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Impact of Amino Acid Application on Growth, Yield and Nutrients Status of Wheat Plant Under Nitrogen Fertilization

Abd El-Rheem Kh. M.[1], **Mona E. El-Azab**[1] and **Yasser A. El-Damarawy**[1]

[1]*Soils and Water Use Dept., National Research Centre, Dokki, Giza, Egypt*

THE EXPERIMENT involved spraying varying concentrations of amino acids (0, 2.5 and 5 cm^3L^{-1}) with varying levels of nitrogen fertilizer (200, 250 and 300 Kg N ha^{-1}) and observing the effects on wheat growth and yield, both qualitatively and quantitatively, as well as the nutritional status of it.

Nitrogen fertilization and amino acid supplementation increase plant height and yield of wheat plants. A synergistic interaction exists between nitrogen and amino acids, promoting optimal plant growth and productivity. Spraying amino acids with low nitrogen rates, especially the second rate, can achieve crop values close to the recommended nitrogen rate, reducing nitrogen fertilizer usage by about 16.7%. The effect of nitrogen fertilization was most pronounced at the highest rate (300 kg N ha^{-1}), where carbohydrate and protein content reached its maximum. The effect of amino acids was most pronounced at the highest concentrations (5 cm^3L^{-1}), where carbohydrate and protein content reached its maximum. The effect of amino acids and nitrogen fertilization was more evident on the nitrogen content of leaves, while the phosphorus and potassium content in leaves were not affected.

It can be said that spraying amino acids at a concentration of 5 cm^3 L^{-1} gives growth, yield and nutritional status to wheat plants with low levels of nitrogen fertilizer, especially 250 kg N ha^{-1}. Therefore, spraying amino acids can reduce the amount of nitrogen fertilizer with the intention of harming the growth and yield of wheat, thus reducing the cost of production and increasing profitability.

Keywords: Wheat, Amino acid, Nitrogen fertilizer, Growth, Yield, Nutrient content.

Introduction

Wheat (*Triticum aestivum* L.) is a globally significant cereal crop, vital to economic activity. It serves as a staple food for both urban and rural populations and provides essential straw for animal feed. In Egypt, approximately 3 million faddan of land is dedicated to wheat cultivation annually. Given the limited arable land in the Nile Valley and the competitive nature of crop production, expanding wheat cultivation into reclaimed areas is a strategic imperative. Consequently, enhancing both the yield and quality of wheat remains a primary focus for researchers **(Rashwan *et al.*, 2024)**. Wheat, a staple food crop worldwide, is heavily reliant on nitrogen fertilization to optimize yield and quality. However, excessive nitrogen application can lead to environmental concerns, such as nitrate leaching and greenhouse gas emissions (**Smith *et al.*, 2018**). To mitigate these issues and promote sustainable agriculture, alternative strategies are being explored. Amino acids, organic compounds essential for plant growth and development, have emerged as a potential solution to enhance wheat productivity while minimizing the negative impacts of nitrogen overuse.

One essential macronutrient that has a big impact on plant development, growth, and production is nitrogen. Nitrogen is essential to photosynthesis and metabolism since it is a component of proteins and chlorophyll. Sufficient availability of nitrogen is especially important for cereal crops like wheat in order to maximize grain yield and quality **(Tahir and Iqbal, 2014).** Therefore, attaining sustainable and effective agricultural operations requires an awareness of the best nitrogen fertilizer techniques for wheat. A crucial component that frequently restricts crop yields is nitrogen, and many agricultural regions lack enough of it. Nitrogen fertilizer is especially important in intensive wheat growing to boost yield and quality **(Bai *et al.*, 2022).**

The basic building blocks of proteins, amino acids, are essential for promoting the growth of plant cells **(Fathi & Zeida, 2021).** Amino acids, well-known as biostimulants, have a favorable effect on plant growth, yield, and resistance to abiotic stressors **(El-Salhy *et al.*, 2021).** Studies demonstrating the direct or indirect effects of amino acids on physiological processes have shown that exogenous amino acid treatments can improve tomato growth,

*Corresponding author email: dr.khaledrheem75@gmail.com - Orcid ID: 0000-0002-3589-4417
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yield, and quality in greenhouse settings **(Khan *et al.*, 2020).** As precursors of phytohormones and other growth agents, amino acids offer several benefits, including enhanced product quality, increased resistance to abiotic stresses, facilitated nutrient translocation, assimilation, and utilization, and improved plant metabolic efficiency **(Calvo *et al.*, 2014).** Amino acids can positively influence wheat (*Triticum aestivum* L.) growth and yield. Foliar applications of amino acids can significantly stimulate physiological and biochemical processes within the plant **(Kandil and Marie, 2017).**

The objective of this study was to examine the impact of varying nitrogen fertilizer rates and amino acid concentrations on wheat plant growth, yield, and nutritional status. Specifically, we sought to determine if the addition of amino acids could mitigate the negative effects of low nitrogen fertilizer levels.

