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Effect of Spraying Foliar Amino Acids with Micronutrients on Seed Yield and Its Quality of Some Soybean Varieties Under Reclaimed Soil Conditions in Upper Egypt

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ABSTRACT

Background and Objective: Agriculture in Upper Egypt faces challenges due to the region's high salinity and high temperatures. A field trial was conducted in 2021 and 2022 summer seasons at the newly reclaimed soils of the Agricultural Research Station of Al-Marashda, Qena Governorate, Egypt. The study aimed to evaluate the effects of foliar spraying of amino acids with micronutrients in addition to water (as control), on seed yield and its quality of Giza 21, Crawford and Giza 111 under reclaimed soil conditions in Upper Egypt. **Materials and Methods:** Twelve treatments were the combinations between foliar spraying of four rates of amino acids with micronutrients (1.0, 1.5 and 2.0 cm^3/L in addition to water as control) and three soybean varieties (Giza 111, Giza 21 and Crawford). The experiment was arranged in a split-plot design with three replicates, foliar spraying of amino acids with micronutrient rates was assigned in the main plots and the three soybean varieties were distributed in the sub-plots. **Results:** The Giza 111 variety showed superior performance compared to other varieties, exhibiting the highest vegetative growth when treated with 2.0 cm^3/L of amino acids and micronutrients on its leaves. At harvest, foliar spraying of amino acids with micronutrients at a rate of 2.0 cm^3/L on soybean plants led to superior seed yield and its components, as well as seed quality, compared to the other rates. Similarly, Giza 111 outperformed Crawford in terms of pod number/plant, seed yield/plant and seed yield/fad, as well as seed quality. **Conclusion:** The Giza 111 exhibited a significant increase in seed yield and its quality when treated with 2.0 cm^3/L of amino acids with micronutrients, leading to the highest profitability under environmental conditions in Upper Egypt.

KEYWORDS

Soybean genotypes, reclaimed soils, salinity, amino acids, micronutrients, seed yield, seed quality

INTRODUCTION

In Egypt, the salinity of the soil and the expansion of urban areas into formerly farmed areas are the main obstacles to agricultural productivity. Because soybeans (*Glycine max* L.) fix atmospheric nitrogen (N), soybeans can serve as a great way to improve soil fertility, especially on reclaimed land with high climatic temperatures. Soybeans are an important crop in Egypt, but they are also a key source of protein for

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people all across the world. Soybeans are important economically and as Egypt has little land for cultivation, efforts are focused on sowing them on recently recovered soils. With a production per ha of about 3.60 tons, soybean acreage expanded to over 63 thousand ha in 2022, according to Abdel-Wahab *et al.*[1]. Soybeans are also used to manufacture vegetable oil seed, which is fed to livestock and consumed by people in developing countries. Seeds of this crop have good nutritional value for humans[2] and livestock[3]. Soybean seeds are rich in edible oil, protein, vitamins and minerals[4]. However, abiotic stresses, including high temperatures and salinity, can have an impact on global agricultural productivity in the present period[5].

It has been estimated that about 30% of Egypt's arable land is salinized. Soils with elevated soluble salt concentrations are known as salt-affected soils (saline and sodic) and they have a negative impact on the growth and yield of most crops[6]. According to Ashraf and Wu[7], soybeans are a crop that is fairly tolerant of salt and will produce less in the end if the soil salinity is higher than 5 dS/m. Moreover, temperature is one of the most important abiotic stresses for crop growth globally[8] and it also lowers yields[9,10]. Heat stress during the soybean seed filling stage decreases seed germination, vigor and quality, as well as yield and its components[11,12]. To enhance seed output, Chinese farmers in Northeast China employed soybean varieties that exhibited a prolonged growth period and great heat tolerance[13]. When filling seeds, high temperatures led to a rise in lipid content but a decrease in protein content[14]. It is anticipated that combining these stresses will lead to damage to soybean yield. As temperatures rise, the negative consequences of salinity may become more pronounced. Particularly, Nikolić *et al.*[15] reports that even at the lowest saline level (4 dS/m), soybeans show the greatest susceptibility to salt of any crop, with a temperature-dependent decline in germination of 21-45%. Studying soybean varieties under these abiotic stresses is therefore necessary for the development and breeding of soybeans.

Consequently, in order to ensure a sustainable crop yield, new techniques should be developed to improve plant salinity tolerance in these areas and generate salt-tolerant crops[16,17]. An *et al.*[18] claim that because of the variations in their roots, the tolerant soybean species have superior growth tendencies over the susceptible ones. Compared to sensitive species, tolerant species' roots absorb less salt[19]. The sensitivity of the various soybean varieties to high temperatures varied, as demonstrated by Onat *et al.*[20]. They also mentioned that high temperatures adversely affected the varieties of soybeans' seed yield. With rising temperatures, Burroughs *et al.*[21] demonstrated a significant drop in pod yield and harvest index. According to Yoosefzadeh-Najafabadi *et al.*[22], the weight of 1000 seeds and the number of pods per plant are the most significant and crucial elements influencing soybean output. Hence, many varieties are negatively affected by even low salt levels, while some are only mildly tolerant of salinity. Subsequently, saline soil conditions may require spraying a combination of amino acids with micronutrients to improve soybean crop productivity and seed quality at high temperatures.

