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USING SOME FERTILIZATION TREATMENTS TO REDUCE THE NEGATIVE IMPACT OF CALCAREOUS SOILS ON PRODUCTIVITY OF EGYPTIAN COTTON

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ABSTRACT: A field experiment was carried out through the two growing seasons of 2021 and 2022 to find out the impact of the addition of humic acid and sulphur at soil and foliar spraying with chelated Zn and/or chelated B in addition to their interactions on cotton cultivar Super Giza 94 (*Gossypium barbadense* L.) grown under calcareous soil located at El-Nubaria Station Farm, Agricultural Research Center, Egypt. The layout of the experiment was a split plot design with three replications. The obtained results revealed that humic acid as well as a mixture of chelated Zn and chelated B increased numbers of monopodia and sympodia/plant, plant height at harvest, total fruiting points number/plant and total bolls number set/plant, bolls setting%, seed cotton yield /feddan, yield components and fiber length in both seasons. Bolls shedding% was decreased in this respect. Humic acid alone significantly improved fiber fineness and decreased the 1st sympodium node. Similarly, a mixture of chelated Zn and chelated B significantly increased fiber strength. Using humic acid interacting with a mixture of chelated Zn and chelated B significantly increased numbers of monopodia and total bolls set/plant, yield of seed cotton/feddan, yield components, fiber fineness and strength in the two seasons of study. In addition, it increased bolls setting% and number of sympodia/plant only in the 1st season. However, bolls shedding% was decreased. Addition of humic acid to the soil interacting with chelated Zn foliar spraying recorded taller plants.

It could be concluded that using humic acid interacting with a mixture of chelated Zn and chelated B alleviated and counteracted harmful effects of calcareous soil in El-Nubaria region on cotton productivity of cultivar Super Giza 94.

Key words: Cotton; calcareous; humic acid; sulphur; chelated boron; chelated zinc; shedding%.

INTRODUCTION

Egyptian cotton occupies a distinguished situation among field crops, as it is a strategic crop plays significant part in the Egyptian national revenue for the next reasons as reported by El-Shazly (2017) : (1)- It characterized by the high-quality recipes in addition to its firmness and popularity in overseas mart (2)- It is considered a basic pillar of the most important industries in Egypt (industry of textile, textile and ready- made clothes) in addition to its importance for the food and oil output and a source of income. (3)-It is very important for the country's social and economic value.

Seeding of calcareous land faces a lot of challenges which associated to one or more of the followings: elevation of salinity and pH, inadequate texture and construction, low water holding ability, high drain proportion, bad structure, very low organic matter or biological activities, low CEC, loss of nutrients through leaching or deep filtration, crusting or cracking of soil surface and low availability of many nutrients (Mohamed, 2011 and El-Hady and Abo-Sedra, 2006). Therefore, certain growth factors such as humic acid and sulphur addition to the soil and foliar spraying with zinc and/or boron should be used to alleviate the harmful effects of calcareous soil in El-Nubaria region and counteracted its harmful effects on cotton productivity.

The beneficial function of humic acid (HA) on plant growth and productivity is associated to its direct impact on physiological and biochemical activities in plants (Ali, 2015), and its indirect effect on enhancing physical, chemical, and biological characteristics of the soil (Taha and Osman, 2018). HA improved plant growth by its

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act in regulating carbon cycle, releasing nutrients (N, P and S) increasing element absorption and improving soil fertility with chelating important elements (El-Razek *et al.,* 2020). Moreover, humic acid has been demonstrated to influencing on techniques included in; photosynthesis, respiration of cell, water and nutrient uptake, changes in membrane permeability, enzyme activities and/or inhibition, biosynthesis of protein and nucleic acids and finally activating biomass production (Kaya *et al.,* 2020). The bio stimulants can be operated in plants at various levels, indicating the primary impacts on effectiveness of plant photosynthetic and metabolic, nutrient intake, growth, production of biomass and yield (Puglia *et al.,* 2021).

The most predominant functional groups in the frame of HA are phenolic (OH), and carboxylic (COOH) groups. They are fundamentally responsible for functions of HA like improving physical and chemical properties of soil as well as plant growth (Nardi *et al*., 2021). Stability of soil structural has been referred to increased uptake of humic acid in the clay surfaces (Chen *et al.,* 2017). The application of HA at the soil leads to the formation of chelates with cationic metals (Billingham, 2012). HA has also been recorded to increase soil water holding capacity (WHC) and Soil Cation Exchange Capacity (CEC) (Yang *et al.,* 2021). Moreover, it was found that HA addition mended the soils chemical properties because it increases the soil microorganisms' number, which decreases pH of soil and promotes cycling of nutrient (Osman and Rady, 2012).

