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Exploring the Impact of Amino Acid Application on Cotton Growth and Yield under Semi-Arid Conditions

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Abstract

Pakistan's cotton production ranks among the top in the world, yet its average yield remains far below the potential of its approved varieties. Poor photosynthetic translocation may be a limiting factor, but foliar sprays can rapidly provide essential nutrients during critical growth stages to help improve yields. In this regard, a two-year field experiment was conducted at the Adaptive Research Station, Sahiwal, under semi-arid conditions to investigate the effects of amino acid applications at 60, 90, and 120 days after sowing on cotton growth and yield. The experiment followed a Randomized Complete Block Design (RCBD) with three replications, using cotton variety MNH-1020, sown with 75 cm spacing between rows and 22.5 cm between plants. Treatments included various amino acids compared with a water spray: T1 - Quantis @ 400 ml acre^{-1}, T2 - Seamaxx @ 330 ml acre^{-1}, T3 - Isabion @ 400 ml acre^{-1}, T4 - water spray, and T5 - control. Results showed that amino acid treatments significantly influenced boll number, boll mass, seed index, lint percentage, and seed cotton yield ($p < 0.05$) during Kharif 2022 and 2023. The highest seed cotton yield (3865 and 4554 kg ha^{-1}) was obtained from T1 (Quantis), followed by T3 (Isabion) with yields of 3762 and 4456 kg/ha. The lowest yields were observed in the control plot (T5) with 3051 and 4080 kg ha^{-1}. The maximum boll weight, seed index, and lint percentage were observed from T1, followed by T3. No amino acid application in the control plot resulted in the lowest values for these parameters.

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Introduction

Cotton, known as "white gold" in Pakistan, is a vital export commodity with significant economic importance. Globally, it was cultivated on 33.1 million hectares in 2020, yielding 136 million bales and accounting for approximately 35% of the total fiber production (FAO, 2021). Pakistan ranks among major global producers, but its average yield remains far below the genotypic potential. The use of growth-promoting substances, combined with essential nutrients, was shown to enhance both the yield and quality characteristics of cotton. (Arif et al., 2019). Amino acids have a significant influence on plant growth and yield potential among various growth promoters (Kowalczyk and Zielony, 2008). Amino acids, as bio-stimulants, are composed of carbon (C), hydrogen (H), oxygen (O), and nitrogen (N), and are characterized by a unique organic side-chain that imparts specific properties and functional roles (Buchanan et al., 2000). Aspartate and glutamate are two prominent amino acids in plants, synthesized through various metabolic pathways, while other amino acids may also be produced. Glutamate plays a key role as a nitrogen assimilator and donor, facilitating the biosynthesis of other important amino acids via transamination reactions catalyzed by amino transferase enzymes (Taiz and Zeiger, 2013). The growth of plants and increases in yield are influenced by amino acids through the modulation of physiological functions, resulting in improved productivity and enhanced performance (Koukounaras et al., 2013; Sadak et al., 2015). Foliar application of amino acids mitigates detrimental effects of oxygen radicals and boosts seed cotton yield, reducing boll shedding (Djanaguiraman et al., 2010) and increase biosynthesis of auxin content (Datta et al., 1986). Additionally, foliar application of amino acids has been found to improve plant height, fruiting branches, opened bolls, boll mass, seed index, lint percentage, and seed cotton yield per acre, along with enhancing chlorophyll content and antioxidant enzyme activity in cotton leaves (Gebaly et al., 2013). Liu and Lee (2012) concluded that foliar application of amino acids improved the fresh and dry matter yield of vegetable crops compared to control groups.

The application of amino acids has also been observed to enhance the synthesis of Bt protein in bolls, leading to a significant increase in Bt protein content, lint percentage, boll number, and boll mass (Liu et al., 2023). Furthermore, amino acid infusion has been shown to increase the concentration of Bt toxin in flowers (Abidallah et al., 2017). To reduce the risk of excessive pesticide and nitrogen consumption, using amino acids during boll formation can improve the effectiveness of insect repellents and enhance the economic output of Bt cotton. Quantis and Isabion, organic products derived from sugarcane and yeast fermentation, contain a mixture of free amino acids and peptide chains. These bio-stimulants enhance nutrient availability and efficiency, strengthen plant defenses, improve pesticide effectiveness, and protect plants from drought, heat stress, and cold injury. They also promote root growth, encourage more flowering, enhance pollination and fruit set, and increase both the quantity and quality of the crop. Similarly, Seamaxx, another bio-stimulant, enhances nutrient uptake, increases drought resilience, boosts fungicide effectiveness, and improves overall plant health, resulting in higher yield potential and optimized crop performance. In light of these benefits, the study was conducted to assess

the impact of amino acid application at various times on growth, seed cotton yield, and yield components under the agro-climatic conditions of Sahiwal, Pakistan.

