956cm shown by Wafia. The maximum number of tillers/plant was 5.308 shown by Hasad, while the minimum number of tillers/plant was 4.092 shown by Rezan. The highest number of tillers/m^2 was 188.125 shown by Wafia, while the lowest number was 146.250 shown by Rezan. Concerning to the average of both locations the differences between varieties were significant for all characters. The highest value of plant height was 79.253cm showed by Rezan, while Wafia gave a minimum value 62.997cm. The maximum number of tillers/plant and tillers/m^2 were 6.369 and 209.056 tillers respectively shown by Wafia, while the minimum value for the number of tillers/plant was 5.322 shown by Rezan, and for tillers/m^2 was 189.389 tillers shown by Hasad. The highest value for leaf area was 25.421cm shown by Hasad, while Rezan shown the lowest value 21.071cm. All crop growth-related characteristics, such as a flag leaf area and plant height, shown cultivar variations, with significant interactions among cultivars, year, and locations. The ranking of cultivars based on these distinct factors revealed that cultivars with the highest early growth, light interception as determined by LAI and PAR, leaf area, and plant height were also the most weed-suppressive (Mwendwa *et al*., 2020).

Table 4. Performance of varieties due to studied growth characters

Variety (B)	Plant height	Tiller Plant^{-1}	Tiller/m^2	Flag Leaf Area
Grdjan				
Hasad	76.558	6.233	189.333	25.335
Wafia	55.517	7.083	245.250	22.880
Rezan	87.958	5.417	181.750	22.695
LSD $_{(0.05)}$	3.852	NS	42.345	NS
Qaladze				
Hasad	69.900	5.308	159.000	24.761
Wafia	51.956	4.517	188.125	22.644
Rezan	80.858	4.092	146.250	21.030
LSD $_{(0.05)}$	2.353	0.784	24.340	NS
The average of both location				
Hasad	72.340	5.694	189.389	25.421
Wafia	62.997	6.369	209.056	22.458
Rezan	79.253	5.322	191.403	21.071
LSD $_{(0.05)}$	2.174	0.814	23.523	2.582

The interaction between herbicides and varieties on growth characters is present in Table 5 Regarding to the Grdjan location the effect of this interaction is not significant for all characters. Regarding to the Qaladze location the effect of this interaction was significant for plant height only. The maximum value for plant height was 84.267cm recorded by the Granstar + Tonic treatment of herbicides coupled with Rezan, this may be due to the difference in the number of internodes and the genetic variations between cultivars (Khudur *et al*., 2019)**.** The lowest value was 50.858cm shown by the Granstar + Tonic treatment of herbicides under Wafia. Regarding to the average of both locations the interaction effect between herbicides and varieties was significant for plant height and number of tillers/plant only. The values of plant height were restricted between 51.996 to 87.969 for Granstar + Tonic with Wafia and (Granstar + Tonic with Rezan) control with Rezan respectively, while for number tillers/plant it was restricted between (4.250) 4.183 to 7.050 for (Atlantis with Hasad) Tonic + 2.4 D with Rezan and Tonic + 2.4 D with Hasad respectively.

Table 5. Effect of interaction between herbicides and variety on studied growth characters at both location and their average

Herbicide / Variety		Plant height	Tiller Plant^{-1}	Tiller/m^2	Flag Leaf Area
Grdjan					
Atlantis	Hasad	74.300	4.333	172.000	25.972
	Wafia	58.200	7.600	253.000	27.033
	Rezan	88.133	6.267	194.667	23.967
Tonic + 2.4 D	Hasad	74.933	7.867	189.000	22.308
	Wafia	56.200	7.000	245.333	22.489
	Rezan	83.333	4.733	164.333	23.062
Granstar + Tonic	Hasad	77.267	4.800	188.000	21.524
	Wafia	53.133	6.800	263.333	19.820
	Rezan	86.433	5.733	183.000	19.224
Control	Hasad	79.733	7.933	208.333	31.537
	Wafia	54.533	6.933	219.333	22.178
	Rezan	93.933	4.933	185.000	24.527
LSD $_{(0.05)}$		NS	NS	NS	NS
Qaladze					
Atlantis	Hasad	61.867	4.167	158.500	27.553
	Wafia	51.800	4.233	202.500	26.400
	Rezan	74.433	4.333	156.000	22.120