Plants need sulphur (S) in an amount like that found in phosphorus (Ali *et al*., 2008). S is an essential nutrient for synthesis of cystine, cysteine, methionine, vitamins, chlorophyll and aids in metabolism of carbohydrates, particularly through its influence on the proteolytic enzymes (Najar *et al*., 2011). S utilized as soil amendment is advised when soil pH exceeds 6.6 for the aim of decreasing pH and changes in soil pH can lead to mobilization of nutrients from unavailable phases into available pools and thus increase the availability of P and micronutrients (Rice *et al*., 2006). On calcareous soils, added S is slowly oxidized under the influence of autotrophic bacteria as follows: $S° \rightarrow S_2O_3^{2-} \rightarrow S_4O_6^{2-} \rightarrow S_3O_6^{2-} \rightarrow SO_3^{2-} \rightarrow SO_4^{2-}$ (Orlov *et al.,* 2005). Sulphate (SO_4^{2-}) is further oxidized to H_2SO_4, which reacts with native Ca_2CO_3 to form $CaSO_4$ [gypsum] (El-Hady and Shaaban, 2010). However, the conversion of $CaCO_3$ to $CaSO_4$ with addition of sulphur resulted in an increase of Ca^{2+} in the soil phase which may lead to exchange of sodium in the colloidal complex thus improve the soil ECe, pH and SAR (Abdelhamid *et al.,* 2013). It is necessary element for plant growth as it aids in peptides synthesis, which include cysteine such as glutathione, different secondary metabolites, vitamins (biotine and thiamine) and chlorophyll in the cell (Abdallah *et al.,* 2010). El-Tarabily *et al. (*2006) reported that S application to soil plays an important role in soil such as reducing soil pH, improving soil water relations and increasing availability of nutrients. Yin *et al*. (2011) recorded that sulphur deficiency has increasingly occurred in crops due to reduced application of S-bearing fertilizers and reduced atmospheric S deposition. It has increased due to the use of high yielding varieties that remove large amounts of sulphur from the soil, and the reduction in the use of S containing fertilizers which in turn leads to a reduction in the amount of S released (Lucheta and Lambais, 2012).

On the other hand, zinc (Zn) and boron (B) are elements directly influence yield and quality due to their functions. Zn affects biological membrane stability, enzyme activation ability and auxin synthesis, while boron plays an essential role in the development and growth of new cells in the growing meristem and required for protein synthesis where nitrogen and carbohydrates are transformed into protein (Swetha *et al*., 2020). B is an important element for plants and single non-metal among plant micronutrients. B is especially involved in carbohydrate metabolism and cellular division. It additionally affected on many functions in plant including production of auxins as well as carbohydrate synthesis and its translocation to the other side of the membrane towards meristem regions (Mesurani and Ram, 2020). Yaseen *et al*. (2013) indicated that scarcity of micronutrients, specially of zinc, boron, and iron, in calcareous soils is of a major concern. It was reported that foliar spraying of Zn and B on cotton plans grown on calcareous soils in the existence of the recommended rates of NPK fertilizers enhanced nutrient state and led to an increase in the flowers number, bolls number and finally the yield of seed-cotton. Reached to 20%–30% more increase over NPK fertilizers alone. However, Sajid *et al.* (2008) detected that soil utilization of Zn and B on calcareous soils was less efficient, as these nutrients were not available to plant roots because of the higher soil pH.

Intensive cultivation of micronutrient-demanding crops on alkaline calcareous soils with low organic matter content has made El-Nubaria's soils deficient in Zn and B with localized deficiency in micronutrients depending upon the cropping intensity (Memon *et al.*, 2012). Enough intake of these nutrients increased enzymatic activities (Oosterhuis and Weir, 2010), which improved biochemical processes such as photosynthesis, respiration, and protein. Foliar feeding of micronutrients is highly recommended for cotton areas especially in calcareous soils with a high pH like in El-Nubaria.

Therefore, this study aimed to assess the effect of the application of humic acid and sulphur at soil and foliar feeding with Zn and/or B as well as their interactions regarding the plant growth traits, measurements of flowering and shedding, seed cotton yield, yield components and fiber properties of Super Giza 94 cotton cultivar that represents the category of long staple Egyptian cotton under calcareous sandy loam soil and environmental conditions of El-Nubaria region.

MATERIALS AND METHODS

A field experiment was carried out during the two growing seasons of 2021 and 2022 at the Farm of El-Nubaria Agricultural Research Station, Agricultural Research Center, Egypt, representing the newly reclaimed desert land of Northwest, Egypt in El-Nubaria, El-Beheira Governorate, which is located at the East side of Cairo-Alexandria desert road, about 47 km south of Alexandria city, (Elevation: 30 m; Latitude: 30° 39' 59'' North, Longitude:30° 4' 36'' East). Highly calcareous sandy loam soil was used.

These experiments conducted to investigate the effect of soil application of humic acid (HA) and sulphur (S), foliar application of zinc and/or B in addition to their interactions on growth traits, flowering and shedding measurements, seed cotton yield, yield components and fiber properties of Super Giza 94 cotton cultivar (*Gossypium barbadense* L.).

The experiment was set up in a split plot design with 3 replications, where the soil application with humic acid and sulphur was allocated in the main plots, while foliar feeding with Zn and/or B were assigned as sub plots.

