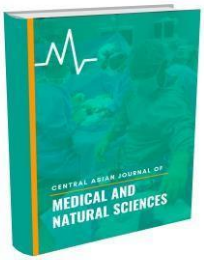

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Article

Effect of Nitrogen Application and Foliar Spraying ascorbic acid on the Vegetative Growth of Wheat (*Triticum aestivum L.*)

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Abstract: A pot experiment was carried out in Al-Hur region in the season 2024-2025, for studying the effect of nitrogen fertilization, Foliar ascorbic acid spraying and its interactions on some vegetative growth characteristics for wheat plants (*Triticum aestivum L.*, cv.);"> Abu Ghraib) which were grown in sandy loam soil. The trial consisted of three nitrogen (B) rates (0, 75, 100 kg N·ha^{-1}) applied in three split applications (post-emergence, three-leaf stage and at flowering). The second comprised three levels of ascorbic acid (A) concentration at 0, 250 and 500 mg·L^{-1} applied by foliary spraying at two times: the thinning stage (four-leaf stage) and the elongation stage (eight-leaf stage). The experiment comprised 27 treatment combinations which were laid out in a CRD with three replications and subjected to statistical analysis. The key findings are: Effects of Nitrogen Fertilization: Nitrogen supply had a large effect on vegetative growth characters which were consistently increased with the level of nitrogen supply. Nitrogen at the highest level (100 kg N·ha^{-1}) produced the tallest plant height (52 cm) and the largest number of leaves (14.4 leaves·plant^{-1}). Effect of Ascorbic Acid Foliar Spraying: 1. Foliar spraying with ascorbic acid significantly affected certain vegetative traits at the highest concentration (500 mg·L^{-1}), resulting in increased plant height, number of tillers (4.2 tillers·plant^{-1}), and flag leaf area (374.1 cm^2·plant^{-1}). 2. Interaction Effect (Nitrogen × Ascorbic Acid): The interaction between 500 mg·L^{-1} ascorbic acid and 100 kg N·ha^{-1} produced a highly significant effect on all vegetative traits, recording the highest values for plant height (57 cm), number of tillers (4.5 tillers·plant^{-1}), number of leaves (15.7 leaves·plant^{-1}), and flag leaf area (379.2 cm^2·plant^{-1}). This combination was identified as the optimal treatment for enhancing vegetative growth.

Keywords: Nitrogen Fertilization, Foliar Spraying, Ascorbic Acid, Wheat, *Triticum Aestivum L.*

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1. Introduction

Wheat (*Triticum aestivum L.*) is considered one of the most strategically important cereal crops due to its wide trade volume in the international market. Consequently, both developed and developing countries have adopted economic policies aimed at enhancing wheat production and minimizing imports in order to achieve self-sufficiency. However, the gap between global wheat production and demand continues to widen. By the year 2000, the world's population exceeded six billion, with nearly two-thirds of this growth occurring in developing countries (FAO, 2000). Iraq, as one of the developing countries, possesses the fundamental components of agricultural activity, including fertile soils, sufficient water resources, and a favorable climate. Over the years, the country has adopted policies to improve wheat production, including direct government support, credit facilities, and tax incentives. Nevertheless, Iraq currently requires approximately 3.025 million tons of wheat grains annually to meet domestic needs, while importing over two million tons, accounting for 60–70% of its total demand. In contrast, the average local production is approximately one million tons per year (General Company for Grain Trading, Ministry of Trade, 2004).

