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ARTICLE

Impact of Paclobutrazol Growth Regulator Spray on the Traits Yield of Two Wheat (*Triticum aestivum* L.) Cultivars

Zainab Ahmed Abdel Razzaq

Department of Field Crops, College of Agriculture, University of Basrah, Iraq; zainab.ahmed@uobasrah.edu.iq

ABSTRACT

The experiment was conducted at a Bhoth 22 station of the College of Agriculture - University of Basrah at the Garmat Ali location during the winter season 2022-2023 to investigate the effect of paclobutrazol growth regulator on the yield of two wheat crop varieties. The study compared two wheat crop varieties (Ibaa 99 and Bhoth 22) after spraying four different concentrations of paclobutrazol (0, 50, 100, and 150 mg/L^{-1}). The experiment was carried out utilizing the factor experiment approach with R.C.B.D and three replications. The quotient properties have been examined. The results demonstrated superiority of the variety Bhoth 22. In the description of the number of spikes and the weight of a thousand grains, the biological yield amounted to 574.93 spike/m-2, 45.86 g, and 12.739 ton/h^{-1}, whereas the variety Ibaa 99 was superior in the description of the number of grains in spike. The experiment also revealed significant differences in the spraying coefficients of the growth regulator paclobutrazol, as the concentration exceeded 100 mg/L^{-1} and produced the highest average characteristic of the number of spikes and the weight of a thousand grains, as well as the yield of grains and bio, which were 604.31 spike/m-2, 47.25 g, 5.07 ton/h^{-1}, and 13.04 ton/h^{-1}, respectively. There was a major introduction of cultivars and spraying variables.

Keywords: *Wheat Varieties; Spray Concentrations; Regulator Paclobutrazol*

Corresponding Author: Zainab Ahmed Abdel Razzaq
E-mail: **zainab.ahmed@uobasrah.edu.iq**
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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important among all cereal crops used as staple food globally. It ranks among the top cultivated crops in most countries and serves as a primary food source for one-third of the world's population, due to its critical role in achieving food security. Wheat provides more than 25% of the calories and proteins in the human diet, in addition to containing small amounts of fats, minerals, and vitamins (Shewry, 2009). Among the key factors influencing wheat productivity and quality is the cultivar, as its genetic traits govern vegetative growth characteristics, plant height, tiller number, number of spikes, and the number of grains per spike all of which collectively determine final yield (Sharma *et al*., 2022). Cultivars differ in their ability to absorb nutrients and in their efficiency in utilizing water and light. They also vary in their response to regulatory factors such as growth regulators or environmental stresses (Ahmad *et al*., 2018).

Understanding this genetic variation is a crucial step toward developing precise crop management systems that ensure maximum productivity under specific environmental conditions. Therefore, evaluating cultivar performance under different treatments is a modern approach in agricultural improvement, reflecting the extent of genotype-by-environment or genotype-by-treatment interactions (Khan *et al*., 2019).

Cultivars also vary genetically in terms of plant height, which depends on internode length, especially the upper internode that constitutes nearly half of the plant height. This trait is important in distinguishing cultivars from one another (Mohammed, 2000). Among the agricultural methods affecting the growth and productivity of wheat, plant growth regulators (PGRs) have emerged as effective tools in managing crop growth and physiological development (Taiz *et al*., 2018).

These are chemical or natural compounds that are used in very low concentrations to regulate biological processes within the plant (Taiz *et al*., 2018). They affect the synthesis or activity of plant hormones such as gibberellins, auxins and cytokinins, which leads to improved photosynthetic efficiency and enhanced yield and grain quality, thereby exerting their influence on vegetative growth and yield (Rademacher, 2016). Paclobutrazol (PBZ), a triazole regulator, inhibits the enzyme kaurene oxidase which is involved in the biosynthesis of gibberellins (Davis *et al*., 1991; Fletcher *et al*., 1999). This inhibition reduces cell elongation and internode extension, delaying plant growth, with positive effects on the number of spikes and yield components. PBZ also improves stem thickness, membrane stability and chlorophyll content of leaves thereby increasing photosynthetic efficiency (Zhang *et al*., 2018; Xia *et al*., 2018; Ali *et al*., 2020).