A- Soil treatments addition

a_1- Untreated as a control.

a_2- Sulphur addition in the form of Soreil-KZ 95% S at the rate of 120 kg/fed incorporated into soil before ridging.

a_3- Soil application with humic acid (95%) at the rate of 2 kg/fed. It soluble with 100% in water and added during first irrigation.

B- Foliar feeding with chelated Zn and/or chelated B

b_1- Control (water spray).

b_2- Foliar application with 2 g zinc-EDTA (15% Zn)/liter.

b_2- Foliar application with 2 g boron-EDTA (12% B)/ liter.

b_4- Foliar application with [2 g zinc-EDTA (15% Zn) + 2 g boron-EDTA (12% B)]/liter.

Foliar application of Zn and B was applied twice (at squaring stage and flowering start) using hand operated sprayer compressed at a low volume of 200 liter/fed using Tween 20 (0.05%) as surfactant.

Representative soil surface samples (0-60 cm) were taken before 10 days of sowing from the experimental soil sites in both seasons and prepared for analysis according to the method described by Jackson (1973) and the obtained data are shown in Table 1.

Table 1: Some soil properties of the experimental sites at El-Nubaria in 2021 and 2022 seasons.

Soil properties	Season	
	2021	2022
Mechanical analysis		
Clay%	20.12	19.54
Silt%	28.26	28.93
Sand% (fine +coarse)	51.62	51.53
Texture	Sandy loam	Sandy loam
Chemical analysis		
pH (1 soil: 2.5 distilled water)	8.29	8.23
EC (ds/m), (1 soil: 2.5 distilled water)	2.37	2.39
Organic matter (%)	0.27	0.29
Total $CaCO_3$ (%)	21.94	22.13
Available macronutrients (ppm)		
N	20.73	19.95
P	2.94	3.01
K	87.43	88.10
S	7.2	7.8
Available micronutrients (ppm)		
Fe	8.00	7.40
Mn	7.00	6.50
Zn	0.56	0.49
Cu	3.00	2.50
B	0.40	0.38

In the two seasons of study, the texture of the soil was sandy loam, alkaline in reaction, low organic matter content, very high calcium carbonate and low saline (Table 1). Moreover, the available amounts of macro elements were very low for nitrogen, phosphorus and potassium, low for sulphur. Concerning micro-nutrients content, available amounts of Fe, Zn and Mn were low in the soil, while B and Cu existed in low and very high amounts, respectively according to Ankerman and Large (1974).

In both seasons, the sub-plot area was 16.25 m^2, (3.25 m x 5 m) including 5 ridges 0.65 m apart and 5 m long and 25 cm between hills with two vigour seedlings $hill^{-1}$ at thinning time (before the 1st irrigation) to insure 51,692 plant/fed.

The cotton seeds of Egyptian long staple cotton cultivar Super Giza 94 (*Gossypium barbadense* L.) obtained from Cotton Research Institute (CRI), Agricultural Research Center (ARC), Egypt and sowing on 11/5/2021 and 16/5/2022 at the rate of 30 kg/fed after Egyptian clover berseem (*Trifolium alexandrinum* L.) and faba bean (*Vicia faba* L.) as preceeding crops in 2021 and 2022 seasons, respectively.

Prior to land preparation, phosphorus fertilizer was used in the form of mono calcium super phosphate (12.5% P_2O_5) at the rate of 22.5 kg P_2O_5/fed. Nitrogen fertilizer was applied in the form of ammonium nitrate (33.5% N) at the rate of 100 kg N fed^{-1} in two equal portions with the 1^{st} and 2^{nd} irrigations. Potassium fertilizer in the form of Potasin-P at the rate of 1 liter fed^{-1} was foliar application twice (at squaring stage and flowering start). The other cultural practices were followed, throughout the two growing seasons, as recommended (CRI, ARC).

In both seasons, five guarded hills (10 plants) from the second row of each sub-plot were randomly taken to evaluate the next traits.

Data recorded

I-Growth traits: At harvest, final plant height (cm) and its numbers of monopodia and sympodia were recorded.

II-Flowering and shedding measurements: First sympodium node, numbers of total fruiting points and total bolls set/plant as well as percentages of bolls setting and bolls shedding were measured.

III- Yield and yield components: At harvest, numbers of open and unopen bolls per plant, yield of seed cotton/plant, boll weight (g), lint% and seed index (g) were determined from the above ten representative plants. The seed cotton yield/feddan was calculated as the weight of seed cotton in kilograms picked twice from each sub-plot and transformed to kentar per feddan (one kentar = 157.5 kg seed cotton). Earliness index (percentage of the first picking) was measured.

VI-Fiber quality: The following fiber properties were determined at Cotton Technology Research Division, Cotton Research Institute, Giza, ARC, Egypt as reported by **A.S.T.M. (1986):** fiber length (upper half mean length in mm) and length uniformity index (%) by fibrograph instrument, fiber fineness (micronaire reading) by micronaire instrument and fiber strength (Pressley index) by Pressley tester.