Tonic + 2.4 D	Hasad	71.733	6.233	155.500	21.062
	Wafia	53.933	4.467	174.000	21.798
	Rezan	82.733	3.633	109.000	21.500
Granstar + Tonic	Hasad	71.333	5.033	149.000	19.345
	Wafia	50.858	5.133	230.000	19.270
	Rezan	84.267	3.867	193.000	17.500
Control	Hasad	74.667	5.800	173.000	31.084
	Wafia	51.233	4.233	146.000	23.108
	Rezan	82.000	4.533	127.000	23.000
LSD $_{(0.05)}$		4.706	NS	NS	NS
The average of both location					
Atlantis	Hasad	68.083	4.250	165.250	26.763
	Wafia	55.000	5.917	227.750	26.717
	Rezan	81.283	5.300	175.333	23.043
Tonic + 2.4 D	Hasad	73.333	7.050	172.250	21.685
	Wafia	55.067	5.733	209.667	22.144
	Rezan	83.033	4.183	136.667	22.281
Granstar + Tonic	Hasad	74.300	4.917	168.500	20.434
	Wafia	51.996	5.967	246.667	19.545
	Rezan	85.350	4.800	188.000	18.362
Control	Hasad	77.200	6.867	190.667	31.310
	Wafia	52.883	5.583	182.667	22.643
	Rezan	87.967	4.733	156.000	23.764
LSD $_{(0.05)}$		4.347	1.628	NS	NS

The effect of locations on growth characters is presented in Table 6 this effect was significant for plant height and number of tillers/plant only, showing the superiority of the Grdjan location compared to the Qaladze location for both characters by 8.54 and 34.59% respectively. performed over multiple locations and years and addressed both genetic and environmental factors that impacted cultivar performance and weed establishment (Mwendwa *et al*., 2020).

Table 6. Effect of locations on studied growth characters

Location	Plant height	No. Tiller Plant^{-1}	Tiller/m^2	Flag Leaf Area
Grdjan	73.344	6.244	205.444	23.637
Qaladze	67.572	4.639	164.458	22.812
LSD $_{(0.05)}$	4.645	0.547	NS	NS

The results of the statistical analysis of the yield and yield component characters in Table 7 showed that the impact of herbicides was not significant for all studied characters at the Grdjan location, while in the Qaladze location this effect was highly significant for the weight of grain m^{-2} while biological yield and significant of a number of grains spike^{-1} and not significant of the other characters. About the varieties affect the differences among varieties were highly significant for spike length, number of grain spike^{-1}, and 1000-grain weight while significant for both characters weight of grain m^{-2} and biological yield but not significant for harvest index at the Grdjan location, while in the Qaladze location, it was highly significant for all the studied characters. As the average of both locations differences among the effect of herbicides was not significant for all studied characters, while the average differences among varieties were highly significant for all studied characters. In relation to the interaction effect between herbicides and varieties, it was found that the effect of this interaction was highly significant for the number of grain spike^{-1}, weight of grains m^{-2}, and harvest index and only significant for 1000-grains weight at the Qaladze location while highly significant for harvest index and significant for the number of grains spike^{-1} on average of both locations and not significant for the others. Relating to the effect of locations, it was highly significant for

the number of grain spike^{-1} and weight of grain m^{-2} while significant for the characters 1000-grain weight and biological yield but not significant for the rest. Meena *et al.* (2017) and Safi *et al.* (2022) They reported increase in grain yield due to maximum values obtained those of yield components by the application of herbicides in treated plots.