Rai[23] stated that amino acids are essential for fostering cell growth since they are parts and building blocks of proteins. Amino acids have a significant role in plant metabolism, including the production of vitamins, nucleotides and hormones. The amino acids enhance plant growth physiology[24]. Research has shown that adding exogenous amino acids can boost the growth promotion effects of soybeans[25]. Additionally, micronutrients are essential for plant growth, although they are required in smaller quantities compared to macronutrients[26]. Iron (Fe) is necessary for the synthesis of chlorophyll in plants and is also involved in the upkeep of the structure and functionality of chloroplasts[27]. Zinc (Zn), which is found in many enzymes, is known to make plants more tolerant to hot, dry weather[28]. Meanwhile, manganese (Mn) is involved in many different types of enzyme-catalyzed reactions, such as hydrolysis, phosphorylation, decarboxylation and redox reactions[29]. Magnesium (Mg) is necessary for the growth of the skeleton[30]. It is required for the structural stability of macromolecules such as nucleic acids, according to Sreedhara and Cowan[31]. Foliar sprays that fertilize with molybdenum (Mo) can efficiently restore internal Mo deficits and restore Mo activity[32]. On the other hand, Hu *et al.*[33] have shown that cobalt (Co) is an essential component of vitamin B12, which is required by numerous enzymes involved in the fixation of N. Nickel (Ni) is important for plant antioxidant metabolism, especially under stressful conditions, as shown by Fabiano *et al.*[34].

Accordingly, Gul *et al.*[35] revealed that the efficiency of micronutrients will be obtained with the addition of macronutrients. Micronutrients had an impact on soybean variety growth, development, yield formation and seed quality against the backdrop of mineral fertilizers. The practice time of a soybean variety is prolonged when microelements are present[36]. In this respect, El-Azab[37] studied the effects of NPK fertilizers with micronutrients spraying at different amino acid levels on soybean plants. Their results showed that spraying of NPK with 2.0 g/L amino acids plus micronutrients as 2.0 kg/fad increased the growth of soybean plants compared to the control. Therefore, this experiment aimed to evaluate the effects of foliar spraying of amino acids with micronutrients at 1.0, 1.5 and 2.0 cm^3/L rates in addition to water (as control) on the growth and yield, along with seed quality of Giza 21, Crawford and Giza 111, under reclaimed soil conditions in Upper Egypt.

MATERIALS AND METHODS

The present study was carried out at Al-Marashda Agricultural Research Station, ARC, Qena Governorate, Egypt (26°9'N, 32°42'E), during the two successive seasons of 2021 and 2022. Twelve treatments were the combinations between foliar spraying of four rates of amino acids with micronutrients (1.0, 1.5 and 2.0 cm^3/L in addition to water as control) and three soybean varieties (Giza 111, Giza 21 and Crawford).

A split-plot design with three replicates was used for this experiment; foliar spraying of amino acids with micronutrient rates was assigned in the main plots and the three soybean varieties were distributed in the sub-plots. The soybean seeds got from the Field Crops Research Institute, ARC, Egypt. Four seeds per hill, spaced at 20 cm, were sown on one side of the ridge at a depth of 3 cm on May 18th and May 8th, 2021 and 2022, respectively. Plants were thinned to two per hill after full germination 18 days after sowing. As 4.0 m in length and 60 cm in width made up the 3.0×4.0 m experimental unit. Before seeding in both seasons, phosphorus was provided as calcium superphosphate (15.5% P_2O_5) at a rate of 100 kg/fad. Before the first irrigation, 50 kg/fad of potassium sulfate (48% K_2O) was applied. A 60 kg N/fad mineral N fertilizer was applied in the form of ammonium sulfate (20.6% N) in three equal doses before the first, second and third irrigations.

In this experiment, a drip irrigation system was used. From sowing until harvest, irrigation was applied for 30 min each day. Over the two summer seasons, solar radiation, minimum and maximum temperatures and relative humidity were presented in Table 1, 2 and 3, respectively, present the results of the chemical analysis performed on the experimental site and irrigation water.

The components of the micronutrient complex are as follows: 10% amino acids; 3.5% Fe; 2.5% Zn; 2% Mn; 1.5% Mg; 0.1% Mo; 0.1% Co and 0.001% Ni. The AGIAD, Cairo, Egypt's Agricultural Technology Developed Company, produces it. At New Valley University in Egypt, the Soils Department used techniques[38,39] to analyze the mechanical and chemical properties of soil (0-30 cm) as well as water in the experimental soil.

Wheat was the preceding winter crop in both seasons. The other prescribed cultural procedures for soybean plants were followed. Using a hand-operated compressed air sprayer, soybean plants were treated three times throughout each growing season-30, 45 and 60 days following sowing.

Studied traits

Vegetative growth: Ten plants from each treatment were randomly taken 80 days after sowing to measure plant growth traits such as plant height, number of branches/plant and dry weights of shoots (leaves and stems)/plant. The vegetative parts were dried at 60ºC for 3-5 days to measure the dry weight/plant.

Table 1: Meteorological data of solar radiation, minimum and maximum temperatures and relative humidity during the two summer seasons

Months	Solar radiation ($MJ/m^2/day$)	Minimum temperature (°C)	Maximum temperature (°C)	Relative humidity (%)
First season				
May	29.07	21.27	40.16	17.12
June	29.29	23.32	41.12	19.11
July	28.11	25.35	41.78	20.75
August	26.91	24.79	42.22	20.51
September	24.08	22.64	39.52	27.60
Second season				
May	27.56	21.52	39.27	17.02
June	28.84	24.09	40.42	21.45
July	28.70	24.14	40.57	20.86
August	26.02	26.05	42.09	23.21
September	23.60	23.15	40.42	25.62

Table 2: Physical and chemical properties of the experimental soil

Properties	Soil depth (0-30 cm)	Properties	Soil depth (0-30 cm)
Sand (%)	81.00	pH (1:5)	08.01
Silt (%)	12.30	Na^+ (meq/L)	30.00
Clay (%)	6.70	K^+ (meq/L)	00.84
Texture class	Sandy	Ca^{++} (meq/L)	12.10
$CaCO_3$ (%)	81.10	Mg^{++} (meq/L)	06.40
EC (dS/m) (1 : 2.5)	3.03	CO^{-} (meq/L)	00.01

EC: Electrical conductivity

Table 3: Water analysis of the water for the experimental site

Properties	Analysis	Properties	Analysis
TDS (mg/L)	225.00	Na^+ (mg/L)	31.40
pH (1:5)	7.60	K^+ (mg/L)	06.30
EC (dS/m) (1 : 2.5)	3.30	CO_3^-	24.10
Ca^{++} (mg/L)	28.30	HCO_3^-	110.00
Mg^{++} (mg/L)	8.60	SO_4^-	41.30

TDS: Total dissolved solids and EC: Electrical conductivity

Seed yield and yield components: At harvest, ten plants were randomly taken to estimate the following traits: Number of pods/plant, 100-seed weight (g) and seed yield/plant (g). Seed yield/fad was recorded based on the experimental plot (kg) and then converted to ton/fad [One ha is equivalent to 2.38 fad].