Materials and Methods

A two-year field study was conducted at the Adaptive Research Station Sahiwal in the first fortnight of March, 2022 and 2023, to examine the influence of amino acid application at different times on cotton growth, seed cotton output, and yield components under the agro-climatic conditions of Sahiwal, Pakistan. The study was arranged in a Randomized Complete Block Design (RCBD) with three replications, using the cotton variety MNH-1020, seeded on a well-prepared seedbed with a row spacing of 75 cm and plant spacing of 22.5 cm. The treatments included T1 (Quantis @ 400 ml/acre), T2 (Seamaxx @ 330 ml/acre), T3 (Isabion @ 400 ml/acre), T4 (Water spray), and T5 (Control). These treatments were applied at different times: 60, 90, and 120 days after sowing. The recommended dosage for NPK was 250-85-94 kg/ha, with all phosphorus and potassium supplied at sowing and nitrogen applied in four equal splits.

Soil samples were collected pre-planting from the experimental sites and analyzed according to the procedure outlined by Ryan et al. (2001). The soil at the location was medium-textured loamy clay with a pH of 8.36, organic material content of 0.78%, nitrogen content of 0.039%, available phosphorus of 7.1 ppm, and available potassium of 152 ppm. Pre-emergence weedicide, Dual Gold @ 800 ml/acre, was applied to control weeds. Agronomic practices and plant protection measures were followed throughout the growing period.

To assess agronomic performance, ten randomly selected plants from each plot were tagged at 60, 90, and 120 days after sowing. Data was collected on various parameters using established standard operating procedures. The following parameters were measured: plant height was measured in each plot; fruit-bearing branch count was recorded for each experimental unit; boll number per plant was counted for each plant; mean boll weight was determined by randomly selecting twenty bolls from plants to measure the average boll weight; seed cotton yield was measured in kg/ha by obtaining data from each experimental plot three times; lint yield was extracted from bolls sampled from each plot and converted to kg/ha; lint percentage was calculated by dividing the weight of lint by the weight of seed cotton; and cotton seed index was determined by the weight of 100 cotton seeds, typically obtained from five average-sized bolls.

During the growing period, the mean maximum temperature was recorded as 43.37°C and 45.37°C, the mean minimum temperature was 21.67°C and 20.43°C, and the total precipitation was 218.3 mm and 241.1 mm for 2022 and 2023, respectively. The collected data was statistically analyzed using the MSTATC computer-based program. To assess variations among treatment means, the LSD test was applied at a 5% significance level, following the method outlined by Gomez and Gomez (1984).

Results and Discussion

The data in Table 1 indicate that plant height after 120 days of sowing ranged from 102.2 cm to 121.6 cm under the treatments studied. The maximum plant height of 121.6 cm, which represents a 19% increase over the control, was observed in T1, where Quantis was sprayed. This was followed by a plant height of 120.8 cm (an 18.2% increase) achieved with the application of Isabion in T3, compared to the minimum plant height of 102.2 cm in the control plot.

The number of fruit branches ranged from 11.8 to 18.6, recorded after 120 days of sowing under the treatments, as shown in Table 1. The maximum number of fruit branches, 18.6, with a 74% increase over the control, was observed with T1 (Quantis spray). This was followed by 15.7 fruit branches (46% increase over control) in T2, where Seamaxx was sprayed, compared to the minimum of 10.7 fruit branches in the control plot.

The mean data in Table 1 show that foliar spraying of different amino acids gradually enhanced plant height and the number of fruiting branches over a 30-day interval when compared to the control. The enhancement in plant height and sympodial branches due to amino acid foliar spraying could be attributed to their role in promoting the production of growth hormones, such as gibberellic acid, which stimulate cellular proliferation and expansion (Sadak et al., 2015), and increase chlorophyll concentration (Hammad and Ali, 2014), ultimately improving photosynthetic efficiency and mineral nutrient uptake (Sadak et al., 2015).

