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RESPONSE OF WHEAT CROP TO FOLIAR APPLICATION OF GROWTH REGULATOR PACLOBUTRAZOL

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SUMMARY

The presented study sought to determine the effects of the growth regulator paclobutrazol (0, 50, 100, and 150 mg L^{-1}) on two wheat (*Triticum aestivum* L.) cultivars Ibaa-99 and Bhoth-22, carried out at the University of Basrah, Iraq. The experiment layout had a randomized complete block design with two factors and three replications. The results showed the cultivar Ibaa-99 was superior in plant height and days from 50% flowering to full maturity, with average values of 88.08 cm and 40.88 day, respectively. The cultivar Bhoth-22 was superior in chlorophyll content, number of tillers, days of planting up to 50% flowering, and flag leaf area. Their averages were 460 mg m^{-2}, 576.33 tiller m^{-2}, 103.85 days, and 39.76 cm^2, respectively. Foliar coefficients of the growth regulator paclobutrazol showed significant differences. The highest concentration of Paclobutrazol (150 mg L^{-1}) revealed the topmost average number of days from 50% flowering to full maturity (45.65 day), while the Paclobutrazol at 100 mg L^{-1} had the maximum average chlorophyll content, flag leaf area, and tillers per plant in wheat.

Keywords: Wheat (*T. aestivum* L.), cultivars, paclobutrazol, earliness and yield traits, chlorophyll content

Key findings: The wheat (*T. aestivum* L.) cultivar Bhoth-22 proved leading in chlorophyll content, tillers per plant, days to 50% flowering, and flag leaf area. For the traits plant height and days from 50% flowering to full maturity, the cultivar Ibaa-99 was superior to the cultivar Bhoth-22. Paclobutrazol (100 mg L^{-1}) foliar application was superior in most characteristics under study. Interaction of cultivar Bhoth-22 with Paclobutrazol (100 mg L^{-1}) gave the highest averages for leaf chlorophyll content, flag leaf area, and tillers per square meter.

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INTRODUCTION

Wheat (Triticum aestivum L.) is the leading source of human food in various developing countries, providing approximately 50% of the daily calories to these countries' populations having valuable contents of starch, fiber, carbohydrates, minerals, vitamins, and antioxidants (Elsahookie *et al*., 2021). Wheat also plays a strategic role in global food security, as it ranks first in production, consumption, and cultivated area worldwide. The global production reached 3.51 t ha^{-1} during the crop season 2022 (Peterson, 2022), while in Iraq, the production rate reached 1.79 t ha^{-1} (CSO, 2021).

The low production rate requires paying attention to this crop and working on its different aspects to increase its productivity. The production capacity of crop genotypes depends upon the processes and inputs required in the field as per accurate scientific recommendations, considering the appropriate environmental conditions for crop growth and development. In recent decades, attention has focused on developing new wheat cultivars adapted to prevailing environmental conditions with high productivity based on the genetic composition. With approved scientific methods in agriculture, and by adding recommended fertilizers and field practices, achieving the optimum crop yield can succeed (Dubcovsky *et al*., 2012; Rollin, 2014).

Paclobutrazol is a chemical growth regulator belonging to the family Triazole, which has the properties of regulating growth and a highly active synthetic chemical affecting almost all crop plants, whether sprayed or immersed in soil. The crop plants' response to paclobutrazol with foliar application proved better than adding to the soil and amending the important properties of plant hormones, including gibberellin, abscisic acid, and cytokinin. It also inhibits the synthesis of gibberellins and enhances the synthesis of cytokinins. Paclobutrazol also causes a decrease in stem elongation and reduces the decomposition of crop plants, improving the grain weight and its quality on increasing carbohydrates, and, thus, enhancing grain yield in crop plants (Strydhorst *et al*., 2018).

Paclobutrazol works to cause adverse effects to growth promoters by inhibiting cell division and elongation, which leads to shortening phalanges, and, thus, a decrease in plant height. It also has the most critical effects as monitored in the laboratory to enhance the thickness of the cuticle and columnar layers, spongy, and phloem elements, and boost the chlorophyll content and the rate of photosynthesis (Tesfahun, 2018). Based on the foregoing findings and its importance, the presented study sought to verify the effects of the growth regulator paclobutrazol's foliar application on the growth and yield-related traits of the two wheat cultivars.