Quality of soybean seeds: Seed total amino acids, protein and oil contents were determined by the Chemistry Department, Faculty of Agriculture, South Valley University. The total amino acids were determined using the ethanol extract of dry material. Total free amino acids were determined using ninhydrin reagent according to Moore and Stein[40]. The N was calculated using Parnas-Wagner's micro-kejeldahl device, as detailed by Horneck and Miller[41]. The amount of protein and crude oil in the seed was measured using methods outlined by Al-Moakail *et al.*[42].

Economic evaluation: An economic evaluation was conducted to compare the costs and returns for soybean varieties that were sprayed with amino acids and micronutrients compared to those with untreated treatment. The average production costs of soybeans/fad were recorded from market price. The production costs were 11430 Egyptian pounds/fad and the sale price of soybeans was 40000 Egyptian pounds/ton (market price) (One euro is equivalent to 33.41 Egyptian pounds). Net profit (Egyptian pounds/fad) was calculated by subtracting the financial costs from the gross returns. The benefit-cost (B:C) ratio was obtained by taking the ratio of gross returns to the financial costs. The price of the compound of amino acids with micronutrients was 30 Egyptian pounds/cm^3.

Statistical analysis: The recorded data from the two seasons were subjected to analysis of variance and LSD at 5% was used to evaluate the differences between means according to Snedecor and Cochran[43].

RESULTS

Vegetative growth traits at 80 days from sowing

Foliar spraying of amino acids with micronutrients rates: The application of amino acids with micronutrients had a significant impact on plant growth, as indicated in Table 4. Foliar spraying at rates of 1.5 and 2.0 cm^3/L resulted in higher values for plant height (79.78 and 81.84 cm in the first season, 77.76 and 81.51 cm in the second season, respectively), number of branches/plants (4.13 and 4.76 in the first season, 4.50 and 4.77 in the second season, respectively) and plant dry weight (85.42 and 88.77 g in the first season, 87.29 and 90.34 g in the second season, respectively), compared to other rates in both seasons.

Soybean varieties: Soybean varieties showed significant differences in plant height, number of branches per plant and plant dry weight in both seasons (Table 5). The Giza 111 had the highest values for plant height (80.83 and 81.10 cm in the first and second seasons, respectively), number of branches/plants (4.73 and 5.10 in the first and second seasons, respectively) and plant dry weight (90.29 and 90.81 g in the first and season seasons, respectively), followed by Giza 21 (78.03 cm in the first season and 77.05 cm in the second season for plant height, 4.12 in the first season and 4.53 in the second season for number of branches/plants and 83.55 g in the first season and 85.82 g in the second season for plant dry weight). Crawford ranked the lowest (72.79 cm in the first season and 71.53 cm in the second season for plant height, 3.68 in the first season and 3.94 in the second season for number of branches/plants and 79.44 g in the first season and 82.58 g in the second season for plant dry weight). Specifically, in the first season, the plant height of Giza 111 was increased by 3.58 and 11.04% compared to Giza 21 and Crawford, respectively. In the second season, these values were 5.25 and 13.37%, respectively. In terms of the number of branches/plant, Giza 111 had 14.80 and 28.53% more branches compared to Giza 21 and Crawford, respectively, in the first season. In the second season, these values were 12.58 and 29.44%, respectively. Regarding plant dry weight, Giza 111 had 8.06 and 13.65% more dry weight compared to Giza 21 and Crawford, respectively, in the first season. In the second season, these values were 5.81 and 9.96%, respectively.

Interaction between foliar spraying of amino acids with micronutrients rates and soybean varieties: The interaction between foliar spraying of amino acids with micronutrients rates and soybean varieties on plant height, number of branches/plant and plant dry weight were observed (Table 6). The highest relative increase of plant height was recorded with Giza 111 which received 2.0 cm^3/L, while the lowest was that of untreated Crawford. In other words, foliar spraying of Giza 111 with 2.0 cm^3/L gave the highest plant height (85.53 cm in 1st season and 84.83 cm in 2nd season) with a significant increase of 18.86 and 23.10 cm, respectively, over the control treatment with Crawford (66.67 cm in 1st season and 61.73 cm in 2nd season). Also, the highest relative increase in number of branches/plants was recorded with Giza 111 which received 2.0 cm^3/L, while the lowest was that of untreated Crawford. In other words, foliar spraying of Giza 111 with 2.0 cm^3/L gave the highest number of branches/plant (5.77 in 1st season and 5.57 in 2nd season) over the control treatment with Crawford (3.37 in 1st season and 3.63 in 2nd season).

Moreover, the highest relative increase in plant dry weight was recorded with Giza 111 which received 2.0 cm^3/L, while the lowest was that of untreated Crawford. In other words, foliar spraying of Giza 111 with 2.0 cm^3/L gave the highest plant dry weight (97.73 g in 1st season and 96.80 g in 2nd season) with a significant increase of 21.30 and 18.27 g, respectively, over the control treatment with Crawford (76.43 g in 1st season and 78.53 g in 2nd season).