Statistical analysis

The statistical analysis of the data obtained in the two seasons was performed according to Gomez and Gomez (1984). When the results were significant, the averages of treatments were compared using LSD at a probability level of 0.05 (Waller and Duncan, 1969).

RESULTS AND DISCUSSION

I- Plant growth traits

I-1. Effect of soil treatments addition

Table 2 shows that soil treatments addition significantly affected height of cotton plant and its numbers of monopodia and sympodia in the two seasons of study. Humic acid (HA) application was the most effective treatment in this respect. This treatment recorded the tallest plants with higher numbers of monopodia and sympodia /plant amounted to 165.00 cm, 2.02 and 15.43; 155.83 cm, 0.61 and 14.64 in 2021 and 2022 seasons, respectively as compared to the control, which recorded the lowest values of these traits amounted to 157.5 cm, 1.58 and 13.69; 145.92 cm, 0.48 and 12.42 in both seasons, respectively. The positive effects of HA may be due to its indirect influence on soil through increasing soil microbial activity and effectiveness of nutrient uptake by root hairs as a chelating agent, which increases nutritional status in leaves, then increasing leaf area and leaves dry weight (Canellas and Olivares, 2014). They added that the application of HA improved the rhizosphere ecosystems, resulting in a root zone suitable for the development of soil microorganism. HA as a soil application increased soil porosity, so it's associated with aeration and improved root respiration and penetration into the soil, this can reflect an increase in vegetative growth (Abdel-Mawgoud *et al.*, 2007). HA includes hormone like substances, which may cause an increase in endogenous levels of cytokinin, auxin and gibberellins (Mayi and Saeed, 2015) as well as plant growth (Nardi *et al.*, 2016 and Olaetxea *et* *al.*, 2020). Hussain *et al.* (2021) added that humic substances have antioxidant activity, which is assumed to prevent ROS production and protect cells from oxidative damage. Increasing acidity of soil, uptake of nutrients and yield of plants, mend the soil physical properties, like aggregation, aeration, permeability, water holding capacity, transmit and availability of ions via pH buffering. Humic acid composes with micronutrients chelates to secure a slow-release rate over plant growth, thus avoiding micronutrient deposition, fixation, leaching and oxidation in soil (Ahmed *et al.*, 2013). Humic substances with its auxin activity stimulate hormonal effect on catalytic activity, cell permeability and increase uptake of

Table 2: Effect of some soil treatments addition and foliar feeding with zinc and/or boron as well as their interactions on cotton growth traits in 2021 and 2022 seasons.

Treatments \ Traits		Plant height at harvest (cm)		Monopodia number plant^{-1}		Sympodia number plant^{-1}	
		Season		Season		Season	
		2021	2022	2021	2022	2021	2022
A- Soil treatments addition							
a_1-Control		157.50	145.92	1.58	0.48	13.69	12.42
a_2-Sulphur addition		159.08	148.00	1.72	0.52	14.39	13.23
a_3-Humic acid addition		165.00	155.83	2.02	0.61	15.43	14.64
LSD at 5%		1.24	0.52	0.09	0.04	0.10	0.32
B- Foliar feeding with zinc and/or boron							
b_1-Control		156.56	145.56	1.56	0.47	13.83	12.62
b_2- 2 g chelated zinc/L		161.00	150.56	1.73	0.52	14.16	13.16
b_3- 2 g chelated boron/L		161.11	150.44	1.89	0.57	14.82	13.83
b_4-(b_2+ b_3)		163.44	153.11	1.91	0.57	15.20	14.10
LSD at 5%		0.99	0.70	0.12	0.03	0.28	0.26
A×B Interaction							
a_1	b_1	152.33	140.67	1.20	0.36	12.90	11.60
	b_2	157.67	145.67	1.53	0.46	13.20	12.20
	b_3	159.33	147.67	1.87	0.56	14.20	12.77
	b_4	160.67	149.67	1.73	0.52	14.47	13.10
a_2	b_1	154.00	142.33	1.53	0.46	13.80	12.60
	b_2	158.67	147.67	1.67	0.50	14.00	12.93
	b_3	160.33	149.67	1.73	0.52	14.60	13.63
	b_4	163.33	152.33	1.93	0.58	15.17	13.75
a_3	b_1	163.33	153.67	1.93	0.58	14.80	13.67
	b_2	166.67	158.33	2.00	0.60	15.27	14.33
	b_3	163.67	154.00	2.07	0.62	15.67	15.10
	b_4	166.33	157.33	2.07	0.62	15.97	15.47
LSD at 5%		1.72	1.21	0.22	0.05	0.48	NS

NS: not significant.