Additionally, PBZ application has been reported to increase the accumulation of osmoprotective compounds such as proline, which assists the plant to tolerate better abiotic stresses such as drought and salinity (Mahmoud *et al*., 2019). It also increases cytokinin synthesis which reduces stem elongation, decreases lodging, increases grain weight per spike and improves grain quality by increasing carbohydrate content which ultimately increases yield (Desta and Amare, 2021). The cultivars have different genetic responses to the growth regulators. Each cultivar has a specific ability to absorb the active compound and to express some morphological and physiological responses (Ahmad *et al*., 2018). Therefore, studying the effect of Paclobutrazol foliar application on two different wheat cultivars holds scientific and practical significance in identifying the most responsive genotypes to growth regulators. This, in turn, allows for yield improvement and better yield components with minimal agricultural inputs. Based on the foregoing, this study seeks to assess the influence of foliar application of the growth regulator Paclobutrazol on several physiological and morphological parameters, as well as yield and its components, in two wheat cultivars. The goal is to determine the role of genetic and chemical factors in increasing grain productivity.

MATERIALS AND METHODS

The research was carried out at one of the Bhoth 22 at the University of Basra. College of Agriculture in 2022-2023, which aims to study the effect of spraying the paclobutrazol growth regulator with four concentration's (0 mg/L^{-1} as control, and spraying at concentration of 50, 100, and 150 mg/L^{-1}) in the characteristics of the yield of the two varieties of bread wheat Ibaa 99 and Bhoth 22 and the interaction between them. Crop and soil service operations carried out as needed, nitrogen fertilizer was added rates 120 kg of nitrogen per hectare in the form of urea fertilizer (N46%) and at a rate of 120 kg N/ha^{-1} in the form of urea (46% N) and is added in two installments (Alrubaiee *et al*., 2021). The first batch is formed after the seedlings appear, while the second batch occurs during the elongation stage. As for the phosphate fertilizer (20% P) was added at a rate of 120 P_2O_5 per hectare at once before planting (Al-Halfi, 2015; Alrubaiee *et al*., 2019a; Alrubaiee *et al*., 2019b). The growth regulator paclobutrazol was sprayed according to the required concentration's until completely wet twice, the first spray at the stage of five unwrapped leaves and the second spray at the stage of the beginning of the tillers (Kilic, 2010; Mohsen *et al*., 2022). The experiment applied according to the method of factor using the experiments design of the complete block (R. C. B. D) with three repeaters, the following characteristics were studied:

- **The number of spike M^{-2}** was calculated from an area of 1 m^2 per unit of experimental.
- **Number of grains in a spike** (grains/$spike^{-1}$) if the number of grains is calculated in spike to 10 spikes at harvest from each experimental unit, as the spikes were overdone manually and according to the grain's number manually.
- **1000 grains weight (g)** was randomly selected from the yield of each experimental unit and then each sample was

weighed using a sensitive balance.

- **Grain yield (ton ha^{-1})** conducted the process of manual threshing of plants harvested from an area of 1 m^2 of each experimental unit and after isolating straw from the grain and cleaning it well, the grain was weighed plus the grain used in calculating the weight of 1000 grains for the same treatment and then the weight was transferred from g m^2 to ton/h^{-1} on the basis of moisture 13% (A.O.A.C, 1975).
- **The biology yield (ton ha^{-1})** was calculated for all existing plants from an area of 1 m^2 and per experimental unit, where the whole plants were weighed (grain + straw) and then the weight was converted from gm/ m^{-2} to ton/ha^{-1}.

RESULTS AND DISCUSSION

Spikes Number (spike/m^{-2})

The results presented in Table (1) indicate significant differences among cultivars, Paclobutrazol spray treatments, and the interaction between the two factors in terms of number of spikes per square meter. The cultivar (Bhoth 22) outperformed the others, recording the highest mean of (574.93spikes/m^{-2}), while the Ibaa99 showed the lowest mean of (545.60 spike/m^{-2}). This superiority is due to genetic differences in cultivars' tiller production and fruitful shoot formation, which is a trait directly related to total grain yield. The number of spikes is considered one of the key yield components, influenced by a combination of genetic, environmental, and physiological factors (Sharma *et al*., 2022).