Table 4: Effect of foliar spraying of amino acids with micronutrients rates on some vegetative growth traits of soybean plants at 80 days from sowing in both seasons

Treatments	Plant height (cm)	Number of branches/plant	Plant dry weight (g)
First season			
Control	69.59	3.71	79.80
1.0 cm^3/L	77.66	4.11	83.72
1.5 cm^3/L	79.78	4.13	85.42
2.0 cm^3/L	81.84	4.76	88.77
LSD 0.05	2.04	0.63	3.17
Second season			
Control	68.41	4.14	81.57
1.0 cm^3/L	71.89	4.68	86.41
1.5 cm^3/L	77.76	4.50	87.29
2.0 cm^3/L	81.51	4.77	90.34
LSD 0.05	3.16	0.58	2.11

Table 5: Some vegetative growth traits of three soybean varieties at 80 days from sowing in both seasons

Treatments	Plant height (cm)	Number of branches/plant	Plant dry weight (g)
First season			
Giza 111	80.83	4.73	90.29
Giza 21	78.03	4.12	83.55
Crawford	72.79	3.68	79.44
LSD 0.05	1.62	0.47	2.34
Second season			
Giza 111	81.10	5.10	90.81
Giza 21	77.05	4.53	85.82
Crawford	71.53	3.94	82.58
LSD 0.05	2.32	0.39	1.72

Table 6: Interaction between foliar spraying of amino acids with micronutrients rates and soybean varieties on some vegetative growth traits at 80 days from sowing in both seasons

Treatments		Plant height (cm)	Number of branches/plant	Plant dry weight (g)
First season				
Giza 111	Control	73.97	4.13	82.80
	1.0 cm^3/L	81.33	4.53	88.37
	1.5 cm^3/L	82.47	4.50	92.27
	2.0 cm^3/L	85.53	5.77	97.73
Giza 21	Control	68.13	3.63	80.17
	1.0 cm^3/L	78.17	4.13	84.33
	1.5 cm^3/L	82.33	4.20	84.27
	2.0 cm^3/L	83.50	4.53	85.43
Crawford	Control	66.67	3.37	76.43
	1.0 cm^3/L	73.47	3.67	78.47
	1.5 cm^3/L	74.53	3.70	79.73
	2.0 cm^3/L	76.50	3.97	83.13
LSD 0.05		03.34	1.02	3.68
Second season				
Giza 111	Control	75.37	4.53	84.43
	1.0 cm^3/L	81.73	5.13	89.37
	1.5 cm^3/L	82.47	5.17	92.63
	2.0 cm^3/L	84.83	5.57	96.80
Giza 21	Control	68.13	4.27	81.73
	1.0 cm^3/L	78.27	4.77	86.77
	1.5 cm^3/L	78.37	4.50	86.13
	2.0 cm^3/L	83.43	4.57	88.63
Crawford	Control	61.73	3.63	78.53
	1.0 cm^3/L	75.67	4.13	83.10
	1.5 cm^3/L	72.43	3.83	83.10
	2.0 cm^3/L	76.27	4.17	85.60
LSD 0.05		4.14	0.92	2.83

Seed yield and yield components

Foliar spraying of amino acids with micronutrient rates: Foliar spraying of amino acids with micronutrient rates had a significant effect on seed yield and yield components in both seasons, as shown in Table 7. Foliar spraying of 1.5 and 2.0 cm^3/L led to higher values for the number of pods/plant (66.66 and 69.08 in the first season, 66.21 and 67.20 in the second season, respectively), seed yield/plant (11.29 and 12.47 g in the first season, 11.57 and 11.99 g in the second season, respectively), 100-seed weight (12.03 and 14.10 g in the first season, 11.52 and 13.05 g in the second season, respectively) and seed yield/fad (0.78 and 0.86 t in the first season, 0.81 and 0.85 t in the second season, respectively) compared to the other rates in both seasons.

Soybean varieties: In both seasons, there were notable variations in the seed yield and yield components of three soybean varieties (Table 8). The highest values for the number of pods/plant (67.28 in the first season and 67.30 in the second season), seed yield/plant (12.96 g in the first season and 12.09 g in the second season) and seed yield/fad (0.87 t in the first season and 0.84 t in the second season) were observed in Giza 111. The Giza 21 came in the second rank (63.74 in the first season and 65.09 in the second season for number of pods/plant, 11.08 g in the first season and 10.73 g in the second season for seed yield/plant and 0.75 t in the first season and 0.76 t in the second season for seed yield/fad). Crawford, on the other hand, weighed more than the other varieties at 100 seeds (13.25 g in the first season and 13.02 g in the second season).

With respect to number of pods/plant, number of pods of Giza 111 increased by 5.55 and 10.00% compared to Giza 21 and Crawford in the first season, respectively. In the second season, these values were 3.39 and 9.20%, respectively.

With respect to seed yield/plant, seed yield of Giza 111 was increased by 16.96 and 33.47% compared to Giza 21 and Crawford, respectively. In the second season, these values were 12.67 and 21.62%, respectively. There was a significant difference in 100-seed weight among the tested soybean varieties, 100-seed weight of Crawford was increased by 17.67 and 32.63% compared to Giza 21 and Giza 111, respectively, in the first season. In the second season, these values were 12.14 and 29.16%, respectively. With regard to seed yield/fad, seed yield of Giza 111 was increased by 16.00 and 24.28% compared to Giza 21 and Crawford, respectively, in the first season. In the second season, these values were 10.52 and 18.30%, respectively.

Interaction between foliar spraying of amino acids with micronutrient rates and soybean varieties: The interaction between foliar spraying of amino acids with micronutrient rates and soybean varieties on seed yield and yield components was observed (Table 9). The highest values of number of pods/plant (73.70 in the first season and 71.47 in the second season), seed yield/plant (14.32 g in the first season and 13.41 g in the second season) and seed yield/fad (0.96 t in the first season and 0.95 t in the second season) were recorded with Giza 111 which received 2.0 cm^3/L of amino acids and micronutrients, while the lowest was that of untreated Crawford (56.77 in the first season and 58.23 in the second season for number of pods/plant, 8.66 g in the first season and 8.82 g in the second season for seed yield/plant and 0.62 tons in the first season and 0.63 t in the second season for seed yield/fad). The highest values of 100-seed weight (16.30 g in the first season and 15.33 g in the second season) were recorded with Crawford which received 2.0 cm^3/L of amino acids and micronutrients.