Table 7. Mean squares of ANOVA components for studied characters

S.O.V	df	Spik Length	No. of Grain Spike^{-1}	1000 grain weight	Weight of grain m^{-2}	Biological yield	Harvest Index
Grdjan							
Block	2	0.166	16.751	50.746	24384.622	101743.750	0.002
A	3	0.335^{ns}	86.394^{ns}	50.003^{ns}	14979.778^{ns}	68852.778^{ns}	0.010^{ns}
E(a)	6	0.618	146.990	37.787	39600.800	174863.194	0.011
B	2	44.436**	861.481**	406.389**	72123.021*	176589.583*	0.016^{ns}
AB	6	0.422^{ns}	118.062^{ns}	17.102^{ns}	6336.082^{ns}	10664.583^{ns}	0.004^{ns}
E(b)	16	0.443	135.045	23.840	12299.909	41530.208	0.006
Qaladze							
Block	2	0.775	61.643	25.235	498.994	12057.333	0.220
A	3	0.017^{ns}	82.647*	0.118^{ns}	19748.234**	65872.833**	0.196^{ns}
E(a)	6	0.672	11.583	4.628	622.900	6701.500	0.113
B	2	13.150**	1024.230**	1609.443**	187754.008**	71847.438**	0.239**
AB	6	0.622^{ns}	175.127**	8.671*	11474.577**	9768.021^{ns}	0.035**
E(b)	16	0.274	14.376	2.183	378.516	4707.583	0.006
Combined Analysis							
Location	1	0.294^{ns}	835.042**	317.352*	374874.087**	788768.000*	0.007^{ns}
Block/L(EA)	4	0.471	39.197	37.990	12441.808	56900.542	0.111
A	3	0.179^{ns}	104.183^{ns}	24.089^{ns}	30343.341^{ns}	121250.861^{ns}	0.124^{ns}
A*L	3	0.172	64.858	26.032	4384.671	13474.750	0.081
E(b)/L	12	0.645	79.286	21.208	20111.850	90782.347	0.062
B	2	52.955**	1858.761**	1789.599**	239764.060**	230559.760**	0.144**
B*L	2	4.631	26.951	226.232	20112.968	17877.260	0.111
AB	6	0.240^{ns}	244.331*	20.078^{ns}	7827.516^{ns}	13642.691^{ns}	0.020**
AB*L	6	0.804	48.857	5.695	9983.143	6789.913	0.019
E(c)/L	32	0.359	74.710	13.012	6339.213	23118.896	0.006

The information in Table 8 shows how some yield and yield component characters at both locations and their average are affected by the herbicide. It was confirmed that the effect of herbicides was significant for the number of Grain Spike^{-1}, the weight of grain m^{-2} and biological yield at Qaladze locations only, indicating that the Tonic + 2.4 D treatment that produced the highest value for the character number of Grain Spike^{-1}, recording 45.400. Mekonnen (2022) reported that the significantly, higher number of grains spike^{-1} may be due to effective weed management that reduces weed density and dry matter with low weed infestation which resulted in lower weed competition. The control treatment gave the highest value for the weight of grain m^{-2} showing 355.298, it obtained that higher Biological yield of 761.667 with the application of the Granstar + Tonic. While the Granstar + Tonic treatment had produced lowest value for the character number of Grain Spike^{-1}, recording 39.167. Atlantis treatment gave the minimum value for the weight of grain m^{-2} and biological yield, producing 241.245 and 606.500 respectively.

Table 8. Effect of herbicides on studied yield and its components character at both location and their average

Herbicide	Spik Length	No. of Grain Spike^{-1}	1000 grain weight	Weight of grain m^{-2}	Biological yield	Harvest Index
Grdjan						
Atlantis	11.289	47.111	42.800	402.791	879.444	0.451
Tonic + 2.4 D	11.311	50.667	46.998	404.268	783.333	0.531

Granstar + Tonic	10.911	49.689	44.847	466.514	921.111	0.502
Control	11.289	54.578	48.118	480.470	992.778	0.485
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS
Qaladze						
Atlantis	11.133	44.900	41.520	241.245	606.500	0.405
Tonic + 2.4 D	11.033	45.400	41.330	292.600	615.167	0.642
Granstar + Tonic	11.067	39.167	41.600	287.647	761.667	0.365
Control	11.056	45.333	41.517	355.298	756.000	0.636
LSD $_{(0.05)}$	NS	3.926	NS	28.790	94.431	NS
The average of both location						
Atlantis	11.211	46.006	42.160	322.018	742.972	0.428
Tonic + 2.4 D	11.172	48.033	44.164	348.434	699.250	0.586
Granstar + Tonic	10.989	44.428	43.223	377.081	841.389	0.433
Control	11.172	49.956	44.817	417.884	874.389	0.561
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS

