Response of bread wheat crop to tillage systems and chemical herbicides in moderate rainfall area2

Ammar Habeeb Mahmood[1], Islam. A. A. Alrijabo[1], Ahmed Ibrahim Abed, Salim.H. Antar[1], Maan Mohammed Salih[1*], Mohammed Subhi Al -Taweel[1]

[1]Center for Arid Farming and Conservation Agriculture Research, University of Mosul, Iraq

*Corresponding author's email: maan.m.salih@uomosul.edu.iq

Email addresses of coauthors: ammar.habeeb@uomosul.edu.iq, islam_zt@uomosul.edi.iq, ahmedalshahin82@uomosul.edu.iq, sanoth2017@uomosul.edu.iq, draltwel@uomosul.edu.iq

Abstract

A field experiment was carried out in Nineveh Governorate for the 2024–2025 growing season to investigate the effect of tillage systems (conventional tillage and conservation agriculture) and three bread wheat cultivars (Triticum aestivum L.) (Arabia, Wafia, and Ebaa 99) on growth traits, yield performers, and associated weed flora.

The experiment was conducted in a Randomized Complete Block Design (RCBD) in factorial arrangements of three replications. The treatments included two tillage systems: conventional tillage, with no herbicide application, and conservation agriculture (zero tillage), with the application of the herbicide Limitless. Weed characteristics along with various agronomic and yield-related traits were examined.

The results showed that conservation agriculture significantly increased plant height and biological yield, as well as a significant decrease in density and dry biomass of weeds compared to conventional tillage. On the other hand, in number of tillers, number of spikes and 1000-grain weight: conventional tillage was superior. However, there was no significant difference in grain yield between both systems probably due to compensatory responses among yield components.

In terms of cultivar, Arabia shows a better response results in grain yield and its related components whereas Ebaa 95 had the highest number of tiller and spike hence lowest grain weight that led to a lower yield. In addition, a significant interaction was found between tillage systems and cultivars where Arabia shows a better response to conservation agriculture than the other cultivars.

ISSN 2072-3857

These results imply that the prime determinant of wheat productivity is not a single factor but rather the interplay of increasingly well-suited management practices and the adoption of cultivar with defined adaptations. In this sense, the use of conservation agriculture together with vigor management and adapted cultivars such as Arabia is suggested to obtain higher yields according to the context of agro-environmental conditions.

Key words:, Bread wheat, Zero Tillage, weeds control. *Limitless* herbicide.

Introduction

Bread wheat (Triticum aestivum L.) is an important cereal crop around the world and contributes about 20% of dietary calories and plant-derived protein intake for human beings [1]. It is a main component for food security, especially within West Asia and North Africa region and occupied the first position in initiative to support economy development[1] [2]. Bread wheat is one of the most widely cultivated major crops, grown over large areas of arable land worldwide and ranking as the top crop globally in terms of total agricultural production. Wheat cultivation covers around 30.46% of all the major crop cultivated areas, and its production is nearly 48.02% of the total crops production in Arab region [3]. More recent reports show that due to global temperature increase, drought frequency and climate variability, cereal productivity will be significantly disrupted [4];[5]. It is the heat and water stress during the flowering and grain-filling stages that cause considerable reductions in both grain number and final grain weight, making wheat especially sensitive to heat stress.

In Iraq bread wheat is a strategic crop supported by policies, and its production making closely follows changes in water resources and rainfall variability. Annual wheat consumption in the country has reportedly been at least four to five million tons according to some studies and reports. In several seasons, including 2024, Iraq managed to reach a transient level of wheat self-sufficiency, also approaching near self-sufficiency in 2019 and 2021 2024 under favorable production conditions[6]. Nevertheless, subsequent studies suggested that the continuing water crisis could lead to a decrease in domestic production and an increase in import reliance due to crop production, demonstrating how sensitive the production system is against fluctuations with regards to water resources. Moreover, the Food and Agriculture Organization (FAO) revealed that there was a decline in the production of cereals in Iraq over recent seasons, which correlates directly with areas impacted by droughts especially northern regions that rely partially on rainfed agriculture[7].