MATERIALS AND METHODS

A field experiment began at the Agricultural Research and Experiments Station of the University of Basra, Iraq, during the crop season 2022–2023 in clay-blended soils. It aimed to study the bread wheat's response to foliar application of the growth regulator paclobutrazol on growth and yield-related traits. The experiment, laid out in a randomized complete block design, had two factors and three replications. The experiment included 18 experimental units (3×3×2), and the area of the experimental unit was 4 m^{-2} with dimensions of 2 m × 2 m, containing 10 rows, with spacing of 20 cm.

Planting of two wheat cultivars (Ibaa-99 and Bhoth-22) occurred on November 15, 2022. The experimental soil fertilization used nitrogen fertilizer at the rate of 120 kg N ha^{-1} (Al-Abdullah, 2015), in the form of urea (46% N). urea The addition was in two batches. The first, after the emergence of seedlings, and the second, at the tillering stage. Phosphate fertilizer superphosphate triple (20%) application transpired once at the rate of 120 P_2O_5 ha^{-1}, before planting (Al-Hilfi, 2015). All other soil service operations and practices proceeded according to wheat crop recommendations.

Traits studied

The field and laboratory data included recording the various traits. The plant height (cm) measurement began from the base of the plant to the spike. The measuring of number of tillers (tiller m^{-2}) happened on 10 plants and averaged. The days from planting to 50% of flowering and maturity also reached calculation. The leaf chlorophyll content (mg g^{-1}) estimation occurred in the laboratory (Palta, 1990). The flag leaf area (cm^2) computation for 10 leaves received averaging according to the equation described by Thomas (1975), as follows:

$$\text{Flag leaf area} = \text{Leaf Length} \times \text{Max Width} \times 0.95$$

RESULTS AND DISCUSSION

Plant height

The results indicated the cultivar Ibaa-99 excelled in the plant height and recorded the highest average (88.08 cm), while the cultivar Bhoth-22 gave the lowest average for the plant height trait at 84.16 cm (Table 1). The wheat cultivars' difference for the said trait might be due to their different genetic make-up. These results were also consistent with past findings reporting significant differences among the genotypes for this indicator, and it may be because of the varietal characteristic (Alrubaiee *et al*., 2018).

The growth regulator paclobutrazol also revealed a significant effect on the characteristic of plant height in the wheat crop. However, the control treatment outperformed significantly in the plant height, reaching the highest average (93.12 cm) compared with the foliar application of paclobutrazol spray treatment with the concentration of 150 mg L^{-1}. It recorded with the lowest average plant height (80.00 cm). The lowered plant height could be due to the increased concentration of paclobutrazol in the growing apex, which leads to the auxin antagonists effect in decreasing the cell division in that area.

The interactions between the wheat cultivars and paclobutrazol concentrations exhibited notable effect on the plant height. The interaction between the cultivar Ibaa-99 and the control treatment enunciated the highest average for the plant height (95.06 cm). However, it did not differ significantly with the interaction of cultivar Bhoth-22 with the control treatment (93.12 cm). The interaction between the cultivar Bhoth-22 and foliar application of paclobutrazol (150 mg L^{-1}) recorded the shortest plant height (78.30 cm). These findings were analogous to past findings for plant height reduction due to paclobutrazol-induced alleviation in wheat (Dwivedi *et al*., 2017) and Indian mustard (Banoo *et al*., 2022).

Tillers per square meter

The findings indicated a significant effect of paclobutrazol concentrations on the number of tillers per square meter (Table 2). The paclobutrazol (100 mg L^{-1}) foliar application recorded with the most tillers (612.25 tillers m^{-2}), compared with the control treatment with the lowest average (518 tillers m^{-2}). This could refer to the positive action of paclobutrazol, causing inhibition of shoot elongation and stimulating the growth of lateral shoots with increased number of tillers in crop plants (Strydhorst *et al*., 2018). The combination between the cultivar Bhoth-22 with paclobutrazol (100 mg L^{-1}) spraying gave the maximum average tillers (616.3 tiller m^{-2}). The interaction between the wheat cultivar Ibaa-99 with the control treatment provided the lowest average number of tillers (510.4 tillers m^{-2}).

Days to 50% flowering

Cultivars showed a substantial influence on the number of days to 50% flowering (Table 3). The wheat cultivar Bhoth-22 prevailed with the lowest average number of days to 50% flowering (103.85 days), while the cultivar Ibaa-99 recorded with the highest average number of days (107.4 days). The difference between the cultivars for the said trait may be due to the varied genetic structures and their potential in wheat (Akhtar *et al*., 2012).