This significant gap between production and consumption persists despite Iraq being one of the primary centers of wheat domestication. The reduction in local production is attributed to several factors, primarily poor crop management practices, along with increased soil salinity and drought stress. Ascorbic acid (Vitamin C) plays a vital role in many physiological processes in plants, including cell growth, division, wall biosynthesis, secondary metabolism, photoprotection, and stress tolerance. Being a low-molecular-weight antioxidant, ascorbic acid functions as a cofactor in several biochemical pathways and regulates redox homeostasis (Ahmad et al., 2011). It also protects the photosynthetic apparatus from reactive oxygen species (ROS) generated during photosynthesis (Hassanein et al., 2009), delays leaf senescence, and participates in nodulation, nitrogen fixation, mRNA synthesis, flowering, and lateral bud development (Azzedine et al., 2011). Khan et al. (2011) reported that ascorbic acid deficiency induces premature senescence in plants, as it directly regulates gene expression associated with aging. Moreover, ascorbic acid serves as a key cofactor in the biosynthesis of various plant hormones such as ethylene, gibberellins, and abscisic acid (ABA), and it modulates plant responses to environmental stress through complex biochemical interactions, including the activation or inhibition of essential enzymes involved in stress-responsive protein synthesis and defensive compound production. In contrast, one of the macronutrients in high demand of plants is nitrogen. It is important for various physiological and biochemical activities, like the formation of nucleic acids (DNA, RNA), proteins, chlorophyll, energy carriers, coenzymes and membrane structures like mitochondria and chloroplasts (Bidwell, 1979). Thus, nitrogen is essential for vegetative growth, protein synthesis, photosynthetic mechanisms, chlorophyll synthesis, and abiotic stress amelioration such as drought and low temperature stress (Javeed et al., 2021). In contrast, nitrogen (N) is one of the macronutrients necessary in relatively large amounts by plants. It becomes an essential nutrient for various physiological and biochemical processes, which participate in nucleic acids (DNA, RNA) synthesis, proteins, chlorophyll, energy carriers, coenzymes, and membrane components (like mitochondria and chloroplast) synthesis (Bidwell, 1979). Nitrogen is thus believed to be essential in areas of vegetative growth, protein synthesis, chlorophyll production, and abiotic stress tolerance, like drought and low temperature (Javeed et al., 2021).

Research Objective:

This study sought to determine how some vegetative development features of wheat (*Triticum aestivum L.*) were affected by nitrogen fertilisation and ascorbic acid foliar spraying.

2. Materials and Methods

Using a Completely Randomised Design (CRD) with three replications, a pot experiment was carried out in the winter of 2024–2025. There were two primary components to the experiment: Ascorbic acid foliar spraying at three concentrations was the first factor. (0, 250, and 500 mg·L^{-1}), applied after plant thinning (35 days after sowing) and again at the elongation stage on February 10, 2025. The second factor involved soil nitrogen fertilization at three levels (0, 75, and 100 kg N·ha^{-1}) using the recommended nitrogen fertilizer, which was applied in three split doses: the first after seedling emergence, the second at the three-leaf stage, and the third at the flowering stage. In addition, single superphosphate fertilizer was applied once at sowing.

Wheat seeds (*Triticum aestivum L.*, cultivar Abu Ghraib) were sown on December 1, 2024 in plastic pots with a capacity of 5 kg soil per pot, with 10 plants per pot. Soil samples were collected prior to sowing for analysis. Stock solutions of ascorbic acid were prepared by dissolving the required weight in water, mixing until complete dissolution, and diluting to the target concentration. A non-ionic surfactant (Zahi solution) was added to ensure complete wetting of plant foliage, and spraying was carried out early in the morning using a 5-liter hand sprayer. Control plants were sprayed with distilled water only. The experiment included a total of 27 experimental units.

1.2 Vegetative Growth Measurements and Statistical Analysis

Once plants reached the maturity stage, vegetative growth features were measured at 100% blooming. Using the Wiersma et al. (1986) approach, the height of each plant (in centimetres) was measured from the soil surface to the top of the spike, excluding the awns, for three plants per pot. The total number of tillers per experimental unit at full flowering was counted and divided by the total number of plants to get the number of tillers (tillers·plant^{-1}). The number of leaves (leaves·plant^{-1}) was determined by counting all leaves per pot and dividing by the number of plants in that pot. The flag leaf area (cm^{2}·plant^{-1}) was calculated according to the formula described by Thomas (1982):

Leaf area=Leaf length×Maximum width×0.95

using three flag leaves per experimental unit at the 100% flowering stage.

All collected data were analyzed using Analysis of Variance (ANOVA) for the Completely Randomized Design (CRD), and treatment means were compared using the Least Significant Difference (LSD) test at a 5% probability level ($P \leq 0.05$). Statistical analyses were performed using the Genstat software (Al-Rawi, 1980).

3. Results and Discussion

1.3 Plant Height (cm)

As shown in Table 1 foliar application of ascorbic acid had a highly significant effect on plant height and the spraying of plants at a concentration of 500 mg·L^{-1} was superior in plant height with the highest average plant height 52 cm, while the spraying with the control treatment (distilled water) only gave a plant height recorded by 43 cm. This may be due to the function of Vitamin C in promoting cell division and cell expansion and in stimulating the carbon assimilation in the growing leaves, leading to the production of several metabolites which are indispensable for the growth of the plants (Smirnoff, 2000).