Materials and Methods

To investigate the influence of various nitrogen fertilization levels (200, 250, and 300 kg N ha^{-1}) and amino acid foliar application (0, 2.5, and 5 cm^3L^{-1}) on wheat (*Triticum aestivum* L., cv Sakha 69) growth, yield, and nutrient content, a field experiment was conducted at the Ismailia Agricultural Research Station during the 2021/2022 and 2022/2023 winter season. Prior to wheat planting, soil samples were collected and analyzed for their chemical properties following the standard methods outlined by **Cotteine (1980).** The results are presented in Table (1).

Table 1. Some chemical properties of soil before wheat cultivation.

Soil properties	Value	Soil property	Value
Particle size distribution %		pH (1:2.5 soil suspension)	8.0
Sand	84.1	EC (dS m^{-1}), soil paste extract	1.20
Silt	5.70	Soluble ions (mmol L^{-1})	
Clay	10.2	Ca^{++}	6.12
Texture	Loamy sandy	Mg^{++}	4.60
$CaCO_3$ %	2.10	Na^+	1.54
Organic matter%	0.10	K^+	0.52
Available N (mg kg^{-1})	61.4	CO_3^{--}	nd
Available P (mg kg^{-1})	4.11	HCO_3^-	1.10
Available K (mg kg^{-1})	8.20	Cl^-	0.96
		SO_4^{--}	9.60

A randomized complete block design with four replications was used in a split-plot arrangement. Main plots were assigned to three nitrogen fertilization rates (200, 250, and 300 kg N ha^{-1}), while subplots received three amino acid concentrations (0, 2.5, and 5 cm^3 L^{-1}). The seeds of wheat (*Triticum aestivum* L., cv Sakha 69) were sown on the 14th November in season 2021/2022 and on the 15th in season 2022/2023in rows. Each row length was 3.5 meter and row to row distance was 20 cm and hill to hill distance was 20 cm (plot size was 3.0 m in width and 3.5 m in Length). The recommended agricultural practices of growing wheat seed were applied and the seeding rate was (60 kg seeds fed^{-1}). Pre-sowing, 150 kg fed^{-1} of Mono-Super-phosphate (15.5 % P_2 O_5) was applied to the soil. Potassium sulfate (48.52 % K_2O) was added at two equal doses of 50 kg/fed, before the 1st and 3rd irrigations. Irrigation was carried out using the new sprinkler irrigation system where water was added every 5 days. Weeds and diseases were controlled when needed according to the recommendations of the ARC, Egypt.

Data recorded

1- Plant height: It was measured as the height of plant at maturity, measured from the soil surface to the level of the tip of spike, excluding awns (average of 10 plants were taken.).

2- Photosynthetic capacity: flag leaf weight (g)/flag area (cm^2).

3- Grain index: Weight of 100 grain of wheat as grain yield quality.

4- Grain yield /ha: It was measured as the weight of grains per square meter (adjusted at 14% grain moisture).

5- Straw yield/ha.

Total nitrogen content was estimated by modified Kjeldahl's methods **(Motsara and Roy, 2008).** Phosphorus was determined calorimetrically by NH_4-Metavanidate method **(Motsara and Roy, 2008)**. Potassium was flame-photometrically estimated (**Motsara and Roy, 2008).** Total protein percentage in straw and grain of wheat: a factor of 6.25 was multiplied by total nitrogen concentration to obtain protein percentage. Total carbohydrate percentage (%): dry matter of each treatment was used for determination total carbohydrates% were colorimetrically determined using phenol-sulfuric acid reagent method as outlined by **Dubois *et al.*,(1956).**

Statistical Analysis

All data were subjected to statistical analysis using Mstatc software. The comparison among means of the different treatments was determined, as illustrated by **Snedecor and Cochran (1982).** Means of the treatments were compared by the Least Significant Differences Test at (0.05) level of significance.