Nineveh Governorate, whose administrative center is the city of Mosul, and which is considered one of the most important wheat-producing regions in Iraq and a major component of the national grain basket. But the dependence of extensive cultivated areas on seasonal rainfall makes production extremely sensitive to variability, especially during years with either low precipitation or erratic rainfall distribution. Thus, supplemental irrigation becomes an important measure to minimize the risk of water stress at critical growth stages. This approach helps to stabilize yield and increases water-use efficiency in a rainfed/semi-arid climate and However, limited studies have investigated the combined effects of tillage systems, weed management, and cultivar performance under supplemental irrigation in semi-arid regions such as northern Iraq.

Conversely, the soil management system systems significantly improve crop production under semi-arid conditions. Common tillage, though successful in weed control and improving the seedbed and germination, is typically correlated with enhanced soil moisture loss along with degrading soil structure. On the other side, conservation agriculture practices including zero tillage and reduced tillage systems help in conserving soil moisture as well as better improves soil structure and rising soil organic matter content [8] which lead to improve. The build-up of weed seeds in the upper soil layers has highlighted that effective transition to reduced tillage systems could modify weed community dynamics as they establish [9] during these years. Also, keeping crop residues of the previous season on soil surface and low soil disturbance are practices that evidence a significant agronomic and environmental advantages compared to conventional systems. To this end, the current study seeks to support and widen the adoption of zero tillage systems as a way to strengthen sustainability in northern Iraq, which would ultimately alleviate negative effects associated with variability in climate and bolster agricultural resilience amid shifting social environmental contexts[10].

Weeds represent one of the more significant biotic factors impeding wheat production as competing species for water, nutrients and light on a given piece of land; if successful establishment and control do not occur significant yield loss can follow. The diversification of crop

ISSN 2072-3857

production systems led to reduced tillage, which resulted in an increased dependency on chemical herbicides as the primary method of weed control. The excessive use of herbicides, on the other hand, has caused some weed species to become resistant and gives rise to increasing environmental concerns(Nath et al., 2024). Recent works show that combining chemical control with better crop management methods will result in more effective weed control and consequently higher yield performance [12].

The genotype background of wheat cultivars strongly impacts their performance under different tillage systems and weed management practices. In this context, a balance between source sink relationships and resource-use efficiency stands as a key determinant of final yield performance. In previous studies, it has been reported that the interaction of cultivar with the tillage system can cause significant differences in productivity based on the management adopted[8]. Additionally, genetic variation and heritability of yield-related traits are crucial factors for improving selection efficiency and orienting breeding efforts towards niche cultivars suited better to various agro-ecological settings [13].

Therefore, the substantial of research addressing the individual effects of (tillage systems) - (the weed management)-and (genetic variability), studies that integrate these factors within a comprehensive interactive framework under supplemental irrigation conditions remain limited, particularly in semi-arid environments such as Nineveh Governorate. Therefore, the present study aimed to evaluate the response of three bread wheat (*Triticum aestivum* L.) cultivars to different cropping systems and weed management strategies using a chemical herbicide under supplemental irrigation conditions. This was achieved through the assessment of growth traits, yield components, final grain yield, and weed dynamics, with the objective of identifying the most efficient and sustainable system for enhancing wheat productivity in northern Iraq.

Material and method

The field experiment was conducted during the 2024–2025 growing season in Nineveh Governorate, at a farmer’s field located (west of Mosul), northern Iraq. Sowing date was carried out on 15 November 2024 under rain-fed conditions. Due to irregular rainfall and dry periods, supplemental irrigation was applied as needed, with a total of five full irrigation events to avoid severe moisture stress. The study included two main factors. The first factor was

ISSN 2072-3857

the **tillage system**, with two levels: conventional tillage (without herbicide application) and conservation agriculture (zero tillage) combined with the application of ***Limitless* herbicide**. The second factor consisted of three bread wheat (*Triticum aestivum* L.) cultivars: **Arabia**, **Wafia**, and **Ebaa**. Sowing was carried out in mid-December 2024 using a seeding rate of 100 kg ha^{-1}. Fertilization was applied according to the recommendations of the Ministry of Agriculture, with 100 kg ha^{-1} of diammonium phosphate (DAP) applied at sowing. The experiment was arranged as a factorial experiment within a Randomized Complete Block Design (RCBD) with three replications. The herbicide (*Limitless*) was applied during the last week of February. Due to insufficient rainfall during the growing season, supplemental irrigation was applied to ensure proper crop growth and development. The following agronomic and weed-related traits were recorded: plant height (cm), number of tillers (tillers m^{-2}), number of spikes (spikes m^{-2}), spike length (cm), number of grains per spike, 1000-grain weight (g), grain yield (kg donum^{-1}), biological yield (kg donum^{-1}), number of narrow-leaved weeds, dry weight of narrow-leaved weeds, number of broad-leaved weeds, and dry weight of broad-leaved weeds. The weeds were recorded in Table 1.