Seed quality

Foliar spraying of amino acids with micronutrient rates: Foliar spraying of amino acids with micronutrient rates had a significant effect on seed quality in both seasons, as shown in Table 10. In comparison to other rates in both seasons, foliar spraying of 1.5 and 2.0 cm^3/L of amino acids with

Table 7: Effect of foliar spraying of amino acids with micronutrient rates on seed yield and yield components of soybean plants in both seasons

Treatments	Number of pods/plant	Seed yield/plant (g)	100-seed weight (g)	Seed yield/fad (t)
First season				
Control	59.03	9.74	9.01	0.68
1.0 cm^3/L	61.47	11.50	10.88	0.77
1.5 cm^3/L	66.66	11.29	12.03	0.78
2.0 cm^3/L	69.08	12.47	14.10	0.86
LSD 0.05	3.27	2.08	1.95	0.15
Second season				
Control	61.60	9.38	8.37	0.66
1.0 cm^3/L	63.69	10.74	10.68	0.74
1.5 cm^3/L	66.21	11.57	11.52	0.81
2.0 cm^3/L	67.20	11.99	13.05	0.85
LSD 0.05	2.12	1.62	1.22	0.12

Table 8: Seed yield and yield components of three soybean varieties in both seasons

Treatments	Number of pods/plant	Seed yield/plant (g)	100-seed weight (g)	Seed yield/fad (t)
First season				
Giza 111	67.28	12.96	9.99	0.87
Giza 21	63.74	11.08	11.26	0.75
Crawford	61.16	9.71	13.25	0.70
LSD 0.05	2.41	1.68	1.42	0.11
Second season				
Giza 111	67.30	12.09	10.08	0.84
Giza 21	65.09	10.73	11.61	0.76
Crawford	61.63	9.94	13.02	0.71
LSD 0.05	1.86	1.45	0.96	0.08

Table 9: Interaction between foliar spraying of amino acids with micronutrient rates and soybean varieties on seed yield and yield components of soybean plants at harvest in both seasons

Treatments		Number of pods/plant	Seed yield/plant (g)	100-seed weight (g)	Seed yield/fad (t)
First season					
Giza 111	Control	62.37	10.63	7.93	0.76
	1.0 cm^3/L	64.83	13.96	9.33	0.88
	1.5 cm^3/L	68.20	12.94	10.63	0.87
	2.0 cm^3/L	73.70	14.32	12.06	0.96
Giza 21	Control	57.97	9.91	8.71	0.66
	1.0 cm^3/L	62.30	11.04	10.73	0.74
	1.5 cm^3/L	66.90	11.18	11.69	0.78
	2.0 cm^3/L	67.80	12.19	13.93	0.82
Crawford	Control	56.77	8.66	10.37	0.62
	1.0 cm^3/L	57.27	9.50	12.57	0.68
	1.5 cm^3/L	64.87	9.76	13.76	0.69
	2.0 cm^3/L	65.73	10.92	16.30	0.79
LSD 0.05		4.86	2.89	2.25	0.22
Second season					
Giza 111	Control	63.60	10.00	6.85	0.71
	1.0 cm^3/L	64.87	11.98	8.95	0.81
	1.5 cm^3/L	69.27	12.98	9.45	0.87
	2.0 cm^3/L	71.47	13.41	11.08	0.95
Giza 21	Control	62.97	9.33	7.70	0.66
	1.0 cm^3/L	63.90	10.61	10.52	0.73
	1.5 cm^3/L	67.10	11.28	11.50	0.81
	2.0 cm^3/L	66.40	11.69	12.72	0.82
Crawford	Control	58.23	8.82	10.57	0.63
	1.0 cm^3/L	62.30	9.63	12.58	0.68
	1.5 cm^3/L	62.27	10.44	13.60	0.75
	2.0 cm^3/L	63.73	10.86	15.33	0.78
LSD 0.05		3.41	2.32	1.73	0.18

Table 10: Effect of foliar spraying of amino acids with micronutrient rates on seed quality of soybean plants in both seasons

Treatments	Seed total amino acids content (%)	Seed protein content (%)	Seed oil content (%)
First season			
Control	31.13	33.64	18.54
1.0 cm^3/L	32.32	36.02	17.49
1.5 cm^3/L	32.67	36.59	17.45
2.0 cm^3/L	32.79	37.02	17.39
LSD 0.05	0.38	0.95	0.33
Second season			
Control	30.08	32.64	17.38
1.0 cm^3/L	31.28	35.10	16.47
1.5 cm^3/L	31.62	35.75	16.53
2.0 cm^3/L	31.74	36.12	16.46
LSD 0.05	0.41	0.99	0.39

Table 11: Seed quality of three soybean varieties in both seasons

Treatments	Seed total amino acids content (%)	Seed protein content (%)	Seed oil content (%)
First season			
Giza 111	33.39	36.71	18.09
Giza 21	31.70	35.44	17.53
Crawford	31.59	35.39	17.53
LSD 0.05	0.24	0.61	0.21
Second season			
Giza 111	32.33	35.77	16.87
Giza 21	30.66	34.56	16.67
Crawford	30.54	34.37	16.59
LSD 0.05	0.29	0.74	0.26

micronutrients produced greater values for seed total amino acids (32.67 and 32.79% in the first season, 31.62 and 31.74% in the second season) and protein contents (36.59 and 37.02% in the first season, 35.75 and 36.12% in the second season). Meanwhile, foliar spraying of 1.5 and 2.0 cm^3/L of amino acids with micronutrients resulted in lower results for seed oil content (17.45 and 17.39% in the first season, 16.53 and 16.46% in the second season).