nutrients and dry matter yield (Eshwar *et al*., 2017). Enhanced plant growth, plant canopy due to HA application may be due to its plus impact on net assimilation rate, enhanced uptake of macro and micronutrients and concentration of chlorophyll, which positively affect shoot growth (Sible *et al*., 2021). It was found that HA improved activities of soil physical and biochemical through improving structure, texture, capacity of water holding, capacity of cation exchange, pH, soil carbon, enzymes, cycling of nitrogen, availability of nutrients and microbial population (Nardi *et al*., 2017, 2021; Fuentes *et al*., 2018 and Shah *et al*., 2018), soil nutrients availability, particularly micronutrients by chelating and co-transporting micronutrients to plants (Yang *et al.*, 2021) and reduced the toxic heavy metals transmission via precipitating them, so reducing intake of toxic heavy metals by plants (Wu *et al*., 2017). Humic acids also increase crop growth by increasing plant growth promoting hormones like auxin and cytokinin, which help in stress resistance, nutrients metabolism and photosynthesis (Canellas *et al.,* 2020; Laskosky *et al.,* 2020 and Nardi *et al.,* 2021). Also, Sible *et al.* (2021) mentioned that application of HA can have inconsistent results on yield, possibly due to the different biological origins of HA. Duary (2020) found that soil organic matter is required up to a satisfactory level for sustainable crop production and high crops yields over long periods. Humic Acid (HA), an organic substance, may help to overcome the production limitations through its growth stimulating property. As for sulphur (S), data in Table 2 show that its application gave the highest averages of traits in respect amounted to 159.08 cm, 1.72 and 14.39; 148.00 cm, 0.52 and 13.23 in the first and second seasons, respectively compared to the control. It may be due to the reduced in soil pH as well as enhanced availability of macro and micronutrients like N, Fe and Mn (Motior *et al*., 2011) and Zn (Kayser *et al*., 2001). The synergistic effect of S leading to an increase in plant growth. Elemental sulphur is considered as a suitable and cost-effective modification to lower the value of the substrate pH (Tarek *et al*., 2013) due to the acid produced (Singh *et al*., 2006). In this concern, Prasad (2000) showed an increase in the sympodia number per plant with added sulphur.

I-2. Effect of foliar feeding with zinc and/or boron

Significant variations in plant height at harvest and numbers of monopodia and sympodia/plant were obtained among the four treatments. Foliar spraying with a mixture of Zn and B was found to be superior to that of applying each nutrient alone compared to the control (Table 2). This may be due to significant increase in internodes of main stem and/or length of internodes. In this respect, the synthesis of tryptophan (a precursor of auxin) required zinc and thus involved in auxin synthesis which involved in elongation. Favourable responses to B were indicated to a greater need of B by cotton than most other field crops (Shorrocks, 1992).

I-3. Effect of the interaction

The interaction significantly varied in cotton plant height and monopodia number /plant in both seasons and number of sympodia/plant in the first growing season only (Table 2), where HA application to the soil interacting with foliar spraying of Zn recorded taller plants. Humic acid addition to the soil interacting with foliar spraying with a mixture of Zn and B was superior regarding numbers of monopodia and sympodia/plant. However, untreated soil with amendments combined with foliar application with water (the control) recorded the lowest averages of these traits.

II- Flowering and shedding measurements

II-1. Effect of soil treatments addition

Data in Tables 3 and 4 show that soil treatments significantly affected positively in flowering and shedding measurements (number of total fruiting points/plant, number of total bolls set/plant and bolls setting%) in both seasons. HA gave the highest values in this respect amounted to 29.38, 19.16 and 65.17%; 26.66, 11.83 and 44.35% in comparison with untreated treatment (the control), which recorded the lowest values amounted to 28.03, 10.92 and 38.84%; 25.53, 9.80 and 38.38% in 2021 and 2022 seasons, respectively. But an opposite trend was obtained for node of the first sympodium and boll shedding percentage. These results may be due to the importance of HA and S as division of cell and meristematic tissue development. Therefore, they have a stimulating impact on the increase of flowers and bolls numbers/plant. However, HA and S addition significantly lowered the node of the 1st sympodium which reflects on increasing sympodia number, early flowering and consequently early maturity.

II-2. Effect of foliar feeding with zinc and/or boron

Significant variations in flowering and shedding measurements (number of total fruiting points/plant, number of total bolls set/plant and bolls setting%) were obtained among the four treatments in both seasons (Tables 3 and 4). The treatment received foliar spraying with a mixture of Zn and B registered the highest values in this regard and significantly reduced bolls shedding% as compared to the control. Node of the first sympodium did not affected. These results may be due to the importance of Zn in the synthesis of tryptophan, which is a precursor for the synthesis of indole-3-acetic acid (Oosterhuis *et al.*, 1991), and it is the main hormone that prevents squares and bolls abscission.