Table 1. The weeds narrow and broad leaves were Recorded

Narrow weeds	Broad weeds
Avena fatua	*Malva parviflora*
Hordeum murinum	*Trifolium repens*
Hordeum bulbosum	*Melilotus indicus*
Spergularia flaccida	*Cardaria draba*
Lolium rigidum	*Sinapis arvensis*
Phalis minor	*Raphanus raphanistrum*

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a factorial experiment arranged in a Randomized Complete Block Design (RCBD). Mean comparisons among treatments were performed using Duncan's Multiple Range Test (DMRT) at the 5% probability level [14].

Result and dissection

Effect of Tillage Systems on Wheat Traits and Associated Weed

The results presented in Table 2 indicate that the use of conservation agriculture (zero tillage) combined with *Limitless* herbicide significantly increased plant height to 54.78 cm, compared to 47.89 cm under conventional tillage, representing an increase of 6.89 cm. This improvement can be largely attributed to enhanced soil moisture

ISSN 2072-3857

conservation, reduced soil disturbance, and more uniform plant spacing under conservation systems. Similar results found by[15], which implies that such conditions aid root development. This outcome is in line with sustainability as a pathway to the principle of conservation agriculture as sustainable intensification approach[16]. However, traditional tillage dominated over (332.33 and 311.44) in the number of tillers with a difference of 20.78 and in (325 and 309.89) for the number of spikes with an increase of 15.78 in perforated pots filled with soil. Pots were also used to explore other growth conditions since root distribution is different from field condition. In bottom-land soils, conventional tillage promotes looseness and aeration of surface soil layer possibly promoting early vegetative growth which may explain that. But these higher rates do not automatically lead to increased final yield unless sufficient water and nutrient supplies are sustained throughout critical phases of growth especially stem elongation and grain filling.

Regarding the 1000-grain weight, conventional tillage recorded a higher value (40.11 g) compared to conservation agriculture (36.89 g), with a difference of +3.22 g. This variation may be attributed to differences in source–sink dynamics, where assimilate translocation and carbohydrate partitioning toward the grains may be enhanced under certain management conditions. Such trends are consistent with recent findings highlighting the sensitivity of grain weight to post-anthesis source–sink relationships[17]. Despite these differences in yield components, grain yield did not differ significantly between the two systems (345.44 vs. 341.89 kg donum^{-1}), indicating the presence of compensatory mechanisms among yield components. In contrast, biological yield was higher under conservation agriculture (1148.33 vs. 1105.33 kg donum^{-1}), which is in agreement with recent studies reporting that zero tillage systems improve crop performance as well as soil physical and chemical properties [18] .

With respect to weed parameters, a marked reduction was observed under conservation agriculture combined with *Limitless* herbicide. The density of narrow-leaved weeds decreased from 13.78 under conventional tillage to 7.89 under conservation agriculture, representing a reduction of 5.89. Similarly, their dry weight declined from 45.44 to 30.89, with a decrease of 14.55. For broad-leaved weeds, density was reduced from 8.56 to 4.75 (a decrease of 3.75), while dry weight decreased from 68.67 to 56.89, reflecting a reduction of 11.78. These reductions can be attributed to the combined effects of reduced soil

ISSN 2072-3857

disturbance and integrated weed management practices, in addition to the retention of crop residues from the previous season. Such residues act as a surface mulch, suppressing weed germination and modifying the microenvironment of the soil. Previous studies have reported that residue retention can significantly reduce weed seed emergence and enhance wheat productivity[9]; [19] .

Table (2) Effect of tillage system on traits of wheat and the weeds that accompany it.