Table 1. Effect of wheat cultivars and paclobutrazol and their interactions on the plant height.

Cultivars	Paclobutrazol concentration (mg L^{-1})				Means (cm)
	0	50	100	150	
Ibaa-99	95.06	90.35	84.53	82.38	88.08
Bhoth-22	91.18	86.39	80.59	78.30	84.16
Means (cm)	93.12	88.37	82.56	80.34	

$LSD_{0.05}$ Cultivars: 3.30, Paclobutrazol concentration: 3.30, Interaction: 6.60

Table 2. Effect of wheat cultivars and paclobutrazol and their interactions on the tillers per square meter.

Cultivars	Paclobutrazol concentration (mg L^{-1})				Means (tillers m^{-2})
	0	50	100	150	
Ibaa-99	510.40	561.50	608.20	581.20	565.33
Bhoth-22	526.50	575.10	616.30	597.40	576.33
Means (tillers m^{-2})	518.45	568.30	612.25	589.30	

$LSD_{0.05}$ Cultivars: N.S., Paclobutrazol concentration: 40.30, Interaction: 80.60

Table 3. Effect of wheat cultivars and paclobutrazol and their interactions on the days to 50% flowering.

Cultivars	Paclobutrazol concentration (mg L^{-1})				Means (tillers m^{-2})
	0	50	100	150	
Ibaa-99	109.20	109.30	106.60	104.50	107 .40
Bhoth-22	107.40	105.70	102.20	100.10	103.85
Means (tillers m^{-2})	108.30	107.50	104.40	102.30	

$LSD_{0.05}$ Cultivars: 1.60, Paclobutrazol concentration: 1.60, Interaction: 3.20

Likewise, significant differences surfaced among the concentrations of paclobutrazol spraying. The comparison treatment was prominent with the maximum number of days to 50% flowering (108.3 days), while the paclobutrazol spraying treatment (150 mg L^{-1}) recorded with the minimum average (102.3 days). The early flowering might be due to the role of paclobutrazol in increasing the number of tillers and chlorophyll (Tables 2). This means, the emergence of additional tillers helped the plants to enhance the process of photosynthesis and absorption of nutrients in the shortest period (Rani *et al*., 2012).

The interaction between cultivars and paclobutrazol concentrations revealed a remarkable effect on the number of days to 50% flowering. The interaction between the cultivar Ibaa-99 and the control treatment recorded the higher number of days to 50% flowering (109.20 days). It did not differ significantly from the interaction between the cultivar Ibaa-99 and paclobutrazol (50 mg L^{-1}), compared with the lowest number of days recorded with the interaction between the cultivar Bhoth-22 and paclobutrazol concentration (150 mg L^{-1}). It amounted to 100.10 days. An explanation may be the emergence of additional tillers helped the plants to enhance the process of photosynthesis and absorption of nutrients in the shortest time (Rani *et al*., 2012).

Flag leaf area

Wheat cultivars displayed significant differences for flag leaf area (Table 4). The cultivar Bhoth-22 recorded the supreme average of flag leaf area (39.76 cm^{-2}), while the cultivar Ibaa-99 had the lowest average for the said trait (34.73 cm^{-2}). The differences in cultivars for flag leaf area could be due to their different genetic make-up. These results agree with past findings for flag leaf area in wheat and oat genotypes (Alrubaiee *et al*., 2018; Mohsen *et al*., 2022). As noted from Table 4, a noteworthy effect existed in spraying paclobutrazol with different concentrations. The paclobutrazol (100 mg L^{-1}) recorded with the highest average flag leaf area (42·16 cm^{-2}), while the control treatment provided with the lowest mean (16.30 cm^{-2}).

Similarly, a varying effect of the interaction between the wheat cultivars and the growth regulator paclobutrazol occurred for the flag leaf area (Table 4). The cultivar Bhoth-22 treated with paclobutrazol (100 mg L^{-1}) showed the maximum flag leaf area (45.23 cm^{-2}), while the cultivar Ibaa-99 with the control treatment showed the minimum leaf area (28.20 cm^{-2}). The reason for an increase in flag leaf area may refer to the positive role of the growth regulator paclobutrazol in enhancing the leaf surface area due to increased size of the chloroplasts in the leaves (Bayat and Sephri, 2012).