Results and Discussion

The results presented in Table (2) demonstrate the significant impact of nitrogen fertilization and amino acid supplementation on wheat growth and yield in two consecutive seasons. Increasing nitrogen fertilization rates generally led to taller plants, especially in the second season. The addition of amino acids also positively affected plant height, but the effect was less pronounced than that of nitrogen. Higher nitrogen rates and amino acid concentrations resulted in increased photosynthetic capacity. The grain index was generally higher with higher nitrogen rates and amino acid concentrations. This indicates that these treatments produced larger, heavier grains. Overall, both nitrogen fertilization and amino acid supplementation led to increased grain and straw yields. The combination of higher nitrogen rate and higher amino acids concentration often obtained the highest yields. These findings suggest that a synergistic interaction exists between nitrogen and amino acids, promoting optimal plant growth and productivity. On the other hand, it was found that amino acids with low nitrogen rates, especially the second rate, can obtain crop values, whether straw or grains, that are very close to the crop values for both when spraying amino acid concentrations with the highest rate of nitrogen fertilization, as it is the recommended rate. Therefore, it can be said that spraying amino acids, especially the highest concentration of it, with the second level of nitrogen fertilization, can obtain a straw and grain crop for wheat plants with values that are very close to the recommended nitrogen rate. Therefore, by using amino acids, it is possible to reduce the amounts of nitrogen fertilizer used, as the amount of nitrogen fertilizer can be reduced by about 16.7%.

According to **Yousaf *et al*., (2021)**, a rise in nitrogen levels may be responsible for the growth-stimulating effect of nitrogen, as evidenced by the growth-related increases in plant height, number of leaves/plant, number of tillers/plant, and flag leaf area. This illustrates the role that nitrogen plays in increasing the photosynthetic area of wheat plants and, as a result, the accumulation of additional dry matter, as seen in these characteristics. **Gehan *et al*., (2011)** demonstrated that the possibility that nitrogen has a function in activating the growth and yield components accounts for the increase in yield parameters with an increase in nitrogen level. As a result, more dry matter accumulates, reflecting the importance of nitrogen in increasing the photosynthetic area of wheat plants and, ultimately, in grain yield and its constituent parts. The increase in accessible nitrogen (N) in the soil may have caused the wheat plants' response to the nitrogen application.

Table 2. Effect of amino acid concentration and nitrogen fertilization rate on growth and yield of wheat plants.

N fertilization Kg N ha^{-1}	Amino acid cm^3L^{-1}	Plant height cm	Photosynthetic capacity *	Grain index (g)**	Yield ton ha^{-1}	
					Grain	Straw
			First season			
200	0	74.2	3.14	37.4	4.37	11.1
	2.5	76.1	3.56	40.1	5.83	11.9
	5	79.4	4.00	40.8	6.38	12.5
250	0	76.3	3.78	38.5	4.80	12.6
	2.5	80.1	4.45	41.2	6.38	14.4
	5	81.8	5.02	42.0	6.74	15.2
300	0	79.3	4.44	40.3	6.52	14.7
	2.5	81.2	5.22	44.2	6.72	15.0
	5	82.0	5.64	46.5	6.82	15.2
$LSD_{0.05}$		3.02	0.73	2.91	0.94	1.00
			Second season			
200	0	74.1	3.14	37.3	4.34	11.1
	2.5	76.2	3.55	40.2	5.86	11.9
	5	79.4	4.01	40.7	6.43	12.5
250	0	76.2	3.79	38.6	4.84	12.6
	2.5	80.2	4.46	41.1	6.41	14.6
	5	81.9	5.03	42.1	6.77	15.2
300	0	79.2	4.45	40.2	6.50	14.7
	2.5	81.3	5.24	44.1	6.74	15.0
	5	82.1	5.64	46.4	6.82	15.2
$LSD_{0.05}$		3.09	0.73	2.91	0.96	1.00

*Photosynthetic capacity = flag leaf weight (g)/flag area (cm^2)

** Grain index = grain yield quality

Abd El-Rheem *et al*., (2015) observed that increasing the rate of nitrogen fertilization resulted in an increase in plant height, photosynthetic capacity, grain index, and both straw and grain yield of wheat. According to **Abada *et al*., (2023)**, amino acids are a known bio-stimulant that can improve yield, promote root and plant growth, and considerably lessen the detrimental effects of abiotic stress. In addition to being the building blocks of proteins, amino acids are also the building blocks of numerous other compounds that are essential to plant physiology. They function as building blocks for many plant activities that are regulated by organic molecules such as proteins, alkaloids, vitamins, enzymes, terpenoids, and plant hormones **(Dromantiene *et al*., 2013). Galal *et al*., (2017)** found that, in comparison to a control treatment, foliar sprays of a 4% amino acid solution to wheat plants twice during the growth season significantly increased the yield of both grains and straw. For grain and straw, yields were increased by about 10.3% and 7.7%, respectively, in the first season. In the second season, these beneficial effects persisted, increasing by 8.9% and 10.0%, respectively. Amino acids presumably serve a vital role in regulating plant growth and development by influencing cellular differentiation and general metabolism, ultimately effecting morphogenesis.