Cultivars with a high tillering potential tend to form a greater number of vegetative shoots that develop into productive spikes. This ability is associated with efficient nutrient uptake, elevated enzymatic activity in the basal nodes, and effective translocation of carbohydrates from leaves to lateral buds (Fischer, 2011). Moreover, the increase in leaf area during the early stages of growth enhances the photosynthetic activity and thus increases the production of assimilates required for tiller formation and consequently increases the number of spikes (Khakwani *et al*. 2012). Also, Table 1 showed that the highest mean (604.31 spike/m^{-2}) was obtained from the 100 mg/L^{-1} Paclobutrazol foliar spray treatment and it was statistically similar to the 150 mg/L^{-1} treatment (581.46 spikes/m $^{-2}$). The control treatment (no spray) recorded the lowest mean of (502 spikes/m^{-2}). This is due to the role of Paclobutrazol in improving photosynthesis and accumulation of dry matter that leads to increased formation of tillers and thus an increase in the number of spikes that are consistent with the findings (Haneen, 2023; Obaid *et al*., 2025). There was also a significant interaction between cultivar and spray treatment. The Bhoth 22 + 100 mg/L^{-1} spray combination produced the most spikes (614.51 spike/m^{-2}), while the Ibaa99 cultivar without spray had the fewest (482.1 spike/m^{-2}).

Table (1) Effect of cultivars, Paclobutrazol, and their interaction on number of spike (spike/m^{-2})

Variety Type	Paclobutrazol Concentration (mg/L^{-1})				Average of Variety
	0	50	100	150	
Ibaa 99	482.1	536.3	594.12	569.9	545.60
Bhoth 22	522.01	570.2	614.51	593.03	574.93
Average of concentration	502.05	553.25	604.31	581.46	
LSD$_{(0.05)}$	Variety Type = 37.35		Paclobutrazol Concentration= 37.35		Interaction= 74.70

Grains Number of in spike (grains/spike^{-1})

The Ibaa99 cultivar was significantly superior with the highest mean number of grains per spike (44.18 grains/spike^{-1}), whereas Bhoth 22 had the lowest mean number of grains per spike (41.57 grains/spike^{-1}) (Table 2).

The advantage is due to genetic differences between cultivars in the efficiency of fertilization, number of flowers formed and the percentage of these that develop into mature grains. The cultivars differ in their ability to form flowers in the spike and in the fertility rate. The fertility rate depends on the photosynthesis activity of the plant in the stages of flowering and fertilization (Curtis and Halford, 2014). The superiority of a cultivar for this trait is often related to its high efficiency in assimilate partitioning to the spike during grain-filling, as well as improved photosynthetic performance during reproductive phases (Fischer, 2011). Foliar application of Paclobutrazol at 150 mg/L^{-1} gave the highest grain number per spike (46.48 grains/spike^{-1}) as shown in table 2 while the control (no spray) recorded the lowest (39.44 grains/spike^{-1}). The improvement was due to the role of Paclobutrazol in improving photosynthesis and increasing the accumulation of the sugar in the leaves thus providing sufficient energy and carbon compounds during flowering and fertilization. This leads to improved grain set and reduced competition between developing grains (Khan *et al*., 2019). Moreover, the inhibition of stem elongation reduces competition between plant organs, leads to the redistribution of the nutrient flow toward reproductive growth, and increases the rate of fertilization and the number of grains (Ali *et al*., 2020; Obaid *et al*., 2025).

The interaction of variables was significant. The combination of Ibaa99 cultivar with 150 mg/L Paclobutrazol spray recorded the maximum grain number per spike (47.14 grains/spike^{-1}), whereas the Bhoth 22 cultivar under control treatment (no spray) recorded the lowest (36.66 grains/spike^{-1}). This suggests a beneficial connection between the cultivar's genetic endowment and its response to Paclobutrazol. Some cultivars have higher absorption capacity and physiological sensitivity to Paclobutrazol, resulting in improved grain formation and spike fertility (Sharma *et al*., 2022).