Table 3: Effect of some soil treatments addition and foliar feeding with zinc and/or boron as well as their interactions on flowering and shedding measurements of Super Giza 94 cotton variety in 2021 season

Treatments \ Traits		Node of the first sympodium	Total bolls number $plant^{-1}$	Fruiting points number $plant^{-1}$	Bolls setting %	Bolls shedding %
A- Soil treatments addition						
a_1-Control		8.24	10.92	28.03	38.84	61.16
a_2-Sulphur addition		7.43	13.64	29.23	46.62	53.38
a_3-Humic acid addition		7.22	19.16	29.38	65.17	34.83
LSD at 5%		0.41	0.68	0.65	2.39	2.39
B- Foliar feeding with zinc and/or boron						
b_1-Control		7.67	11.77	28.27	41.45	58.55
b_2- 2 g chelated zinc/L		7.68	13.79	28.92	47.49	52.51
b_3- 2 g chelated boron/L		7.61	15.59	29.17	53.30	46.70
b_4-(b_2+ b_3)		7.57	17.14	29.17	58.59	41.41
LSD at 5%		NS	0.55	0.45	2.11	2.11
A×B Interaction						
a_1	b_1	8.20	6.97	27.50	25.32	74.68
	b_2	8.23	10.40	27.97	37.17	62.83
	b_3	8.23	12.67	28.27	44.86	55.14
	b_4	8.30	13.64	28.40	48.02	51.98
a_2	b_1	7.40	11.67	28.80	40.52	59.48
	b_2	7.47	11.77	29.33	40.14	59.86
	b_3	7.47	14.37	29.40	48.90	51.10
	b_4	7.40	16.73	29.40	56.92	43.08
a_3	b_1	7.40	16.67	28.50	58.52	41.48
	b_2	7.33	19.20	29.47	65.17	34.83
	b_3	7.13	19.73	29.83	66.15	33.85
	b_4	7.00	21.03	29.70	70.82	29.18
LSD at 5%		NS	0.98	NS	3.66	3.66

NS: not significant.

Table 4: Effect of some soil treatments addition and foliar feeding with zinc and/or boron as well as their interactions on flowering and shedding measurements of Super Giza 94 cotton variety in 2022 season

Treatments \ Traits		Node of the first sympodium	Total bolls number plant^{-1}	Fruiting points number plant^{-1}	Bolls setting %	Bolls shedding %
A- Soil treatments addition						
a_1-Control		7.81	9.80	25.53	38.38	61.63
a_2-Sulphur addition		7.03	10.42	26.40	39.42	60.58
a_3-Humic acid addition		6.82	11.83	26.66	44.35	55.65
LSD at 5%		0.38	0.56	0.36	1.91	1.91
B- Foliar feeding with zinc and/or boron						
b_1-Control		7.29	9.45	25.57	36.93	63.07
b_2- 2 g chelated zinc/L		7.28	10.34	26.20	39.44	60.56
b_3- 2 g chelated boron/L		7.20	11.12	26.44	42.03	57.97
b_4-(b_2+ b_3)		7.11	11.82	26.57	44.46	55.54
LSD at 5%		NS	0.46	0.16	1.78	1.78
A×B Interaction						
a_1	b_1	7.87	8.45	25.00	33.80	66.20
	b_2	7.83	9.90	25.40	38.99	61.01
	b_3	7.80	10.22	25.70	39.76	60.24
	b_4	7.73	10.64	26.00	40.95	59.05
a_2	b_1	7.00	9.04	25.80	35.00	65.00
	b_2	7.07	10.14	26.40	38.42	61.58
	b_3	7.07	11.00	26.70	41.19	58.81
	b_4	7.00	11.50	26.70	43.06	56.94
a_3	b_1	7.00	10.88	25.90	41.98	58.02
	b_2	6.93	10.97	26.80	40.91	59.09
	b_3	6.73	12.16	26.93	45.13	54.87
	b_4	6.60	13.33	27.00	49.38	50.62
LSD at 5%		NS	0.80	NS	NS	NS

NS: not significant.

Therefore, the number of bolls retained /plant increased and as a result the yield of seed cotton was increased. Output of more chlorophyll and IAA resulting in delaying plant aging thus extending the photosynthesis period. This promotes production of carbohydrate and their convey to the growing parts. Data indicated that Zn and B increased numbers of lateral branches and bolls by preventing squares, flowers and bolls from falling (Tables 2, 3 and 4). This may be due to the directly effect of foliar application on enhancing utilization and nutrients translocation into the boll which increase the number and size of it. The enhancement in status of nutrients led to an increase in the numbers of flowers and bolls. Marschner (2012) reported that B restriction passively changes the reproductive production of plants by causing sudden changes in flowering and fruiting modes (bursting of pollen tubes, loss viability of pollen, flower buds abscission, fruit setting failure and premature fruit drop due to photosynthetic transport failure leading to loss of yield). Boron is involved in pollen development, pollen germination and pollen tube growth (Lee *et al.*, 2009).

II.3. Effect of the interaction

Tables 3 and 4 showed that HA addition to the soil and foliar feeding with a mixture of Zn and B significantly increased total bolls number set/plant in the two growing seasons and percentage of bolls setting in the first growing season. However, untreated soil with amendments combined with foliar application with water (the control) recorded the smallest averages in this regard, since a significant increase in bolls shedding% in the first season was detected. However, node of the 1st sympodium was not influenced in both seasons.