The information in Table 9 describes how different varieties performed in relation to yield and yield component characters. At the Grdjan location, the differences among varieties were significant for all characters except the harvest index. The maximum values for the characters spike length, number of grain spike^{-1}, 1000 grain weight, weight of grain m^{-2} and biological yield were 13.417, 58.417, 49.728, 527.820, and 1027.917 respectively recorded by Rezan, while the lowest values for spike length, number of grain spike^{-1}, 1000 grain weight and biological yield were 9.958, 41.567, 39.020, 791.250 respectively exhibited by Wafia, but the lowest value only for weight of grain m^{-2} it was 388.550 recorded by Hasad. Regarding Qaladze location the differences among varieties were significant for all studied characters. Rezan exhibited maximum value for the characters spike length, number of grain spike^{-1}, 1000 grain weight, the weight of grain m^{-2}, biological yield, and harvest index they were 12.275, 53.500, 52.000, 433.461, 756.625, and 0.672 respectively, while the minimum value for all of them which 10.367, 35.150, 29.075, 191.394, 602.875 and 0.404 respectively recorded by Wafia. Concerning to the average of both locations the differences between varieties were significant for all the studied characters. The highest value for the characters spike length, number of grain spike^{-1}, 1000 grain weight, the weight of grain m^{-2}, and biological yield were 12.203, 51.422, 46.476, 452.450 and 934.653 respectively exhibited by Rezan, while Wafia gave minimum values for the characters spike length, number of grain spike^{-1}, 1000 grain weight and biological yield they were 10.565, 44.800, 41.592 and 745.250 respectively. While the minimum values for the weight of grain m^{-2} and harvest index were 355.284 and 0.439 recorded by Hasad. This might be due to the genetic nature of the cultivar (Safi *et al*, 2022; Zangana and Aljburi, 2023).

Table 9. Performance of varieties due to studied characters

Variety	Spik Length	number of Grain Spike^{-1}	1000 grain Weight	Weight of grain m^{-2}	Biological yield	Harvest Index
Grdjan						
Hasad	10.225	51.550	48.323	388.550	863.333	0.450
Wafia	9.958	41.567	39.020	399.163	791.250	0.516
Rezan	13.417	58.417	49.728	527.820	1027.917	0.511
LSD $_{(0.05)}$	0.576	10.058	4.226	95.987	176.377	NS
Qaladze						
Hasad	10.575	42.450	43.400	257.738	695.000	0.460
Wafia	10.367	35.150	29.075	191.394	602.875	0.404
Rezan	12.275	53.500	52.000	433.461	756.625	0.672

LSD $_{(0.05)}$	0.453	3.282	1.279	16.838	59.383	*0.068*
The average of both location						
Hasad	10.718	48.778	45.242	355.284	803.153	0.439
Wafia	10.565	44.800	41.592	373.798	745.250	0.551
Rezan	12.203	51.422	46.476	452.450	934.653	0.472
LSD $_{(0.05)}$	0.353	5.095	2.126	46.933	89.629	0.045

The impact of herbicides and varieties on yield and yield component characters is shown in Table 10 regarding to Grdjan location the effect of this interaction is not significant for all characters. Regarding Qaladze location the effect of this interaction was significant for all characters except spik length and biological yield. Maximum value for the number of grains spike^{-1}, 1000 grain weight and harvest index were 61.000, 52.440 and 0.823 recorded by Tonic + 2.4 D treatment of herbicides coupled with Rezan, while the lowest value was 28.500, 26.970 and 0.178 showed by Granstar + Tonic treatment of herbicides under Wafia. While the highest value for the weight of grain m^{-2} was 510.225 exhibited by Granstar + Tonic treatment of herbicides under Rezan, this may belong to the ability of cultivars to produce the longest spike length, number of grain per spike, and 1000 grain weight (Khudur *et al.,* 2019)**.** While the lowest value was 116.605 exhibited by Atlantis treatment of herbicides under Wafia. Regarding the average of both locations the interaction effect between herbicides and varieties was significant for the number of grain spike^{-1} and harvest index only. The values of number of grain spike^{-1}restricted between 64.133 to 31.267 for Tonic + 2.4 D with Rezan and Tonic + 2.4 D with Wafia respectively, while for harvest index it was restricted between 0.670 to 0.337 for Tonic + 2.4 D with Rezan and Granstar + Tonic with Wafia respectively.

Table 10. Effect of interaction between herbicides and variety on studied characters at both location and their average