Tillage system	Plant high (cm)	No of tillers	No of Spikes	Spike length (cm)	No of grain (spike)	Weight of 1000 grain (gm)
conventional	47.89 n	332.22 a	325.67 a	7.78 a	36.67 a	40.11 a
Conservation+ limitless herbicide	54.78 a	311.44 b	309.89 b	8.11 a	36.89 a	36.89 b
Tillage system	**Yield grain (kg / donum)**	**Biological yield kg / donum**	**Number of narrow leaves weeds**	**Dry weight of narrow leaves weeds**	**Number of wide leaves weeds**	**Dry weight of wide leaves weeds**
conventional	341.89 a	1105.33 b	13.78 a	45.44 a	8.56 a	68.67 a
Conservation+ limitless herbicide	345.44 a	1148.33 a	7.89 b	30.89 b	4.78 b	56.89 b

Effect of Wheat Cultivars on Agronomic Traits and Associated Weed Flora

The data in table 3 show that there were significant differences among the wheat cultivars. The treatment of Arabia was the best among all the cultivars (59.33 cm), followed by Wafia with a plant height of 51.00 cm and Ebaa which gave minimum plant height (43.67 cm). These differences reflect genetic variation in stem elongation and vegetative growth vigor among cultivars.

For yield components, the cultivar Arabia exhibited better performance than Ebaa as it had more grains per spike (38.17 grains spike^{-1} versus

ISSN 2072-3857

34.17) and higher 1000-grain weight (41.83 g versus 33.17 g). These trends indicate that, particularly for yield advantage, it is largely determined by the genetic characteristics of individual cultivars.

Ebaa recorded the lowest 1000-grain weight, however, it also produced the highest number of tillers (329.67 tillers m^{-2}) and spikes (325.83 spikes m^{-2}). This observation was in line with previous findings from [20] and support the idea that a large sink size, represented by the number of spikes/grains, may hinder grain filling due to limited assimilate supply during this stage. These findings also further align with recent studies highlighting the sensitivity of grain weight to post-anthesis source–sink dynamics and its genetic background dependent nature [17].

The same trend appeared in grain yield, with the highest value (356.83 kg $donum^{-1}$) for the cultivar Arabia, followed by 342.67 kg $donum^{-1}$ for Wafia and lowest yield (331.50 kg $donum^{-1}$) for Ebaa. The difference in favor of Arabia on the overall productivity of Ebaa was 25.33 kg $donum^{-1}$. Wafia (1229.67 kg $donum^{-1}$) and Arabia (1191.00 kg $donum^{-1}$) had more biological yield than Ebaa with 959.83 kg $donum^{-1}$. This variability might show variations in the ability of cultivars to accrete dry matter under equivalent management conditions.

For weed traits, differences in dry weight and density between cultivars were recorded. The dry weights of narrow-leaved weeds were 40.33 g in Wafia and 40.17 g in Arabia as opposed to Ebaa which recorded the lowest value (34.00 g). Such an effect was quite common in these studies, indicating that the effect of cultivar on weed community is usually less pronounced than management practices (tillage and weed control). Such results corroborate similar studies which reported that tillage types emerge as dominant drivers of weed dynamics and soil seed banks [9]. Likewise, our results concur with those reported by [21], who argued management practices had a larger influence than genetic traits and thus determine weed distribution and biomass.

ISSN 2072-3857

Table (3) Effect of type of var on traits of wheat and weeds that accompany it.

Var	Plant high (cm)	No of tillers	No of Spikes	Spike length (cm)	No of grain (spike)	Weight of 1000 grain (gm)
Arabia	59.33 a	320.33 ab	315.17 ab	8.17 a	38.17 a	41.83 a
Wafia	51.00 b	315.50 b	310.83 b	8.33 a	38.00 a	40.50 a
Ebaa	43.67 c	329.67 a	325.83 a	7.33 a	34.17 b	33.17 b
Var	Yield grain kg / donum	Biological yield kg / donum	Number of narrow leaves weeds	Dry weight of narrow leaves weeds	Number of wide leaves weeds	Dry weight of wide leaves weeds
Arabia	356.83 a	1191.00 a	10.50 a	40.17 a	7.50 a	58.17 b
Wafia	342.67 b	1229.67 a	11.0 a	40.33 a	6.17 b	66.67 a
Ebaa	331.50 c	959.83 b	11.0 a	34.0 b	6.33 b	63.50 a