Likewise, nitrogen fertilization also greatly affected with the greatest plant height (52 cm) from 100 kg N·ha^{-1} as opposed to the control (no N) treated. This finding can be justified by the fact that nitrogen is the dominant nutrient that controls crop productivity (Abdulhadi, 2009) and is supported by the results of Phares et al. (2022). Proteins, nucleic acids, enzymes, chlorophyll, vitamins and nitrogen-containing organic compounds that modulate key physiological mechanisms and promote an efficient nutrient transference between tissues are made of N. The combined application of foliar sprays of ascorbic acid with nitrogen fertilization also had a significantly high effect on plant height. The maximum value (57 cm) was found with 500 mg·L^{-1} ascorbic acid along with 100 kg N·ha^{-1} as compared to its control. This synergy effect is likely due to the indispensable role of VC in several biochemical and physiological processes within the plant, such as its cofactor in enzymatic reactions, its promotion of carbon assimilation, and its powerful function as a non-enzymatic antioxidant in protecting plant cells from ROS-induced damage, thereby maintaining the cellular homeostasis (Conklin & Barth, 2004). These results compatible with those of Alasadi & Al-Semmak (2020), and Al- Masoudi, (2024).

Table 1. Influence of nitrogen fertilization, foliar spraying of ascorbic acid and N fertilization x ascorbic acid interaction on plant height (cm).

Nitrogen levels (kg N·ha⁻¹)	Ascorbic acid concentrations (mg·L⁻¹)	Mean effect of nitrogen
	0	**250**
0	40	43
75	42	45
100	46	52
Mean effect of spraying	**43**	**47**
LSD (0.05)	A = 6, B = 6, A×B = 14	

2.3 Number of Tillers (tillers·plant^{-1})

Table 2 shows that foliar spraying with ascorbic acid had a significant effect on the number of tillers per plant. The highest mean value (4.2 tillers·plant^{-1}) was obtained at the concentration of 500 mg·L^{-1}, compared to the control treatment sprayed with distilled water only, which recorded (2.8 tillers·plant^{-1}). This improvement can be attributed to the role of Vitamin C in regulating the cell cycle and enhancing many essential physiological processes, in addition to its effectiveness in cell division and expansion (Cheruth, 2009; Noctor & Foyer, 1998).

In comparison, the application of just the nitrogen fertilizer did not result in a substantial increase in the number of tillers. And the interaction between ascorbic acid foliar from N increased effect significantly, the maximum tiller number (4.5 tillers·plant^{-1}) of tiller per plant was obtained when spraying with 500 mg·L^{-1} ascorbic acid with adding 100 kg N·ha^{-1}, which was obviously higher than the control treatment with no N and no ascorbic acid (3.0 tillers·plant^{-1}). This could be attributed to the role ascorbic acid by enhancing uptake of nutrients including nitrogen, phosphorus and carbon leading to better plant growth and tiller development (Hussein et al., 2011).

Table 2. Effect of nitrogen fertilization, foliar spraying with ascorbic acid, and their interaction on the number of tillers (tillers·plant^{-1}).

Nitrogen Levels (kg N·ha⁻¹)	Ascorbic Acid Concentrations (mg·L⁻¹)	Mean Effect of Nitrogen
	0	**250**
0	**2.5**	**2.7**
75	**2.8**	**3.4**
100	**3.1**	**3.8**
Mean Effect of Spraying	**2.8**	**3.3**
LSD (0.05)	**A = 0.4 B = N.S. A×B = 0.6**	

3.3 Number of Leaves (leaves·plant^{-1})

Table 3 shows that foliar spraying with ascorbic acid had a non-significant effect on the number of leaves per plant. In contrast, nitrogen fertilization had a significant effect, where the highest mean value (15.7 leaves·plant^{-1}) was recorded at the application rate of 100 kg N·ha^{-1}, compared to the control treatment (12.4 leaves·plant^{-1}). The interaction between foliar spraying with ascorbic acid and nitrogen fertilization exhibited a significant effect, where the highest value (15.7 leaves·plant^{-1}) was obtained when applying 500 mg·L^{-1} ascorbic acid in combination with 100 kg N·ha^{-1}, compared to the lowest value in the control treatment (no nitrogen + distilled water).