Table 1. Effect of various amino acids on height of plant and No. of sympodial branches, under semi-arid conditions of Sahiwal, Pakistan during Kharif 2022-23 (mean data).

Treatments	**Height of Plant (cm)**			**% increase**	**No. of sympodial branches**			**% increase**
	Days after sowing				**Days after sowing**			
	60	**90**	**120**		**60**	**90**	**120**	
T_1 Quantis	112.4	116.8	121.6	19	11.5	14.8	18.6	74
T_2.Seamax	111.2	115	119.2	16.6	9.7	12.6	15.7	46
T_3.Isabion	112	116	120.8	18.2	10.7	11.5	14.5	35
T_4. Water spray	96.4.	104.2	109	6.6	8.5	10.4	11.8	10
T_5. Control	95.2	98	102.2	-	8.1	9.6	10.7	-

*T1 Quantis, @400ml/acre; bio stimulant based on (amino acids and peptides), T2.Seamax @330ml/acre a.i. Ascophyllum Nodosum (Bio-Stimulant), formulated together with nitrogen, phosphorus plant-available micronutrient T3, Isabion @400ml/acre bio stimulant based on (amino acids and peptides)

The boll number per plant is a crucial yield parameter in cotton, significantly affecting overall productivity. Data revealed that foliar application of amino acids significantly influenced boll number per plant during both cropping seasons, as shown in Tables 2 and 3. The maximum number of bolls (29.6 and 33.4) was produced with T1, where Quantis was sprayed, followed by 28.4 and 32.6 bolls in T3, where Isabion was applied. The minimum number of bolls (20.2 and 23.4) was observed in the control plot during 2022 and 2023, respectively.

The foliar application of amino acids also significantly increased protein content, likely due to the conversion of amino acids into proteins, a crucial step in protein synthesis, as discussed by Hammad and Ali (2014) and El-Ghareib et al. (2014).

Various amino acids significantly affected boll number per plant, boll mass, seed index, lint percentage, seed cotton yield, and lint yield ($p < 0.05$) during Kharif 2022 and 2023 (Tables 2 and 3). The highest seed cotton yield (3865 and 4554 kg/ha) was produced from

T1 (Quantis spray), followed by 3762 and 4456 kg/ha from T3 (Isabion spray). In contrast, the control plot (T5) yielded the lowest seed cotton output of 3051 and 4080 kg/ha. Maximum boll weight, seed index, and lint percentage (3.25g, 10.49g, and 37.2%) were observed in T1, followed by T3 (3.18g, 10.17g, and 36%). The control plot (T5) recorded the lowest values (2.5g, 8.53g, and 30.7%) for these parameters during 2022-23 (Table 4). The highest mean lint yield (1556.8 kg/ha) was recorded in T1 (Quantis spray), followed by 1471.2 kg/ha in T3 (Isabion spray), while the control plot (T5) produced 1099.8 kg/ha. Results from Kharif 2022 (Table 2) indicated that T2 and T3 had a non-significant effect on boll number per plant and seed cotton yield, with T3 (Isabion) ranking highest. Similarly, T1 and T3 did not significantly affect boll weight, although T1 (Quantis) resulted in the maximum boll weight.

For profitable cotton production, growers may consider using Quantis @ 400 ml/acre as a foliar spray at 60, 90, and 120 days after sowing.

The conclusions align with findings from Arif et al. (2019), Koukounaras et al. (2013), and Sadak et al. (2015), who reported that amino acids positively impacted plant physiological processes, promoting growth and increasing productivity. These results are also consistent with Gebaly et al. (2013), who found that foliar sprays of amino acids improved various growth and yield parameters, including fruiting branches, plant height, and boll number per plant, seed index, boll weight, lint percentage, and seed cotton production per acre. Furthermore, Liu and Lee (2012) concluded that foliar application of amino acids enhanced fresh and dry matter yield in vegetable crops.