Interaction Effect of Tillage Systems and Wheat Cultivars

The data in Table 4 indicate that genotype and management interaction (Genotype × Management) determines treatment responses. The highest grain yield (366.67 kg donum^{-1}) was produced by the interaction between cultivar Arabia under conservation agriculture (zero tillage) with Limitless herbicide as compared to 347.00 kg donum^{-1} for the same cultivar under conventional tillage resulting in an increase of 19.67 kg donum^{-1}. This suggests that a positive response to conservation agriculture systems in Arabia is more facilitated due to reduced weed competition and the ameliorated soil environment. This is also contrary to the studied behavior of Wafia under conservation agriculture, where Wafia yield (338.00 kg donum^{-1}) was lesser than conventional tillage (347.33 kg donum^{-1}). This indicates that the same cultivar may be superior or inferior under different management systems and emphasizes the need to apply these ranking(s) in a management context. In agreement with [8], these results demonstrated significant interactions between cultivars and tillage systems for grain yield and their associated traits, indicating differential responses of wheat cultivars to specific tillage practices under dry conditions.

The interaction effect also influenced yield components under conservation agriculture, Yield components were also influenced by the interaction effect. As an example, in case of spike size for the variety Wafia, zero tillage increased size to 9.33 cm as compared to 7.33 cm under conventional tillage with a difference of +2.00 cm. Likewise, the grain number per spike was increased from 33.67 grains spike^{-1} under conventional tillage to 42.33 grains spike^{-1} under conservation agriculture with an increase by 8.66 grains spike^{-1}. Nevertheless, these advancements didn't convert to greater grain yield because the 1000-grain weight significantly decreased from 44.67 g in conventional tillage to 36.33 g under conservation agriculture that represented a reduction of 8.34 g (Table 5). The overall pattern is in line with the sensitivity of grain weight to changes in assimilate supply during the grain-filling interval, notably with respect of photosynthates activity and asimilate translocation. Because the response can be influenced by the genetic background of the cultivar[17].

With respect to weed response under the interaction effect, a clear reduction in weed density was observed under conservation agriculture combined with *Limitless* herbicide. The number of broad-leaved weeds in the cultivar *Arabia* decreased from 9.00 to 6.00, while in *Wafia* it declined from 8.67 to 3.67 under conservation conditions. These findings are consistent with previous studies highlighting the role of conservation agriculture systems, crop residue retention, and integrated weed management practices in suppressing weed emergence through enhanced management strategies [11].

The combined results of the tables indicate that conservation agriculture (zero tillage), when coupled with effective weed management, enhanced vegetative growth and biological yield while significantly reducing weed density. This improvement can be attributed to the efficiency of herbicide application in suppressing both narrow- and broad-leaved weeds. These findings are consistent with those reported by[22].The grain yield remained governed by compensatory mechanisms among yield components, as well as by differences in cultivar response. The presence of a significant cultivar × tillage interaction further suggests that the most effective agronomic recommendation is not based on selecting the best cultivar or the best tillage system independently, but rather on adopting an integrated approach that combines appropriate tillage practices with efficient weed management strategies. This interpretation is in agreement with previous studies [16].

Interaction Effect of Tillage Systems and Wheat Cultivars

The results in Table 4 indicate a significant interaction between management practices (tillage system) and genotype (Genotype × Management); i.e., treatment responses were closely correlated. The greatest yield was obtained (366.67 kg $donum^{-1}$) with the combination of the cultivar Arabia, conservation agriculture (zero tillage), and Limitless herbicide on compared to 347.00 kg $donum^{-1}$ for this cultivar in conventionally tilled soil achieving a lead of 19.67 kg $donum^{-1}$. This suggests that Arabia maybe more responsive than others to conservation agriculture systems especially with the benefit of lower weed pressures and better soil environment. Wafia, however, did not respond positively under conservation agriculture, producing a lower yield (338.00 kg $donum^{-1}$) than that of the conventional tillage system (347.33 kg $donum^{-1}$). This indicates that cultivar performance is not absolute across crop management systems, highlighting the fact that deciding upon soyabean cultivars to implement in any given system must be done with consideration of what other complementary practices will be implemented. The outcomes were similar to what was observed in [8], where they confirmed that wheat cultivars have various responses to tillage management based on significant cultivar × tillage system interactions with grain yield and trait-related components under dry condition.