The Table (3) was presented data on the impact of amino acid concentrations and nitrogen fertilization rate on chlorophyll a and b and carotenoids of wheat leaves. Increasing nitrogen fertilization rates generally led to higher levels of chlorophyll a and b, particularly in the second season. The effect of nitrogen fertilization on carotenoids content was less pronounced, with only slight increases observed at higher rates. The addition of amino acids had a variable effect on pigment levels. In some cases, it led to increases in chlorophyll and carotenoids content, while in others**,** it had no significant impact. The results suggest that both nitrogen fertilization and amino acid supplementation can influence the pigment composition of wheat plants. However, the specific effects can vary depending on the combination of these factors and the environmental condition.

Table 3. Effect of amino acid concentration and nitrogen fertilization rate on chlorophyll a and b and carotenoid of wheat leaves.

N fertilization Kg N ha^{-1}	Amino acid cm^3L^{-1}	Chlorophyll a	Chlorophyll b	Carotenoids	Chlorophyll a	Chlorophyll b	Carotenoids
		mg/100 mg DW			mg/100 mg DW		
		First season			Second season		
200	0	6.65	3.22	1.32	6.65	3.21	1.31
	2.5	6.72	3.33	1.41	6.71	3.31	1.40
	5	6.98	3.91	1.87	6.95	3.90	1.86
250	0	6.90	3.34	1.74	6.91	3.35	1.74
	2.5	7.86	4.21	2.20	7.85	4.20	2.19
	5	7.90	4.33	2.29	7.89	4.32	2.28
300	0	7.00	4.28	1.91	7.01	4.27	1.91
	2.5	7.91	4.32	2.31	7.89	4.31	2.30
	5	7.92	4.35	2.33	7.91	4.34	2.32
$LSD_{0.05}$		0.50	0.39	0.34	0.48	0.38	0.33

Nitrogen is necessary for several cellular processes, including the synthesis of proteins, enzymes, and chlorophyll, which is needed for photosynthesis, metabolism, and growth **(Noor *et al*., 2022).** It's possible that the increased removal of alpha-ketogelutaric acid from the Krebs cycle is the reason for the increase in chlorophyll concentration that occurred after administering amino acids **(Farshid *et***

***al*., 2013)**. Because nitrogen is a part of the chlorophyll molecule, there is an increase in the amount of chlorophyll. Furthermore, the building block of all amino acids found in proteins which function as the structural elements of the chloroplast is nitrogen **(El-Helaly, 2012).** The increase in photosynthetic pigments may be attributed to the role of amino acids in stimulating metabolism and metabolic processes, leading to enhanced plant efficiency **(Sheng *et al*., 2020).**

The results obtained in Figures (1) & (2) indicated the effect of different concentrations of amino acids with different rates of nitrogen fertilization on the carbohydrate and protein content of wheat grains, during two successive growing seasons. Increasing nitrogen fertilization rates generally led to higher carbohydrate and protein content in wheat grains, particularly in the second season. The effect of nitrogen fertilization was most pronounced at the highest rate (300 kg N ha^{-1}), where carbohydrate and protein content reached its maximum. The addition of amino acids had a major effect on carbohydrate and protein content. The effect of amino acids was most pronounced at the highest concentrations (5 cm^3L^{-1}), where carbohydrate and protein content reached its maximum. The effect of amino acids might have been influenced by the nitrogen fertilization rate. Overall, carbohydrate and protein content was generally higher in the second season compared to the first. This could be attributed to factors such as environmental conditions or plant development stages.