Table (2) Effect of cultivars, Paclobutrazol, and their interaction on the number of grains per spike (grains/spike^{-1})

Variety Type	Paclobutrazol Concentration (mg/L^{-1})				Average of Variety
	0	50	100	150	
Ibaa 99	43.22	44.02	45.10	47.14	44.18
Bhoth 22	36.66	40.28	43.52	45.82	41.57
Average of concentration	39.44	42.15	44.31	46.48	
LSD$_{(0.05)}$	Variety Type = 1.42		Paclobutrazol Concentration= 1.42		Interaction= 2.84

1000 grain weights

The results in Table 3 show that the Bhoth 22 cultivar recorded the highest 1000-grain weight, reaching 45.86 g, compared to the control treatment, which recorded the lowest mean of 42.05 g. This difference may be attributed to the genetic variation between the two cultivars in terms of grain size, pericarp thickness, and grain-filling activity. Some cultivars show higher ability to store carbohydrates in grain during maturation period, which is reflected in the increase of individual grain weight (Khakwani *et al*., 2012; Carrasco *et al*., 2021). Furthermore, the elevated activity of enzymes involved in the conversion of sugars to starch during the grain-filling period contributes to weight gain (Kumar *et al*., 2021). Table 3 also shows that the highest mean of this trait was obtained by foliar application of Paclobutrazol at a concentration of 100 mg/L^{-1} which was 47.25 g and the lowest mean was obtained in the control treatment which was 40.22 g. The improvement is probably due to the role of Paclobutrazol in improving the plant growth, activating the antioxidant enzymes in the leaves, delaying senescence, prolonging the grain-filling period and leading to heavier grains. It is also possible that increased accumulation of photosynthates and their directed transport to the grains result in reduced losses from excessive vegetative growth. Paclobutrazol enhances the activity of important enzymes involved in assimilate transport to the grains such as sucrose synthase and ADP-glucose pyrophosphorylase (Ahmad *et al*., 2018) leading to better grain-filling efficiency and increased grain weight.

For interaction effect it was observed in table 3 that the maximum mean of 49.12 g was recorded in Bhoth 22 with 100 mg/L^{-1} Paclobutrazol spray and minimum mean of 38.32 g was noted in other treatment combination. Thus, the response to Paclobutrazol is dependent on the genetic capacity of the grains to accumulate starch.

Table (3) Effect of paclobutrazol, varieties and their interaction on weight of 1000 grain (g)

Variety Type	Paclobutrazol Concentration (mg/L^{-1})				Average of Variety
	0	50	100	150	
Ibaa 99	38.32	41.26	45.38	43.27	42.05
Bhoth 22	42.12	45.08	49.12	47.13	45.86
Average of concentration	40.22	43.17	47.25	45.20	
$LSD_{(0.05)}$	Variety Type = 1.61		Paclobutrazol Concentration= 1.61		Interaction= 3.22

Grain yield (ton/h^{-1})

The results in Table 4 demonstrate no significant difference in grain yield between the two cultivars. However, the table also shows that the foliar application of Paclobutrazol at 100 mg/L^{-1} gave the highest grain yield of 5.07 ton/ha^{-1} while the control treatment (no spray) recorded the lowest yield of 3.96 ton/ha^{-1} . The improvement was attributed to the superiority of the 100 mg/L^{-1} treatment in the main yield components, which were the number of grains per spike and 1000-grain weight (Tables 2 and 3). These two features are regarded as the main components of the final yield. In addition, genetic variation in photosynthetic efficiency and nutrient uptake rates leads to increased dry matter accumulation and its efficient translocation into the grains, which further positively influences grain yield (Fischer, 2011; Curtis and Halford, 2014). Significant interaction between factors was observed where the combination of Bhoth 22 with 100 mg/L^{-1} Paclobutrazol recorded highest grain yield (5.39 ton/ha^{-1}). While the lowest yield (3.26 ton/ha^{-1}) was observed in Ibaa99 cultivar under control treatment. This confirms that the positive response to the growth regulator is conditioned by the genetic characteristics of the cultivar, and especially by its efficiency in absorbing and internally transporting assimilates. The observed effect is a result of a synergistic interaction between genetic and chemical factors, resulting in a more favorable physiological balance for growth.