This result may be attributed to the role of Vitamin C as a cell cycle regulator and its involvement in several essential physiological processes, particularly cell division and expansion (Cheruth, 2009; Noctor & Foyer, 1998). These findings are consistent with those reported by Alasadi & Al-Semmak (2020b), who highlighted the role of ascorbic acid and citric acid in enhancing vegetative growth. Besides, ascorbic acid enhances the uptake of the elemental nutrients, such as nitrogen, phosphorus, potassium and carbon that favorably affect plant growth (Hussein et al., 2011). These values were also recorded by El-God et al. (2012) and Fabunmi (2009) who also reported that combination of integrated nutrient management and use of biostimulant application enhanced plant productivity.

Table 3. Effect of nitrogen fertilization and foliar spraying with ascorbic acid and interaction on leaf number (leaves·plant^{-1})

Nitrogen Levels (kg N·ha^{-1})	**Ascorbic Acid Concentrations (mg·L^{-1})**	**Mean Effect of Nitrogen**
	0	**250**
0	**11.8**	**12.6**
75	**13.4**	**14.2**
100	**14.8**	**15.2**
Mean Effect of Spraying	**13.3**	**14.0**
LSD (0.05)	**A = N.S. B = 0.8**	
	A×B = 1.1	

4.3 Flag Leaf Area (cm²·plant^{-1})

The flag leaf area is significantly affected by the foliar application of ascorbic acid as indicated in Table 4. The maximum one (374.1 cm²·plant^{-1}) was observed at 500 mg·L^{-1} when compared to the control sprayed with pure distilled water, having a percentage increase of 24.87%. The improvement could be related also to the role of ascorbic acid in promoting the uptake of some essential elements such as nitrogen, phosphorus, potassium and carbon which have a good effect on plant growth and leaf expansion (Hussein et al., 2011).

The effect of nitrogen fertilization was also significant, with the highest mean value (308.7 cm². Plant-1) occurring in the 100 kg N · ha-1 dose, when compared to the control. In addition, the foliar spraying of ascorbic acid over interaction with nitrogen fertilization was presented a very significant effect, and 500 mg·L^{-1} of ascorbic acid combined with 100 kg N·ha^{-1}, reached the highest FLA (379.2 cm²·plant^{-1}), which was significantly higher than that of the control (255.1 cm²·plant^{-1}).

This synergism can be attributed to the involvement of Vitamin C in activating several bio-chemical and physiological mechanisms within the plant viz., in promoting carbon assimilation and in the activities of enzymes. Moreover, into the cell, Vitamin C also serves as a non-enzymatic antioxidant, shielding them from reactive oxygen species (ROS), and thus supporting the structural stability of the cell (into the cells) (Conklin&Barth, 2004). These results are in accordance with those of El-God Hak et al. (2012) and Alasadi & Al-Semmak (2020a).

Table 4. Effect of Ascorbic Acid Application.

Nitrogen Levels (kg N·ha^{-1})	**Ascorbic Acid Concentrations (mg·L^{-1})**	**Mean Effect of Nitrogen**
	0	**250**
0	**255.1**	**301.5**
75	**239.1**	**250.9**

100		265.5		281.3
Mean Effect of Spraying		253.2		277.9
LSD (0.05)	A = 40.9	B =40.9	A×B = 90.1	

4. Conclusion

Based on the current findings, it can be said that foliar spraying with ascorbic acid and applying nitrogen fertiliser to the soil had a positive impact on improving the vegetative growth parameters of wheat (*Triticum aestivum L.*, var. Abu Ghraib) cultivated in sandy loam soil. Plant height, leaf count, and flag leaf area were all significantly and successfully increased by foliar spraying with ascorbic acid. In a same vein, nitrogen fertilisation improved vegetative development characteristics, especially heightening plants. More significantly, the study found that the two factors had an integrative and synergistic effect, with the combined impacts of foliar spraying and nitrogen fertilisation outperforming the effects of each element alone . This was clearly demonstrated by the treatment that combined the highest nitrogen level (100 kg $N \cdot ha^{-1}$) with the highest concentration of ascorbic acid (500 $mg \cdot L^{-1}$), which recorded the best performance and highest values for all studied traits without exception. Therefore, it is concluded that adopting an integrated approach that combines soil mineral nutrition with the application of foliar biostimulants represents an effective and recommended strategy for maximizing vegetative growth and improving the overall performance of wheat plants under the experimental conditions.

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