Herbicide	Variety	Spik Length	Number of Grain Spike^{-1}	1000 grain weight	Weight of grain m^{-2}	Biological yield	Harvest Index
Grdjan							
Atlantis	Hasad	10.000	50.133	44.307	311.507	820.000	0.387
	Wafia	10.033	41.267	35.567	339.503	718.333	0.469
	Rezan	13.833	49.933	48.527	557.363	1100.000	0.498
Tonic + 2.4 D	Hasad	10.467	52.200	50.167	348.827	758.333	0.466
	Wafia	9.667	32.533	40.620	411.453	716.667	0.611
	Rezan	13.800	67.267	50.207	452.523	875.000	0.516
Granstar + Tonic	Hasad	9.867	51.067	49.813	431.050	891.667	0.479
	Wafia	10.033	42.533	35.313	429.937	868.333	0.496
	Rezan	12.833	55.467	49.413	538.557	1003.333	0.530
Control	Hasad	10.567	52.800	49.007	462.817	983.333	0.469
	Wafia	10.100	49.933	44.580	415.757	861.667	0.486
	Rezan	13.200	61.000	50.767	562.837	1133.333	0.502
LSD $_{(0.05)}$		NS	NS	NS	NS	NS	NS
Qaladze							
Atlantis	Hasad	11.033	49.200	43.800	259.600	555.000	0.472
	Wafia	9.967	40.600	29.060	116.605	570.000	0.208
	Rezan	12.400	44.900	51.700	347.530	694.500	0.536
Tonic + 2.4 D	Hasad	10.733	45.200	41.390	215.930	610.000	0.508
	Wafia	10.600	30.000	30.160	249.825	560.500	0.594
	Rezan	11.767	61.000	52.440	412.045	675.000	0.823
Granstar + Tonic	Hasad	10.367	32.600	45.780	229.735	775.000	0.297
	Wafia	10.167	28.500	26.970	122.980	688.000	0.178
	Rezan	12.667	56.400	52.050	510.225	822.000	0.621
Control	Hasad	10.167	42.800	42.630	325.685	840.000	0.564
	Wafia	10.733	41.500	30.110	276.165	593.000	0.637
	Rezan	12.267	51.700	51.810	464.045	835.000	0.708

$LSD_{(0.05)}$		NS	6.563	2.557	33.677	NS	0.135
The average of both location							
Atlantis	Hasad	10.517	49.667	44.053	285.553	687.500	0.430
	Wafia	10.000	40.933	32.313	228.054	644.167	0.339
	Rezan	13.117	47.417	50.113	452.447	897.250	0.517
Tonic + 2.4 D	Hasad	10.600	48.700	45.778	282.378	684.167	0.487
	Wafia	10.133	31.267	35.390	330.639	638.583	0.603
	Rezan	12.783	64.133	51.323	432.284	775.000	0.670
Granstar + Tonic	Hasad	10.117	41.833	47.797	330.393	833.333	0.388
	Wafia	10.100	35.517	31.142	276.458	778.167	0.337
	Rezan	12.750	55.933	50.732	524.391	912.667	0.576
Control	Hasad	10.367	47.800	45.818	394.251	911.667	0.516
	Wafia	10.417	45.717	37.345	345.961	727.333	0.561
	Rezan	12.733	56.350	51.288	513.441	984.167	0.605
$LSD_{(0.05)}$		NS	10.190	NS	NS	NS	0.091

Table 11 shows the impact of locations on yield and yield component characters. This effect was significant for all characters except spik length and harvest index. The effect of locations showing the superiority of the Grdjan location compared to the Qaladze location for characters number of grain spike^{-1}, 1000 grain weight, weight of grain m^{-2} and biological yield, by 15.58, 10.12, 0.049 and 30.56% respectively. Zand *et al.* (2007) the findings also highlighted the impact of various wheat cultivars and environmental factors on herbicide effectiveness, demonstrating how the optimum control strategy may change depending on variety and location.

Table 11. Effect of locations on study characters

Location	Spike Length	Number of Grain Spike^{-1}	1000 grain weight	Weight of grain m^{-2}	Biological yield	Harvest Index
Grdjan	11.200	50.511	45.691	438.511	894.167	0.492
Qaladze	11.072	43.700	41.492	294.198	684.833	0.512
$LSD_{(0.05)}$	NS	4.096	4.033	72.984	156.078	NS

The statistical analysis of the weed-related characters in Table 12 showed that the impact of herbicides was highly significant for the number of weeds m^{-2} over 100 days and not significant for all studied characters at the Grdjan location, while at the Qaladze location, this effect was significant for a number of weeds over 120 days and not significant for the other characters. Concerning varieties effect the differences among varieties were not significant for all studied characters at both locations. As the average of both locations differences among effects of herbicides were highly significant for characters a number of weeds m^{-2} over 100 days and the number of weeds for 120 days while only significant for fresh weight for 120 days and not significant for the rest while the average differences among varieties were not significant for all studied characters. With regard to the interaction effect between herbicides and varieties, it was found that the effect of this interaction was not significant for all studied characters at Grdjan and Qaladze locations while significant only for fresh weight of 100 days and not significant for the others on average of both locations. Relating to the effect of locations, it was significant for a number of weeds m^{-2} of 100 days and dry weight for 120 days, but not significant for other characters.