Soybean varieties: In both seasons, there were notable variations in the seed quality of three soybean varieties (Table 11). The highest values for seed total amino acids (33.39% in the first season and 32.33% in the second season), protein (36.71% in the first season and 35.77% in the second season) and oil content (18.09% in the first season and 16.87% in the second season) were found in Giza 111. In terms of total amino acid content, the seeds of Giza 111 showed an increase of 5.33 and 5.69% compared to Giza 21 and Crawford, respectively, in the first season. In the second season, these values were 5.44 and 5.86%, respectively. In the first season, the protein content of Giza 111 seeds increased by 3.58 and 3.72% compared to Giza 21 and Crawford, respectively. In the second season, these values were 3.50 and 4.07%, respectively. In the first season, the seed oil content of Giza 111 increased by 3.19 and 3.19% compared to Giza 21 and Crawford, respectively. In the second season, these values were 1.19 and 1.68%, respectively.

Interaction between foliar spraying of amino acids with micronutrient rates and soybean varieties: This study observed the interaction between the foliar spraying of amino acids with micronutrient rates and soybean varieties on seed quality (Table 12). It is important to note that there were no statistically significant variations found between the rates of 1.5 and 2.0 cm^3/L for any variety of seed total amino acids, protein, or oil content in both seasons. The highest relative increase in seed total amino acids (33.88 and 34.02% in the first season, 32.82 and 32.97% in the second season) or protein content (37.49 and 38.20% in the first season, 36.48 and 37.24% in the second season) was recorded with Giza 111 which received 1.5 and 2.0 cm^3/L of amino acids and micronutrients, while the lowest was that of untreated

Table 12: Interaction between foliar spraying of amino acids with micronutrient rates and soybean varieties on seed quality in both seasons

Treatments		Seed total amino acids content (%)	Seed protein content (%)	Seed oil content (%)
First season				
Giza 111	Control	32.26	34.37	18.92
	1.0 cm^3/L	33.41	36.78	17.87
	1.5 cm^3/L	33.88	37.49	17.82
	2.0 cm^3/L	34.02	38.20	17.75
Giza 21	Control	30.62	33.37	18.35
	1.0 cm^3/L	31.85	35.65	17.30
	1.5 cm^3/L	32.10	36.19	17.28
	2.0 cm^3/L	32.23	36.57	17.22
Crawford	Control	30.51	33.19	18.35
	1.0 cm^3/L	31.70	35.63	17.30
	1.5 cm^3/L	32.04	36.11	17.26
	2.0 cm^3/L	32.14	36.30	17.21
LSD 0.05		0.49	1.08	0.43
Second season				
Giza 111	Control	31.20	33.43	17.14
	1.0 cm^3/L	32.36	35.95	16.62
	1.5 cm^3/L	32.82	36.48	16.90
	2.0 cm^3/L	32.97	37.24	16.82
Giza 21	Control	29.60	32.32	17.55
	1.0 cm^3/L	30.81	34.81	16.45
	1.5 cm^3/L	31.07	35.49	16.38
	2.0 cm^3/L	31.18	35.64	16.30
Crawford	Control	29.46	32.18	17.45
	1.0 cm^3/L	30.67	34.54	16.35
	1.5 cm^3/L	30.98	35.30	16.32
	2.0 cm^3/L	31.07	35.48	16.27
LSD 0.05		0.56	1.15	0.45

Crawford (30.51% in the first season and 29.46% in the second season for seed total amino acids, 33.19% in the first season and 32.18% in the second season for seed protein content and 18.35% in the first season and 17.45% in the second season for seed oil content). The highest relative increase in seed oil content was recorded with untreated Giza 111 (18.92% in the first season and 17.14% in the second season).

Economic evaluation: Data in Table 13 show economic evaluation of three soybean varieties after foliar spraying of amino acids with micronutrients compared to those with untreated treatments in both seasons. In general, foliar spraying of 2.0 cm^3/L of amino acids with micronutrients on leaves of Giza 111 achieved the highest gross returns (L.E. 38400/fad in the first season and L.E. 38000/fad in the second season), net profit (L.E. 26910/fad in the first season and L.E. 26510/fad in the second season) and B:C ratio (3.34 in the first season and 3.30 in the second season) compared to the others in both seasons. Conversely, untreated Crawford achieved the lowest gross returns (L.E. 24800/fad in the first season and L.E. 25200/fad in the second season), net profit (L.E. 13370/fad in the first season and L.E. 13770/fad in the second season) and B:C ratio (2.16 in the first season and 2.20 in the second season) compared to the others in both seasons. With regard to Giza 111, foliar spraying of 2.0 cm^3/L of amino acids with micronutrients increased net profit by 15.36, 13.35 and 41.85%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively, in the first season. In the second season, these values were 13.65, 26.59 and 56.21%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively.

With regard to Giza 21, foliar spraying of 2.0 cm^3/L of amino acids with micronutrients increased net profit by 8.03, 17.47 and 42.35%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively, in the first season. In the second season, these values were 1.83, 20.12 and 42.35%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively.

Table 13: Economic returns of three soybean varieties after foliar spraying of amino acids with micronutrients comparing to those with control treatment

Treatments		Gross returns (Egyptian pounds/fad)	Financial costs (Egyptian pounds/fad)	Net profit (Egyptian pounds/fad)	B:C ratio
First season					
Giza 111	Control	30400	11430	18970	2.65
	1.0 cm^3/L	35200	11460	23740	3.07
	1.5 cm^3/L	34800	11475	23325	3.03
	2.0 cm^3/L	38400	11490	26910	3.34
Giza 21	Control	26400	11430	14970	2.30
	1.0 cm^3/L	29600	11460	18140	2.58
	1.5 cm^3/L	31200	11475	19725	2.71
	2.0 cm^3/L	32800	11490	21310	2.85
Crawford	Control	24800	11430	13370	2.16
	1.0 cm^3/L	27200	11460	15740	2.37
	1.5 cm^3/L	27600	11475	16125	2.40
	2.0 cm^3/L	31600	11490	20110	2.75
Second season					
Giza 111	Control	28400	11430	16970	2.48
	1.0 cm^3/L	32400	11460	20940	2.82
	1.5 cm^3/L	34800	11475	23325	3.03
	2.0 cm^3/L	38000	11490	26510	3.30
Giza 21	Control	26400	11430	14970	2.30
	1.0 cm^3/L	29200	11460	17740	2.54
	1.5 cm^3/L	32400	11475	20925	2.82
	2.0 cm^3/L	32800	11490	21310	2.85
Crawford	Control	25200	11430	13770	2.20
	1.0 cm^3/L	27200	11460	15740	2.37
	1.5 cm^3/L	30000	11475	18525	2.61
	2.0 cm^3/L	31200	11490	19710	2.71

With regard to Crawford, foliar spraying of 2.0 cm^3/L of amino acids with micronutrients increased net profit by 24.71, 27.76 and 50.41%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively, in the first season. In the second season, these values were 6.39, 25.22 and 43.13%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively.