The effect of the interaction also applied to yield components under conservation agriculture. Spike length was 9.33 cm in the zero tillage and 7.33 cm in conventional tillage in the Wafia cultivar forming an increment of 2.00 cm (Table-1). Thus, there was an increase of 8.66 grains $spike^{-1}$ in the number of grains per spike while comparing conservation agriculture and conventional tillage (42.33 vs 33.67 grains $spike^{-1}$). The increase of the aboveground biomass was offset with declines in 1000-grain weight to 36.33 g under conservation agriculture vs. 44.67 g for conventional tillage (i.e., an 8.34-g decrease), which has been demonstrated to be highly sensitive to changes in assimilate supply during the grain-filling phase, especially

ISSN 2072-3857

regarding photosynthetic output and translocation of assimilates (Foulkes et al., 2002). Responses such as these may vary based on the cultivar's genetic background [17].

In response of weeds under the interaction effect, a significant reduction in broad-leaved weed density was noted under conservation agriculture with Limitless herbicide. The number of broad-leaved weeds decreased from 9.00 to 6.00 in Arabia and from 8.67 to 3.67 under cultivation conditions (Wafia). The weed emergence is suppressed and the total decrease in weed pressure has been analyzed through the improved effect of reduced soil disturbance, herbicide management, and crop residue application on conservation agriculture systems. These results correspond to previously reported studies reflecting how more effective management strategies in the conservation agriculture and integrated weed management practices influenced and moderated the effects on weed populations [11].

Overall findings conclude that conservation agriculture (zero tillage) contributed to enhanced vegetative development and biological yield along with considerable reduction of weed density when used in conjunction with effective weed management. The remeasurement is attributed to the effect of herbicide applications that suppresses narrow- and broad-leaved weeds. Such results are similar to the findings reported by [23]. Grain yield, however, was still determined by compensatory relationships between its components as well as differences in cultivar response. Moreover, the large cultivar × tillage interaction indicates that the most optimal agronomic recommendation is not to independently choose of the best cultivar or the best tillage system, but rather an integrated approach combining suitable tillage practices and appropriate weed management strategies. This result is similar to previous observations [16].

ISSN 2072-3857

Table (4) Effect of interaction between tillage systems and types of var on traits of wheat and the weeds that accompany it.

Tillage system	Var	Plant high (cm)	No of tillers	No of Spikes	Spike length (cm)	No of grain (spike)	Weight of 1000 grain (gm)
conventional	Arabia	58.33 a	319.67 a	313.67 b	8.67 ab	41.33 a	41.67 a
	Wafia	41.0 c	338.33 a	328.67 ab	7.33 b	33.67 b	44.67 a
	Ebaa	44.33 b	338.67 a	334.67 a	7.33 b	35.00 b	34.0 b
Conservation+ limitless herbicide	Arabia	60.33 a	321.0 a	316.67 ab	7.67 b	35.0 b	42.0 a
	Wafia	61.0 a	292.67 b	293.0 c	9.33 a	42.33 a	36.33 b
	Ebaa	43.0 bc	320.67 a	317.0 ab	7.33 b	33.33 b	32.33 b
Tillage system	Var	Yield grain kg / dounum	Biological yield kg / dounum	Number of narrow leaves weeds	Dry weight of narrow leaves weeds	Number of wide leaves weeds	Dry weight of wide leaves weeds
conventional	Arabia	347.0 b	1137.33 b	13.0 a	45.33 a	9.0 a	67.33 a
	Wafia	347.33 b	1207.67 a	14.0 a	46.67 a	8.67 a	68.0 a
	Ebaa	331.33 b	971.0 c	14.33 a	44.33 a	8.0 a	70. 67 a
Conservation+ limitless herbicide	Arabia	366.67 a	1244.67 a	8.0 b	35.0 b	6.0 b	49.0 c
	Wafia	338. 0 b	1251.67 a	8.0 b	34.0 b	3.67 c	65.33 a
	Ebaa	331.67 b	948.67 c	7.67 b	23.67 c	4.67 bc	56.33 b

Reference

[1] A. S. Al-Jaddir and S. H. Antar, “Effect of Some Chemical Herbicides and Seeding Rates on the Growth and Productivity of Bread

ISSN 2072-3857

Wheat (*Triticum aestivum* L.) and Its Associated Weeds in Different Environments," *IOP Conf. Ser. Earth Environ. Sci.*, 2024, doi:10.1088/1755-1315/1371/5/052093.

[2] S. H. Antar, I. A. Ismair, N. J. Mohamad, K. J. Ali, and M. A. Mohamad, "Effect of Tillage Systems on Growth and Yield of Bread Wheat (*Triticum aestivum* L.) and Associated Weeds," *Mesopotamia J. Agric.*, vol. 53, no. 3, pp. 146–154, 2025, doi:10.33899/mja.2025.161689.1629.