Litke *et al*., (2018) discovered a favorable association between increasing nitrogen fertilizer rates and protein and carbohydrate in wheat grain. With increasing nitrogen treatments, the wheat grain's protein and carbohydrate contents also increased. According to **Gehan *et al*., (2011**), there was a considerable increase in plant height, 1000-grain weight, straw production, protein content, and carbohydrate percentage when nitrogen fertilizer was applied at rates of 35, 70, and 105 kg N/feddan. Amino acids are important because they are widely used in the biosynthesis of many different kinds of nitrogenous substances that are not proteins, such as vitamins, coenzymes, pigments, and bases of purines and pyrimidines. Research has substantiated that amino acids can exert direct or indirect influences on the physiological processes involved in plant growth and yield **(Matysiak *et al*., 2020)**. **Salwa and Osama (2014)** discovered that the application of amino acid foliar spray resulted in noteworthy enhancements in plant height, leaf count, tiller count, flag leaf area, spike count per square meter, grain count per spike, 1000-grain weight, grain yield (ton per feddan), and straw yield (ton per feddan). According to **Salwa and Osama (2014**), sprinkling amino acid increased the percentage of protein and carbohydrates in wheat grain.

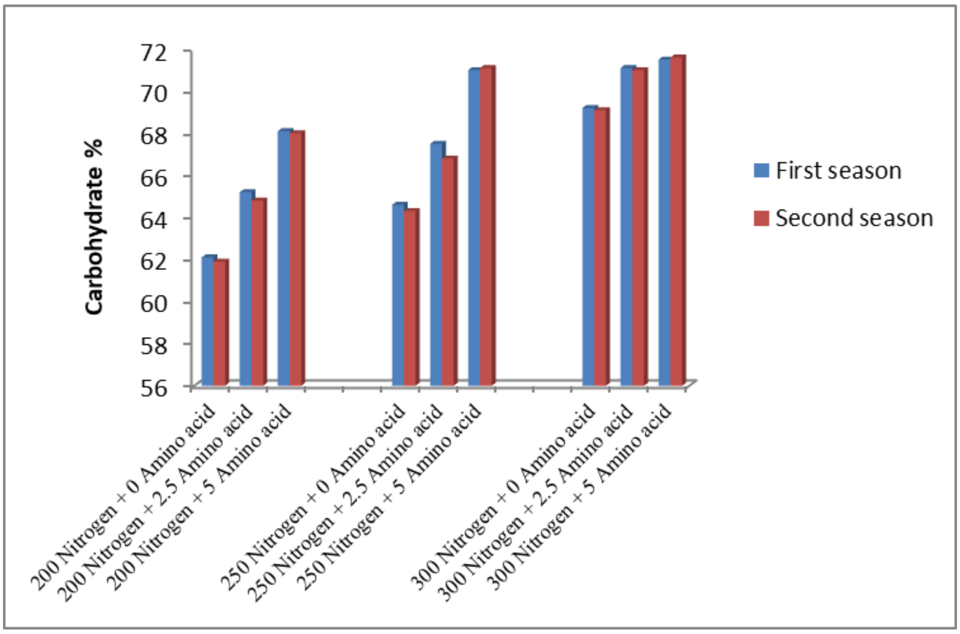

Fig. 1. Effect amino acid concentration and nitrogen fertilization rate on carbohydrate content of wheat grains.

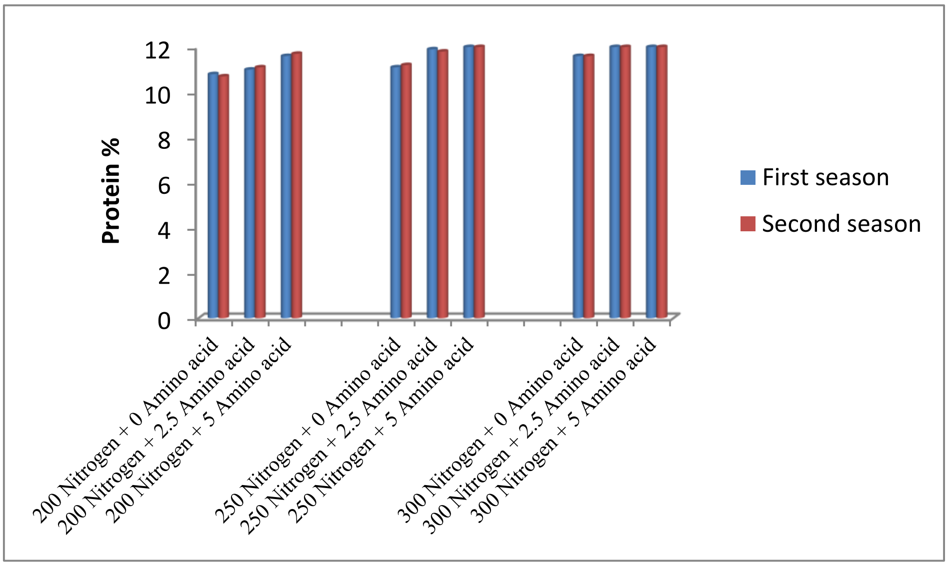

Fig. 2. Effect amino acid concentration and nitrogen fertilization rate on protein content of wheat grains.