With regard to B:C ratio, foliar spraying of Giza 111 with 2.0 cm^3/L of amino acids and micronutrients increased B:C ratio by 10.23, 8.79 and 26.03%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively, in the first season. In the second season, these values were 8.91, 17.02 and 33.06%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively. With respect to Giza 21, foliar spraying of 2.0 cm^3/L of amino acids with micronutrients increased B:C ratio by 5.16, 10.46 and 23.91%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively, in the first season. In the second season, these values were 1.06, 12.20 and 23.91%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively. With respect to Crawford, foliar spraying of 2.0 cm^3/L of amino acids with micronutrients increased B:C ratio by 14.58, 16.03 and 27.31%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively, in the first season. In the second season, these values were 3.83, 14.34 and 23.18%, as compared with those treated with 1.5, 1.0 cm^3/L and control treatments, respectively.

DISCUSSION

It seems that the foliar application of amino acids with micronutrients enhanced the ability of soybean plants to better utilize available environmental resources, particularly solar radiation (Table 1), during different vegetative growth and development stages at 80 days from sowing. By counteracting the negative effects of salt, these results suggest that micronutrients containing amino acids can improve the development of soybean seedlings. To achieve this, the plant's endogenous regulation is supported, which in turn triggers a range of adaptive responses in plants exposed to high temperatures. High salinity can negatively impact soybean agronomic traits, such as plant height and number of branches/plant[44]. Additionally, salt stress inhibits soybean production by affecting growth and development, while amino acids improve plant growth by affecting primary metabolites, protein synthesis and endogenous hormone levels[45-47].

The Zn plays a crucial role in the photosynthetic process's carbon fixation[48]. It also boosts photosynthetic efficiency, which promotes vegetative development. These results were consistent with those of Dass *et al.*[49], who observed applying chelated Zn at a 0.5% concentration through foliar application during the pod initiation stage resulted in a higher number of pods/plant. Genetic makeup of the varieties may be resulted in variations in internode growth, the rate of branch growth, as well as plant dry weight at 80 days from sowing. According to these data, soil salinity had a greater impact on Crawford's vegetative traits than it did on the other two cultivars. The Crawford variety did not accumulate dry matter, which was indicative of this. Conversely, Giza 111's roots extend far below the surface of the soil[50], away from the salinity of the upper soil layers, which may account for some of its superiority over the other two varieties. This is because salinity inhibits plant growth. Because of the salinity of the soil, Zhang *et al.*[51] discovered two novel cultivars of soybeans out of 257 lines. With respect to high temperature, the reason for Giza 111's superiority over the other two varieties could be attributed to its high pubescence density on its leaves[50], which decreases transpiration when exposed to high temperatures, thereby preserving the water balance of the plant. A difference in the soybean varieties' susceptibility to high temperatures was discovered[20].

With regard to the interaction between foliar spraying of amino acids with micronutrients rates and soybean varieties on vegetative growth traits at 80 days from sowing, the positive impact of foliar spraying of 1.5 and 2.0 cm^3/L on Giza 111 enhances their ability to effectively utilize available environmental resources, especially solar radiation (as shown in Table 1), during different vegetative growth and development stages at 80 days from sowing.

To improve soybean crop productivity, it is important to ensure a balanced supply of both macro- and micronutrients[52]. When comparing the best results achieved with foliar spraying of 1.0 to 2.0 cm^3/L, the data suggests that foliar spraying of amino acids with micronutrients improved yield components. This improvement is likely due to the balanced growth and root architecture, which enhances plant productivity by promoting better nutrient and water uptake from the soil. Rashid *et al.*[53] demonstrated that the highest values for all yield-contributing characteristics were achieved by applying 50% recommended dose of Zn at the base and foliarly applying 0.5% $ZnSO_4.7H_2O$ during the pod formation stage. The best result for yield and its components in soybean resulted from spraying of amino acids with mixed micronutrients[37]. Amino acids alter the root volume and number of lateral roots in soybean plants[54].

On the other hand, growth is negatively affected by salt and heat stress, as it slows down the uptake and transfer of water and nutrients[55,56], which in turn decreases dry matter accumulation during growth and development. The positive effects of the treatments may also be due to the important role of micronutrients in plant photosynthesis, which affects growth and yield[48].

It should be mentioned that one major factor influencing the yield is the number of pods/plant, which has a direct impact on the plant's output. These results were confirmed by Abdel-Wahab *et al.*[57] who showed that Giza 111 outperformed other soybean varieties in terms of pod number/plant. According to Waly[58], the two parental genotypes D89-8940 and Line162 registered the highest mean values of pods/plant. The Giza 111 is most likely responsible for these outcomes. Because Giza 111 was more adept at harnessing solar energy, there was an increase in the accumulation of dry matter in several soybean plant organs during the growth and development stages. The increase in seed yield can be attributed to the plant's ability of Giza 111 to produce more pods. Additionally, a higher number of branches allows for better distribution of resources and nutrients, leading to increased overall productivity. According to Khatun *et al.*[59], the seed reaches its maximum dry weight at physiological maturity. Furthermore, seed yield/plant had the highest mean values for both parental genotypes, D89-8940 and Line162[60]. Meanwhile, there were no significant differences among soybean varieties for 100-seed weight.