Table 12. Mean squares of ANOVA components for studied characters

S.O.V	df	Number of weeds m^{-2} -100 days	Fresh Weight. 100 days	Dry weight 100 Days.	Number of weeds 120 Days	Fresh weight -120 Days	Dry Weight -120 Days
ANOVA (A)	Grdjan						
Block	2	123.861	23356.390	1209.841	4.694	692.054	16.511
A	3	1761.583^{**}	17478.026^{ns}	540.949^{ns}	82.296^{ns}	2843.253^{ns}	698.308^{ns}
E(a)	6	123.750	4402.941	242.131	20.991	2271.921	399.456
B	2	7.861ns	2026.478^{ns}	188.301^{ns}	10.778^{ns}	4935.825^{ns}	1156.358^{ns}
AB	6	44.639^{ns}	7233.338^{ns}	302.393^{ns}	6.741^{ns}	3441.020^{ns}	631.961^{ns}
E(b)	16	61.403	3354.008	140.670	7.167	3553.587	634.173
ANOVA (B)	Qaladze						
S.O.V	df						
Block	2	76.861	2161.384	48.683	36.111	5253.657	168.094
A	3	219.889^{ns}	1232.586^{ns}	56.304^{ns}	51.667^{*}	5695.408^{ns}	259.407^{ns}
E(a)	6	107.306	11798.889	918.804	5.667	1466.917	91.308
B	2	146.694^{ns}	10101.853^{ns}	896.896^{ns}	7.528^{ns}	520.532^{ns}	53.637^{ns}
AB	6	151.250^{ns}	21619.600^{ns}	1417.705^{ns}	5.306^{ns}	594.596^{ns}	39.690^{ns}
E(b)	16	79.236	11542.905	867.032	12.069	2052.647	125.687
ANOVA Co	Combined Analysis						
S.O.V	df						
Location	1	1275.125^{*}	30137.580^{ns}	3361.043^{ns}	1.389^{ns}	4300.895^{ns}	2612.982^{*}
Block/L(EA)	4	100.361	12758.887	629.262	20.403	2972.855	92.302
A	3	1571.014^{**}	12012.276^{ns}	249.583^{ns}	97.204^{**}	7089.997^{*}	637.078^{ns}
A*L	3	410.458	6698.335	347.669	36.759	1448.664	320.637
E(b)/L	12	115.528	8100.915	580.468	13.329	1869.419	245.382
B	2	48.389^{ns}	10503.057^{ns}	947.697^{ns}	7.042^{ns}	2507.538^{ns}	688.620^{ns}
B*L	2	106.167	1625.274	137.499	11.264	2948.819	521.376
AB	6	123.056^{ns}	18980.958^{*}	1023.364^{ns}	2.468^{ns}	1564.966^{ns}	259.284^{ns}
AB*L	6	72.833	9871.979	696.735	9.579	2470.650	412.367
E(c)/L	32	70.319	7448.457	503.851	9.618	2803.117	379.930

Data in Table 13 illustrate the effect of herbicides on the weed-related characters at both locations and their average. It was confirmed that the effect of herbicides was significant only for the character number of weeds m^{-2} of 100 days at the Grdjan location, indicating that the control treatment gave the highest value for this character, reaching 37.889, while Granstar + Tonic treatment gave the lowest value for number of weeds m^{-2} of 100 days, recording 4.556. At the Qaladze location, it was confirmed that the effect of herbicides was significant only for the character number of weeds m^{-2} of 120 days, indicating that control treatment gave the highest value for this character, reaching 8.778, while the second treatment gave the lowest value for number of weeds m^{-2} of 120 days, recording 3.444 the fact that certain herbicide mixes were more efficient for controlling weeds than others can be used to explain the variation in weed population between various treatments. The study of Kaur *et al.* (2020) also gave the same result. Relating to the average of both locations, it was confirmed that the effect of herbicides was significant for the number of weeds m^{-2} of 100 days, the number of weeds m^{-2} of 120 days, and the fresh weight of weed of 120 days. The fourth treatment gave the highest value for characters number of weeds m^{-2} of 100 days, number of weeds m^{-2} of 120 days, and fresh weight of weed of 120 days reached 28.222, 8.444 and 75.686 respectively, while Granstar + Tonic treatment gave the lowest value for number of weeds m^{-2} of 100 days and number of weeds m^{-2} of 120 days, recording 5.611 and 2.833 respectively but the lowest value for the fresh weight of weed of 120 days reached 30.343 exhibited by Tonic + 2.4 D treatment.