III-Yield and yield components

III-1. Effect of soil treatments addition

Results in Tables 5 and 6 show that, soil treatments application significantly influenced yield and yield components in both seasons, where HA addition is most effective on increasing number of open bolls/plant, weight of boll, seed cotton yield/plant, earliness index, seed index and lint%. It gave the highest values amounted to 9.59, 2.27 g, 21.89 g, 61.89%, 10.95 g and 38.17%; 11.83, 2.72 g, 32.25 g, 65.27%, 11.36 g and 38.56% compared to the control, which gave the lowest values amounted to 5.45, 2.13 g, 11.63 g, 38.16%, 10.31 g and 37.11%; 9.80, 2.28 g, 22.48 g, 40.25%, 10.75 g and 37.50% in 2021 and 2022 seasons, respectively. As a percentage HA application significantly increased seed cotton yield/fed by 88.47 and 51.09%; 41.07 and 21.20% over that obtained from the control and sulphur addition to soil in 2021 and 2022 seasons, respectively. Also, sulphur application gave the highest values of yield components studied amounted to 6.83, 2.12 g, 14.49 g, 44.04%, 10.71 g and 37.52%; 10.45, 2.53 g, 26.52 g, 46.45%, 11.12 g and 37.90% in the first and second

Table 5: Effect of some soil treatments addition and foliar feeding with zinc and/or boron as well as their interactions on seed cotton yield/feddan and its components of Super Giza 94 cotton variety in 2021 season

Treatments \ Traits		No. of open bolls plant^{-1}	No. of unopen bolls plant^{-1}	Boll weight (g)	Seed cotton yield (g plant^{-1})	Earliness index (%)	Seed index (g)	Lint %	Seed cotton yield fed^{-1} (kentar)
A- Soil treatments addition									
a_1-Control		5.45	5.47	2.13	11.63	38.16	10.31	37.11	2.95
a_2-Sulphur addition		6.83	6.81	2.12	14.49	44.04	10.71	37.52	3.68
a_3-Humic acid addition		9.59	9.57	2.27	21.89	61.89	10.95	38.17	5.56
LSD at 5%		0.31	0.39	0.09	0.92	2.31	0.15	0.26	0.23
B- Foliar feeding with zinc and/or boron									
b_1-Control		5.89	5.88	2.05	12.06	39.56	10.03	36.69	3.06
b_2- 2 g chelated zinc/L		6.91	6.88	2.21	15.25	46.85	10.47	37.48	3.87
b_3- 2 g chelated boron/L		7.78	7.81	2.16	16.92	50.36	10.87	37.67	4.30
b_4-(b_2+ b_3)		8.58	8.56	2.27	19.78	55.35	11.26	38.56	5.02
LSD at 5%		0.25	0.31	0.10	0.79	1.81	0.15	0.28	0.20
A×B Interaction									
a_1	b_1	3.47	3.50	2.04	7.11	27.14	9.60	36.1	1.81
	b_2	5.21	5.19	2.26	11.74	40.52	10.10	36.93	2.98
	b_3	6.29	6.38	2.13	13.46	40.92	10.57	37.24	3.42
	b_4	6.83	6.81	2.08	14.22	44.06	10.97	38.17	3.61
a_2	b_1	5.87	5.80	2.10	12.28	37.68	9.90	36.7	3.12
	b_2	5.89	5.88	2.16	12.71	38.02	10.40	36.67	3.23
	b_3	7.17	7.20	2.07	14.86	46.43	11.13	37.97	3.77
	b_4	8.38	8.35	2.16	18.09	54.05	11.40	38.73	4.59
a_3	b_1	8.33	8.34	2.02	16.80	53.85	10.60	37.27	4.27
	b_2	9.61	9.59	2.22	21.30	62.03	10.90	38.83	5.41
	b_3	9.88	9.85	2.27	22.44	63.73	10.90	37.8	5.70
	b_4	10.53	10.50	2.57	27.03	67.94	11.40	38.77	6.86
LSD at 5%		0.44	0.54	0.17	1.37	3.13	0.25	0.50	0.35

Table 6: Effect of some soil treatments addition and foliar feeding with zinc and/or boron as well as their interactions on seed cotton yield/feddan and its components of Super Giza 94 cotton variety in 2022 season.