Table 2. Effect of various amino acids on yield and yield components under semi-arid conditions of Sahiwal, Pakistan during Kharif 2022

Treatments ml ha^{-1} .	**Boll number plant^{-1}**	**Boll mass(g)**	**Seed index (g)**	**Lint (%)**	**Seed cotton yield (kg/ ha)**	**Lint yield (kg/ ha)**
T_1 Quantis	29.6a	3.17a	10.35a	35.8a	3865a	1367.9a
T_2.Seamax	27.8b	2.91b	9.12c	33.2c	3694b	1217.7b
T_3.Isabion	28.4b	3.11a	10.22b	34.5b	3762b	1281b
T_4. Water spray	25.4c	2.76c	8.67d	31.6d	3459c	1078c
T_5. Control	20..2d	2.45d	8.17e	28.9e	3051d	879.7d
LSD	**0.851**	**0.091**	**0.106**	**1.17**	**91.27**	**72.1**

Means with different letters in the column are significantly different at the 5% probability leve.; T1: Quantis @ 400 ml/acre, a bio-stimulant based on amino acids and peptides; T2: Seamaxx @ 330 ml/acre, containing Ascophyllum Nodosum (bio-stimulant), formulated with nitrogen, phosphorus, and plant-available micronutrients; T3: Isabion @ 400 ml/acre, a bio-stimulant based on amino acids and peptides.

Table 3. Effect of various amino acids on yield and yield components under semi-arid conditions of Sahiwal, Pakistan during Kharif 2023

Treatments ml/ha .	**Boll number/plant**	**Boll mass(g)**	**Seed index (g)**	**Lint (%)**	**Seed cotton yield (kg/ ha)**	**Lint yield (kg/ ha)**
T_1 Quantis	33.4a	3.34a	10.64a	38.6a	4554a	1745.8a
T_2.Seamax	31.8c	3.14b	9.75c	36.4c	4394c	1578.4c
T_3.Isabion	32.6b	3.26a	10.13b	37.5b	4456b	1661.5b
T_4. Water spray	27.6d	2.94c	9.27d	34.8d	4315d	1490.8d
T_5. Control	23..4e	2.56d	8.89e	32.5e	4080e	1320e
LSD	**0.674**	**0.113**	**0.34**	**0.81**	**61.16**	**65.4**

Means with varying letter in the column are significant at the 5% probability level. T1 Quantis, @400ml/acre; bio stimulant based on (amino acids and peptides), T2.Seamax @330ml/acre a.i. Ascophyllum Nodosum(Bio-Stimulant), formulated together with nitrogen, phosphorus plant-available micronutrient T3, Isabion @400ml/acre bio stimulant based on (amino acids and peptides)

Furthermore, it was shown that applying amino acids at the flower initiation stage might improve cotton boll carbohydrate conversion capability, as well as glucose and fructose contents, which is favorable to growth of boll and lint yield generation (Liu et al., 2023). Positive linear correlations (R^2=0.96, 0.98) between boll weight and output of seed cotton during Kharif 2022 and 2023 support these findings (Fig.1). The mean results showed a significant linear connection (R^2=0.99,0.86) among the boll number/plant, seed index, and seed cotton output in both years (Fig 2,3). It was discovered that increasing boll number/plant, boll weight, and the seed index linearly improved seed cotton output owing to the injection of amino acids at the maximum flowering stage, which raised boll protein production and carbohydrate content.

Table 4. Effect of various amino acids on yield and yield components under semi-arid conditions of Sahiwal, Pakistan during Kharif 2022-23 (mean data)

Treatments ml/ha .	**Boll number/plant**	**Boll mass(g)**	**Seed index (g)**	**Lint (%)**	**Seed cotton yield (kg/ ha)**	**Lint yield (kg/ ha)**
T_1 Quantis	31.5a	3.255a	10.49a	37.2a	4209.5a	1556.85a
T_2.Seamax	29.8b	3.025c	9.43c	34.8c	4044b	1398.05c
T_3.Isabion	30.5b	3.185b	10.17b	36b	4109b	1471.25b
T_4. Water spray	26.5c	2.850d	8.97d	33.2d	3887c	1284.4d
T_5. Control	21.8d	2.505e	8.53e	30.7e	3565.5d	1099.85e
LSD	**0.867**	**0.064**	**0.263**	**0.92**	**86.7**	**69.8**

Means with varying letter in the column are significant at the 5% probability level. T1 Quantis, @400ml/acre; bio stimulant based on (amino acids and peptides), T2.Seamax @330ml/acre a.i. Ascophyllum Nodosum(Bio-Stimulant), formulated together with nitrogen, phosphorus plant-available micronutrient T3, Isabion @400ml/acre bio stimulant based on (amino acids and peptides)