Table 13. Effect of herbicides on studied character at both loth location and their average

Herbicide	Number of weeds m^{-2} – 100 days	Fresh Weight. 100 days	Dry weight 100 Days.	Number of weeds 120 Days	Fresh weight -120 Days	Dry Weight -120 Days
Grdjan						
Atlantis	15.889	75.626	16.804	4.889	65.606	22.052
Tonic + 2.4 D	23.556	53.316	10.270	7.667	34.803	7.923
Granstar + Tonic	4.556	54.763	12.811	1.556	64.023	27.141
Control	37.889	146.981	27.838	8.111	76.291	25.820
LSD $_{(0.05)}$	12.832	NS	NS	NS	NS	NS
Qaladze						
Atlantis	12.333	135.607	33.450	4.778	55.633	12.140
Tonic + 2.4 D	10.667	118.804	31.882	3.444	25.882	4.636
Granstar + Tonic	6.667	109.548	28.083	4.111	22.298	3.600
Control	18.556	130.400	28.967	8.778	75.080	14.367
LSD $_{(0.05)}$	NS	NS	NS	2.746	NS	NS
The average of both location						
Atlantis	14.111	105.616	25.127	4.833	60.619	17.096
Tonic + 2.4 D	17.111	86.060	21.076	5.556	30.343	6.280
Granstar + Tonic	5.611	82.156	20.447	2.833	43.161	15.371
Control	28.222	138.691	28.402	8.444	75.686	20.093
LSD $_{(0.05)}$	7.807	NS	NS	2.652	31.404	NS

Data in Table 14 discussed the performance of varieties due to the weed-related characters. At Grdjan and Qaladze locations also on average of both locations, all studied characters recorded no significant effect of varieties for all studied characters. The prevalent species of weeds in the study area were Avena sativa, Galium tricorne, smeller bind weed and Brassica napus. Some species were also found in the field but with low density. The difference in the ability of cultivars to suppress weed growth than others might be due to the differential rooting patterns, allelochemicals production, higher leaf area index and more light interception, tillering capacity and vegetative growth habit (Abouziena *et al*., 2008; Zangana and Aljburi, 2023).

Table 14. Performance of varieties due to studied characters

Variety	Number of weeds m^{-2} -100 days	Fresh Weight. 100 days	Dry weight 100 Days.	Number of weeds 120 Days	Fresh weight -120 Days	Dry Weight -120 Days
Grdjan						
Hasad	20.667	92.674	17.653	4.500	65.498	20.323
Wafia	21.167	87.357	20.482	5.833	77.273	30.750
Rezan	19.583	67.983	12.658	6.333	37.771	11.130
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS
Qaladze						
Hasad	13.417	140.665	33.807	5.250	37.150	6.358
Wafia	8.083	140.015	37.176	6.083	49.108	10.487
Rezan	14.667	90.089	20.804	4.500	47.912	9.213
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS
The avarage of both locations						
Hasad	17.389	99.145	21.390	4.667	63.059	18.709
Wafia	19.139	86.708	20.779	5.694	53.808	18.515
Rezan	12.597	75.069	16.553	4.583	40.466	13.250
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS

The interaction between herbicides and varieties on the weed-related characters is presented in Table (15). Regarding Grdjan location the effect of this interaction is not significant for all characters. Regarding Qaladze location the effect of this interaction was not significant for all characters. Regarding the average of both locations the interaction effect between herbicides and varieties was significant for fresh weeds weight over 100 days only. The maximum value for fresh weeds weight over 100 days was 210.180 recorded by the control treatment of herbicides coupled with Hasad, while the lowest value was 35.617gm showed by Atlantis treatment of herbicides under Hasad (Safi *et al.*, 2022).