Table (4) Effect of paclobutrazol, varieties and their interaction on grain yield (ton/h^{-1})

Variety Type	Paclobutrazol Concentration (mg/L^{-1})				Average of Variety
	0	50	100	150	
Ibaa 99	3.26	4.38	4.75	4.64	4.25
Bhoth 22	4.66	4.90	5.39	5.10	5.01
Average of concentration	3.96	4.64	5.07	4.87	
$LSD_{(0.05)}$	Variety Type = N.S		Paclobutrazol Concentration= 0.91		Interaction= 1.82

Biological yield (ton/h^{-1})

The results shown in Table 5 indicate a significant superiority of the Bhoth 22 cultivar, which recorded the highest mean biological yield of 12.739 ton/ha^{-1}, while the Ibaa99 cultivar had the lowest mean of 12.038 ton/ha^{-1}. This difference is attributed to the superiority of Bhoth 22 in yield components such as number of spikes and 1000-grain weight, as shown in Tables 1 and 3. Table 5 indicates that Paclobutrazol foliar application at 100 mg/L^{-1} yielded the highest biological yield of 13.043 ton/ha^{-1}, whereas the control treatment yielded the lowest at 11.132 ton/ha^{-1}. Paclobutrazol enhanced grain number per spike, 1000-grain weight, and grain yield (Tables 1, 3, and 4), which increased plant productivity. The interaction between cultivar and treatment was significant, with Ibaa99 with 100 mg/L^{-1} Paclobutrazol yielding the greatest (13.520 ton/ha^{-1}) and the control cultivar yielding the lowest (10.802 ton/ha^{-1}). This suggests a beneficial genetic-growth regulator relationship in the cultivar.

A cultivar with high photosynthetic activity and greater capacity for dry matter production responds better to Paclobutrazol by increasing tillering, spike number, and productive leaf area (Al-Hassan, 2007; Sharma *et al*., 2022). The increase in biological yield in this case reflects that Paclobutrazol's impact was not limited to reducing plant height, but also promoted balanced structural growth, increasing the biomass of stems, leaves, and spikes collectively. This interaction demonstrates that the effectiveness of Paclobutrazol is highly dependent on the genetic characteristics of the cultivar and its ability to efficiently utilize available resources.

Table (5) Effect of paclobutrazol, varieties and their interaction on the characteristic of biology yield (ton/h^{-1})

Variety Type	Paclobutrazol Concentration (mg/L^{-1})				Average of Variety
	0	50	100	150	
Ibaa 99	10.802	12.214	12.566	12.572	12.038
Bhoth 22	11.462	12.850	13.520	13.172	12.739
Average of concentration	11.132	12.532	13.043	12.872	
LSD$_{(0.05)}$	Variety Type = 0.32		Paclobutrazol Concentration= 0.32		Interaction= 0.63

CONCLUSIONS

The study results showed that the cultivars differed significantly in yield traits and their components. The Bhoth 22 cultivar outperformed in most of the studied traits; however, no significant difference was observed between of 2-cultivars in grain yield, verifying the significance of genetic variation in the determination of the efficiency of wheat's response to environmental factors. In comparison to the control treatment (no spray), the yield-related characteristics were enhanced by the foliar application of the plant growth regulator Paclobutrazol at concentrations of 100 and 150 mg/L^{-1}. It increased the number of spikes per square meter, number of grains per spike, 1000-grain weight, as well as both grain yield and biological yield. It implies that the application had helped in obtaining an optimum balance between curbing excess vegetative growth and encouraging reproductive and structural growth of the plant. Most of the studied traits also showed significant interaction between cultivar and growth regulator. The cultivar with higher genetic efficiency in absorbing and transporting the active compound of Paclobutrazol performed better at (100 mg/L^{-1}) indicating the presence of genetic variation in physiological responses to plant growth regulators among cultivars. The results confirmed that the targeted application of growth regulators, especially Paclobutrazol, could be an effective tool for increasing the productivity of wheat in semi-arid environments, as long as the application is at the proper concentration and growth stage for each cultivar.

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