[3] A. Abdulrahman, A. Alrijabo, and S. Antar, "Study of Quality Traits of Durum Wheat (*Triticum durum* Desf.) Cultivars Grown Under Two Irrigation Patterns at Two Locations in Nineveh Province," *Euphrates J. Agric. Sci.*, vol. 15, no. 2, pp. 10–23, 2023.

[4] IPCC, *Climate Change 2021: The Physical Science Basis*. Geneva, Switzerland: IPCC, 2021.

[5] IPCC, *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Geneva, Switzerland: IPCC, 2022.

[6] Reuters, "Iraq Self-Sufficient in Wheat and Food for Six Months, Minister Says," Reuters, Apr. 17, 2024. https://www.reuters.com/world/middle-east/iraq-self-sufficient-wheat-food-six-months-minister-says-2024-04-17/

[7] FAO, *The State of the World's Land and Water Resources for Food and Agriculture 2025*. Rome: FAO, 2025. doi:10.4060/cd7488en.

[8] E. Roohi et al., "Genotype × Tillage Interaction and Performance of Winter Bread Wheat Genotypes in Temperate and Cold Dryland Conditions," *J. Integr. Agric.*, vol. 21, no. 11, pp. 3199–3215, 2022.

[9] J. Zhang and L. F. Wu, "Impact of Tillage and Crop Residue Management on Weed Community and Wheat Yield," *Agriculture*, vol. 11, no. 3, 2021.

[10] S. H. Antar and A. M. Almashhadany, *Effect of Tillage System and Seeding Rates on Growth and Wheat Yield (Triticum aestivum L.) and Associated Weeds*. Mosul, Iraq, 2020.

[11] C. P. Nath, R. G. Singh, V. K. Choudhary, D. Datta, R. Nandan, and S. S. Singh, "Challenges and Alternatives of Herbicide-Based Weed Management," *Agronomy 2024, Vol. 14*, vol. 14, no. 1, Jan. 2024, doi: 10.3390/ agronomy 14010126 [12] M. Asif et al., "Effects of Herbicides and Nano Urea Mixture on Weeds and Yield of Wheat (*Triticum aestivum*)," *Int. J. Environ. Clim. Change*, vol.13, no.12, pp.1211–1220, 2023.

[13] N. Chewaka, E. Estifanos, and N. Galeta, "Genetic Variability in Bread Wheat (*Triticum aestivum* L.) Genotypes under Irrigated

ISSN 2072-3857

Conditions," *Curr. Agric. Res. J.*, vol.12, no.2, pp.658–669, 2024.

[14] K. M. Al-Rawi and A. M. Khalaf Allah, *Design and Analysis of Agricultural Experiments*, 2nd ed. Mosul, Iraq: Dar Al-Kutub, 2000.

[15] D. Aljuburi and S. Antar, "Effect of Tillage System and Chemical Herbicides on Growth and Yield of Wheat (*Triticum aestivum* L.) and Associated Weeds in Dryland," 2021. [16] M. L. Jat et al., "Conservation Agriculture for Sustainable Intensification in South Asia," *Nat. Sustain.*, vol.3, no.4, pp.336–343, 2020.

[17] A. F. Arata et al., "Post-Flowering Source/Sink Manipulation Effects on Grain Weight and Quality in Bread Wheat," *Field Crops Res.*, vol.301, 109030, 2023.

[18] M. Sadiq et al., "Conservation Tillage to Improve Yield and Soil Properties in Spring Wheat Agroecosystems," *Front. Microbiol.*, vol.15, 2024.

[19] M. Jalli et al., "Effects of Crop Rotation on Spring Wheat Yield and Pest Occurrence in Different Tillage Systems," *Front. Sustain. Food Syst.*, vol.5, 2021.

[20] W. A. Minhas et al., "Weed Infestation and Productivity of Wheat under Conventional and Conservation Tillage," *Front. Plant Sci.*, vol.14, 2023.

[21] A. Q. Al-Hanoush, M. A. Hashem, and F. H. Kassar, "Effect of Tillage Systems and Foliar Boron Application on Growth and Yield of Soft Wheat (*Triticum aestivum* L.)," *IOP Conf. Ser. Earth Environ. Sci.*, 2023.

ISSN 2072-3857