Table 15. Effect of interaction between herbicides and varieties on studied characters at both location and their average

Herbicide	Variety	Number of weeds m^{-2} -100 days	Fresh Weight. 100 days	Dry weight 100 Days.	Number of weeds 120 Days	Fresh weight -120 Days	Dry Weight -120 Days
		Grdjan					
	Hasad	12.000	45.097	7.533	5.333	102.410	33.990
Atlantis	Wafia	19.333	88.043	21.063	4.000	45.517	16.490
	Rezan	16.333	93.737	21.817	5.333	48.890	15.677
	Hasad	23.000	43.440	8.493	5.667	34.570	7.223
Tonic + 2.4 D	Wafia	21.667	66.467	12.930	7.333	38.140	9.047
	Rezan	26.000	50.040	9.387	10.000	31.700	7.500
	Hasad	5.333	45.443	10.870	1.000	33.823	13.487
Granstar + Tonic	Wafia	4.333	90.247	21.813	1.667	128.000	57.733
	Rezan	4.000	28.600	5.750	2.000	30.247	10.203
	Hasad	42.333	236.717	43.713	6.000	91.190	26.590
Control	Wafia	39.333	104.670	26.120	10.333	97.437	39.730
	Rezan	32.000	99.557	13.680	8.000	40.247	11.140
$LSD_{(0.05)}$		NS	NS	NS	NS	NS	NS
Qaladze							
	Hasad	7.000	26.137	5.443	4.000	28.633	5.383
Atlantis	Wafia	8.000	201.557	55.257	7.333	70.357	19.217
	Rezan	22.000	179.127	39.650	3.000	67.910	11.820
	Hasad	9.000	135.340	36.897	4.000	16.275	2.045
Tonic + 2.4 D	Wafia	11.667	178.113	48.313	3.333	29.907	4.573
	Rezan	11.333	42.960	10.437	3.000	31.463	7.290
	Hasad	9.000	217.540	57.267	3.667	17.463	2.483
Granstar + Tonic	Wafia	6.000	64.207	16.590	5.667	21.363	3.623
	Rezan	5.000	46.897	10.393	3.000	28.067	4.693
	Hasad	28.667	183.643	35.620	9.333	86.227	15.520
Control	Wafia	6.667	116.183	28.543	8.000	74.807	14.533
	Rezan	20.333	91.373	22.737	9.000	64.207	13.047
$LSD_{(0.05)}$		NS	NS	NS	NS	NS	NS
The average of both location							
Atlantis	Hasad	9.500	35.617	6.488	4.667	65.522	19.687
	Wafia	13.667	144.800	38.160	5.667	57.937	17.853
	Rezan	19.167	136.432	30.733	4.167	58.400	13.748
Tonic + 2.4 D	Hasad	16.000	89.390	22.695	4.833	25.423	4.634
	Wafia	16.667	122.290	30.622	5.333	34.023	6.810
	Rezan	18.667	46.500	9.912	6.500	31.582	7.395
Granstar + Tonic	Hasad	7.167	131.492	34.068	2.333	25.643	7.985
	Wafia	5.167	77.227	19.202	3.667	74.682	30.678

	Rezan	4.500	37.748	8.072	2.500	29.157	7.448
Control	Hasad	35.500	210.180	39.667	7.667	88.708	21.055
	Wafia	23.000	110.427	27.332	9.167	86.122	27.132
	Rezan	26.167	95.465	18.208	8.500	52.227	12.093
LSD $_{(0.05)}$		NS	101.749	NS	NS	NS	NS

The effect of locations on the weed-related characters is presented in Table 16. This effect was significant for the number of weeds m^{-2} of 100 days and weeds dry weight of 120 days only, showing the superiority of the Grdjan location compared to the Qaladze location for both characters by 69.80 and 144.96% respectively.

Table 16. Effect of locations on study characters

Location	No. of weeds m^{-2} -100 days	Fresh Weight. 100 days	Dry weight 100 Days.	No of weeds 120 Days	Fresh weight -120 Days	Dry Weight -120 Days
Grdjan	20.472	82.671	16.931	5.556	60.181	20.734
Qaladze	12.056	123.590	30.596	5.278	44.723	8.464
LSD(0.05)	6.555	NS	NS	NS	NS	2.183

Conclusion

The application of herbicide resulted in an 87.98% reduction in the number of weeds. The herbicide combination treatment Granstar + Tonic application with Rezan at Grdjan location and Tonic + 2.4 D treatment with Rezan produced a significantly higher number of grains spike $^{-1}$,1000-grain weight and harvest index of wheat compared to the weedy treatments under this study. The Rezan variety of wheat exceeded by achieving the lowest number of companion weed plants, fresh and dry weight at the average of both locations.

Conflict of interest

The authors declare there are no conflicts of interest among all authors.

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