Conclusion

During Kharif 2022 and 2023, significant differences ($p < 0.05$) were observed in boll number, boll weight, seed index, lint percentage, seed cotton yield, and lint yield. Seed cotton yield increased linearly with boll number and boll weight. Cotton growers can optimize their profitability by utilizing amino acid foliar sprays on their crops. The highest seed cotton yields (3865 and 4554 kg/ha) were obtained with T1, where Quantis was applied at 400 ml/acre. This treatment not only improves yield but also helps protect against drought, heat stress, and cold injury. Additionally, it promotes root growth, stimulates aggressive bud development, induces more flowering, enhances pollination and fruit set, and increases both the quantity and quality of the harvest.

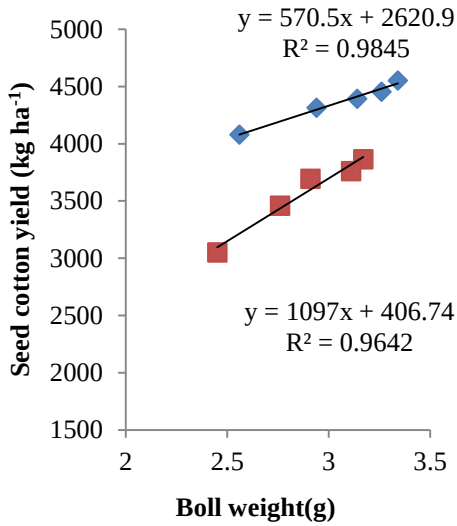

Figure 1. Linear correlation between boll weight and seed cotton yield in years (2022 and 2023)

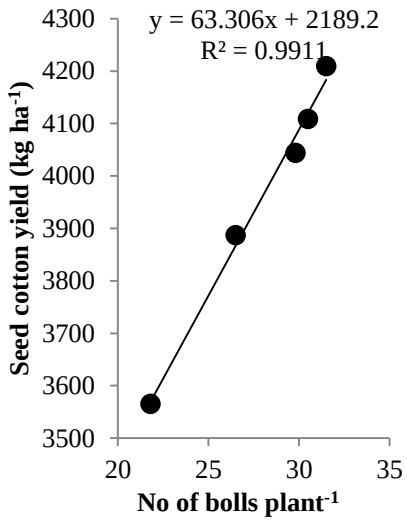

Figure 2. Linear correlation between No of bolls/plant and seed cotton yield (mean data 2022-23)

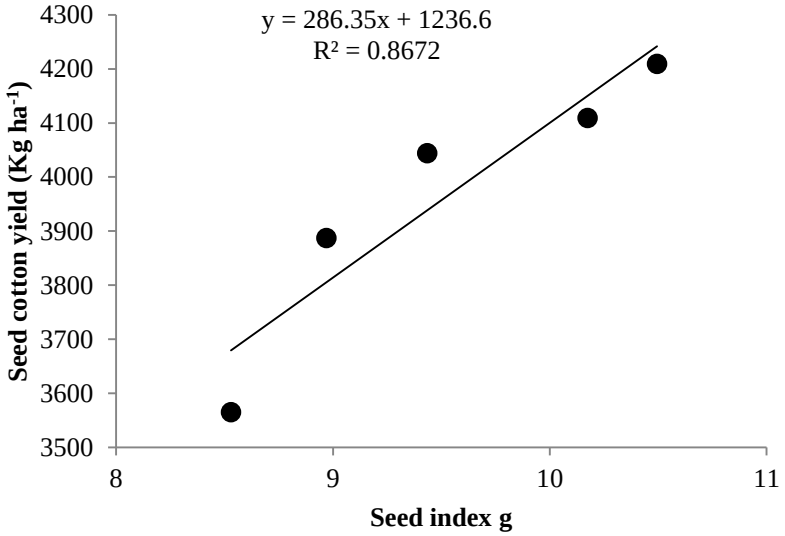

Figure 3. Linear correlation between boll weight and seed cotton yield (mean data)

Declaration

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Competing of Interest

The authors declare that the research was carried without any commercial or financial relationships that could be construed as a potential conflict of interest.

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