Leaf chlorophyll content

The foliar application of the growth regulator paclobutrazol with different concentrations revealed significant differences in leaf chlorophyll content (Table 5). The paclobutrazol treatment with concentration of 100 mg L^{-1} demonstrated the highest average leaf chlorophyll content (486.35 mg m^{-2}), with the comparison treatment recorded the lowest average (405.25 mg m^{-2}). This may be because of the positive role of paclobutrazol in delaying the aging of leaves, keeping them green longer, maintaining their activity because paclobutrazol increases the activity of oxidative enzymes inhibiting +cell maturation (Dwivedi *et al*., 2017).

The results further disclosed the noteworthy differences due to interactions between the wheat cultivars and paclobutrazol concentrations for leaf chlorophyll content. The interaction between the cultivar Bhoth-22 and paclobutrazol (100 mg L^{-1}) showed the highest average leaf chlorophyll content (495.40 mg m^{-2}). Meanwhile, the interaction between the cultivar Ibaa-99 and control treatment recorded the lowest average for the said trait (395.4 mg m^{-2}).

Days to maturity

A notable influence of the wheat cultivars on the number of days from 50% flowering to physiological maturity emerged (Table 6). The cultivar Bhoth-22 provided the maximum number of days from 50% flowering to full maturity (43.43 days), compared with the cultivar Ibaa-99 with the lowest time from 50% flowering to full maturity (40.88 days). The reason may be due to the genetic variation between these wheat cultivars.

Table 4. Effect of wheat cultivars and paclobutrazol and their interactions on the flag leaf area.

Cultivars	Paclobutrazol concentration (mg L^{-1})				Means (cm^2)
	0	50	100	150	
Ibaa-99	28.20	33.40	39.10	38.22	34.73
Bhoth-22	32.12	39.34	45.23	42.36	39.76
Means (cm^2)	30.16	36.37	42.16	40.29	
$LSD_{0.05}$ Cultivars: 4.13, Paclobutrazol concentration: 4.13, Interaction: 8.26					

Table 5. Effect of wheat cultivars and paclobutrazol and their interactions on the leaf chlorophyll content.

Cultivars	Paclobutrazol concentration (mg L^{-1})				Means (mg m^{-2})
	0	50	100	150	
Ibaa-99	395.40	435.50	477.30	470.10	444.57
Bhoth-22	415.10	455.20	495.40	474.30	460.00
Means (mg m^{-2})	405.25	445.35	486.35	472.20	
$LSD_{0.05}$ Cultivars: N.S., Paclobutrazol concentration: 27.23, Interaction: 54.46					

Table 6. Effect of wheat cultivars and paclobutrazol and their interactions on the days from 50% flowering to maturity.

Cultivars	Paclobutrazol concentration (mg L^{-1})				Means (mg m^{-2})
	0	50	100	150	
Ibaa-99	36.30	39.47	41.26	46.50	40.88
Bhoth-22	40.40	43.20	45.33	44.80	43.43
Means (mg m^{-2})	38.35	41.33	43.29	45.65	

$LSD_{0.05}$ Cultivars: 1.82, Paclobutrazol concentration: 1.82, Interaction: 3.64

The different concentrations of the growth regulator paclobutrazol revealed varied number of days from 50% flowering to full maturity (Table 6). The paclobutrazol concentration of 150 mg L^{-1} recorded with the longest time from 50% flowering to maturity (45.65 days). However, the comparison treatment recorded with the lowest said duration (38.35 days). The reason for the prolonged period from 50% flowering to full maturity may refer to the role of paclobutrazol, which causes delay in aging in leaves prolonging the period to full maturity in crop plants (Strydhorst *et al*., 2018; Al-Hakam and Abdul-Alwahid, 2024; Atia and Oraibi, 2024).

For 50% flowering to full maturity, significant differences were evident in the interaction between the wheat cultivars and different concentrations of paclobutrazol (Table 6). The combination between the cultivar Ibaa-99 and paclobutrazol (150 mg L^{-1}) emerged with the longest time from 50% flowering to full maturity (46.5 days), while the combination between the cultivar Ibaa99 and control treatment showed the least period from 50% flowering to full maturity (36.3 days).

CONCLUSIONS

Wheat (T. aestivum L.) cultivars, growth regulator paclobutrazol, and their interactions revealed significant differences for most traits. The cultivar Bhoth-22 with paclobutrazol concentration (100 mg L^{-1}) led to a significant improvement in growth traits.

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