Table (4) presents information on the impacts of amino acid concentration and nitrogen fertilization rate on the nutrient content (N, P, and K) of leaves over the duration of two seasons. Nitrogen-rich leaves were generally produced at higher nitrogen fertilizer rates. With rising amino acid concentrations, especially in the first growing season, nitrogen levels in leaves rose. Fertilizer containing nitrogen had minimal impact on potassium (K) and phosphorus (P) concentrations. The concentration of amino acids had no discernible effect on the amount of potassium or phosphorus. A synergistic relationship between increasing concentrations of amino acids and greater nitrogen fertilization often resulted in the highest nitrogen content in leaves. The favorable effects of nitrogen fertilizer and amino acid concentration on nitrogen content are most likely due to the improved absorption and assimilation of nitrogen.

Amino acid fertilizers not only had a direct impact on protein synthesis but also provided an important supply of nitrogen, as noted by **Ewais *et al*., (2005).** The coriander leaf tissues had the highest nitrogen content when treated with an amino acid solution at a concentration of 10 mg/L, as reported by **Mohammadipour and Souri (2019)**. The study found that aliphatic amino acids in nutritional solutions increase the permeability of the root's channel membrane, which in turn promotes mineral uptake.

Table 4. Effect of amino acid concentration and nitrogen fertilization rate on N, P and K content of leaves.

N fertilization Kg N ha^{-1}	Amino acid cm^3L^{-1}	N	P	K	N	P	K
			%			%	
			First season			Second season	
200	0	2.00	0.33	2.91	2.01	0.32	2.90
	2.5	2.44	0.34	2.92	2.45	0.34	2.91
	5	2.45	0.34	2.93	2.45	0.34	2.92
250	0	2.22	0.33	2.94	2.21	0.33	2.93
	2.5	2.56	0.35	2.95	2.55	0.35	2.95
	5	2.68	0.35	2.95	2.66	0.35	2.95
300	0	2.72	0.34	2.95	2.70	0.34	2.94
	2.5	2.84	0.36	2.96	2.85	0.36	2.96
	5	2.86	0.37	2.96	2.86	0.36	2.96
$LSD_{0.05}$		0.23	0.01	0.01	0.23	0.01	0.01

This conclusion was consistent with that of **El-Mogy *et al*., (2019)**, who observed that date palm leaves treated with an amino acid solution had higher levels of potassium, phosphate, and nitrogen than untreated leaves. This is because nitrogen, which is required for the formation of chlorophyll molecules, is found in amino acids.

According to the study, the current findings show that the nitrogen balance index is positively impacted by light and amino acids. This, in turn, results in changes to the photosynthetic process and plan structure that makes it easier for different mineral contents to be absorbed **(Vitale *et al*., 2021)**. According to **Kılıç, (2022)** adding N fertilizer may encourage the growth of plant roots and boost nutrient uptake. **Campillo *et al*., (2010)** investigated the response of wheat to five different nitrogen rates (0, 150, 200, 250, and 300 kg ha^{-1}). They discovered that the quantities of N in wheat tissues increased together with N rates. According to **Ottaiano *et al*., (2021)** applying nitrogen promotes root growth, which expands the roots' capacity to absorb nutrients and allow them to penetrate additional soil.

Conclusion:

When amino acids are added to nitrogen fertilizer at the low and recommended doses, wheat flourishes and yields abundantly. In particular, increased yields of grain and straw are achieved at the recommended nitrogen addition rate (300 kg N/ha) when amino acids are spraying at a concentration of 5 cm^3/L with a nitrogen fertilizer level equal to 16.7% of the recommended amount of nitrogen fertilizer . Therefore, the amount of nitrogen fertilizer needed can be decreased by spraying wheat plants with amino acids, saving the farmer money and lowering environmental pollution.

Consent for publication:

All authors declare their consent for publication.

Author contribution:

The manuscript was edited and revised by all authors.

Conflicts of Interest:

The author declares no conflict of interest.

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