The Giza 111 and Giza 21 exhibited the highest number of pods/plant and seed yield/plant, respectively. However, it is worth noting that Crawford surpassed other varieties in terms of weight when considering 100 seeds. These findings highlight the superior performance of Giza 111 and Giza 21 in terms of pod and seed production, while also acknowledging Crawford's heavier seed weight. Crawford was able to utilize solar energy more effectively, leading to increased dry matter accumulation in different parts of the soybean plant. This was demonstrated by the 100-seed weight at various growth stages, including stem elongation, pollination and late seed filling throughout the soybean growth cycle (Table 1). As such, all of the varieties mature in September. That is, high humidity during the seed-filling stage positively impacted both the plant's seed output and the weight of 100 seeds. This resulted in all types under study becoming tolerant to the effects of salinity, with a production that was only roughly 40% of what it was when grown normally in Egypt without the application of amino acids with micronutrient compounds. Elevated humidity is known to promote stomatal conductance, reduce Na influx and enhance root activity-all essential components of plant salt tolerance[18].

Higher values of seed yield/ha were found in the soybean varieties Giza 22 and Giza 111[57]. These results reveal that soil salinity had a greater effect on seed yield and yield components of Crawford than the other two varieties under hot conditions. High salinity may negatively impact soybean agronomic traits such number of pods/plant and seed yield/plant[44].

With respect to the interaction between foliar spraying of amino acids with micronutrient rates and soybean varieties on seed yield and yield components, the high rate of amino acids and micronutrients helps the seeds adapt to and tolerate the salinity stress, resulting in a higher yield of Giza 111. This finding suggests that Giza 111 seeds have developed a mechanism to adapt and thrive in high-salinity environments. Additionally, the increased seed yield under hot conditions indicates the potential of Giza 111 as a resilient crop variety for regions with high temperatures and salinity levels. The best way to increase vegetative growth, chlorophyll content, leaf relative water content, proline content and antioxidant enzyme activity was to spray arginine at a dose of 300 mg/L with Giza 111[60]. These data indicate that each of these two factors act dependently on seed yield and yield components.

With regard to seed quality, as the rate of amino acid with micronutrient spraying increased, the total amino acids and protein contents in the seeds also increased. However, the oil content in the seeds decreased. This indicates that soil salinity under hot conditions negatively affected the quality of the seeds. Mature soybean seeds that were subjected to salt stress had lower levels of protein and free amino acids[60,61]. In the same trend, heat stress during the seed filling stage decreases seed quality[12]. Crucially, for seed quality in both seasons, there were no appreciable variations between spraying of the 1.5 and 2.0 cm^3/L rates. These findings imply that, in comparison to other treatments, foliar spraying of amino acids and micronutrients at a rate of 1.5 cm^3/L enhanced seed quality. Amino acids are important in the biosynthesis of proteins, vitamins and hormones, as suggested by El-Azab[37]. These results were in the same context as Chander *et al.*[52] who found that a balanced supply of macro-and micronutrients to the soybean crop is essential for achieving higher seed quality.

The genetic makeup plays a crucial role in determining the characteristics and traits of the tested varieties. It influences factors such as growth habits, salinity tolerance and seed quality. Additionally, genetic makeup also affects the plants' response to environmental conditions like temperature and moisture. It is important for plant breeders and farmers to understand these genetic differences when choosing the most appropriate varieties for specific regions or purposes. Moreover, high temperatures can have a negative impact on crop productivity due to their effects on the biochemical characteristics of plants[62]. The extent of this impact on soybeans depends on genetic variability. El Sabagh *et al.*[63] found that Giza 111 is the cultivar with greater tolerance to salinity, leading to higher seed protein and oil percentages[60].

With regard to the interaction between foliar spraying of amino acids with micronutrient rates and soybean varieties on seed quality, this study showed that growing Giza 111 in salinity soil can improve seed quality. These findings were consistent with Meena *et al.*[64], who showed that applying thiourea at a concentration of 750 ppm led to a protein yield of 901 kg/ha, which was statistically comparable to the protein yield achieved with thiourea at concentrations of 250 and 500 ppm. They also noted that the oil yield was affected by the use of different varieties and foliar spray, with PS 1347 variety exhibiting a 19.03% higher oil yield than SL 958 variety.

With respect to economic evaluation, the results show that farmers in Upper Egypt could achieve an increase in net profit by 7940 and 9540 Egyptian pounds/fad in the first and second seasons, respectively, by foliar spraying of 2.0 cm^3/L of amino acids with micronutrients on leaves of Giza 111 compared to untreated Giza 111. This practice should be recommended. Meena *et al.*[64] found that foliar spraying with thiourea increased soybean gross returns by 14.96, 23.72 and 25.33% compared to the control. The PS 1347 variety of soybeans showed better economic returns than the SL 958 variety, with a 24.54 percent increase in net returns.

CONCLUSION

A two-year study found that farmers in Upper Egypt can more profitably enhance soybean seed output and quality by applying 2.0 cm^3/L of amino acids with micronutrients to the leaves of Giza 111. For the local farmers, this approach has proven to be quite successful and profitable. It has been shown that supplementing Giza 111 seeds with amino acids with micronutrients significantly increases their protein content and boosts their market value. This method has increased the quality and profitability of Giza 111.

SIGNIFICANCE STATEMENT

To enhance crop yields and quality in different regions, this approach could be more widely implemented. This study evaluates the impact of foliar spraying with amino acids and micronutrients on the seed yield and quality of Giza 21, Crawford and Giza 111 crops grown in Upper Egypt on reclaimed soil. The application of 2.0 cm^3/L of minerals and amino acids to the leaves of Giza 111 resulted in improved soybean seed yield and quality. Further research is needed to explore the benefits of supplementing micronutrients and amino acids in various crop species and their potential impact on overall agricultural yield. This method offers a sustainable approach to enhance crop profitability and productivity in various farming systems, leading to improved outcomes.

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