Treatments \ Traits		No. of open bolls $plant^{-1}$	No. of unopen bolls $plant^{-1}$	Boll weight (g)	Seed cotton yield (g/plant)	Earliness index (%)	Seed index (g)	Lint %	Seed cotton yield fed^{-1} (kentar)
A- Soil treatments addition									
a_1-Control		9.80	-	2.28	22.48	40.25	10.75	37.50	5.43
a_2-Sulphur addition		10.45	-	2.53	26.52	46.45	11.12	37.90	6.32
a_3-Humic acid addition		11.83	-	2.72	32.25	65.27	11.36	38.56	7.66
LSD at 5%		0.56	-	0.04	0.41	2.44	0.14	0.27	0.21
B- Foliar feeding with zinc and/or boron									
b_1-Control		9.48	-	2.34	22.40	41.72	10.48	37.07	5.41
b_2- 2 g chelated zinc/L		10.34	-	2.47	25.59	49.42	10.89	37.86	6.11
b_3- 2 g chelated boron/L		11.12	-	2.58	28.75	53.11	11.27	38.06	6.97
b_4-(b_2+ b_3)		11.83	-	2.66	31.59	58.38	11.64	38.95	7.37
LSD at 5%		0.46	-	0.04	0.69	1.90	0.14	0.30	0.20
A×B Interaction									
a_1	b_1	8.45	-	2.00	16.89	28.62	10.07	36.48	4.18
	b_2	9.90	-	2.20	21.78	42.74	10.55	37.32	5.12
	b_3	10.22	-	2.42	24.69	43.16	10.99	37.63	6.11
	b_4	10.65	-	2.49	26.56	46.47	11.37	38.56	6.31
a_2	b_1	9.13	-	2.42	22.07	39.75	10.36	37.08	5.41
	b_2	10.14	-	2.48	25.19	40.10	10.83	37.05	6.03
	b_3	11.00	-	2.56	28.17	48.96	11.53	38.36	6.73
	b_4	11.50	-	2.67	30.67	57.01	11.78	39.13	7.10
a_3	b_1	10.87	-	2.60	28.25	56.80	11.02	37.66	6.64
	b_2	10.97	-	2.72	29.81	65.42	11.31	39.23	7.18
	b_3	12.15	-	2.75	33.40	67.22	11.31	38.19	8.08
	b_4	13.33	-	2.82	37.55	71.66	11.78	39.16	8.72
LSD at 5%		0.80	-	0.08	1.19	3.30	0.24	0.52	0.34

seasons, respectively as compared to the control. The increase may be due to an increase in plant yield. It was found that application of S increased nutrient availability which positively affected on carbohydrate metabolism and acceleration of photosynthates movement from source to sink (boll).

Elevation rate of reproductive dry matter cumulation at boll filling period may be due to increased redistribution of dry matter from leaves to bolls, which was influenced by S fertilizer along with other main elements which led to an increase in boll weight. Moreover, soil application of S significantly increased yield of seed cotton /fed by 24.74 and 16.39% compared to the control in 2021 and 2022 seasons, respectively. The raise in number of open bolls/plant may be due to amelioration of S containing amino acids, which are a prime portion of protein and prevent shedding of bolls. It can use total genetic potency of a crop when it is grown under favourable conditions and a well-balanced provide of nutrients to the crop. Moreover, S affects photosynthesis and synthesis of nucleic acids, proteins, amino acids, and other main components, which are vital components leading to increased boll weight and thus yield of seed cotton. In this concern, S fertilization showed a significant increase in yield of seed cotton, number of bolls and weight of boll. So, cotton yield increased (Tables 5 and 6) mainly with S addition at a rate of 7 kg ha^{-1} in soils with alkaline pH and low organic matter (Makhdum and Malik, 2004). The major effects of S-origin and S-level were significant for bolls harvestable/plant, yield of seed cotton, gin turnout and weight of boll (Görmüş, 2014).

It was suggested that S fertilizer application increased the availability of nutrients and its effects on uptake and movement to bolls and dilution impact which rise reproductive structures formation for nutrient absorption and photosynthesis and increased assimilates output to fill the sinks, leading to higher yield. The high response at this site can be attributed to the low available of S-$SO4^{2-}$ in the soil. Possibly, the low ability to provide S from the soil and a low former of S availability could clarify these results. Extractable level in the 60 cm depth was lower as shown in Table 1 than the reported 10 ppm critical level (Hoeft *et al.,* 1973). The increase in bolls number resulting from the use of sulphur may be due to that S being a major component of enzymatic activity, accountable for nitrogen metabolism inclusive nitrate and nitrite reductase (Swamy *et al.,* 2005).

Regarding the number of unopen bolls/plant, the data in Tables 5 and 6 show that the same trend was obtained as found with open bolls in the first season where about 50% of the total bolls set/plant were not opened due to unfavourable weather in addition to severe infestation with boll worms and white fly. In the second season, the total number of total bolls set/plant produced 100% of open bolls.

III-2. Effect of foliar feeding with zinc and/or boron

The maximum increase in yield of seed cotton (kentar/feddan) and yield components was recorded for the treatment received foliar feeding with a mixture of Zn and B. The treatment significantly increased number of open bolls/plant, boll weight, seed cotton yield/plant, earliness index, seed index and lint% by 45.67%, 10.73%, 64.01%, 15.79%, 12.26% and 1.87%; 24.79%, 13.67%, 41.03%,16.66%, 11.07% and 1.88% in 2021 and 2022 seasons, respectively compared to the control treatment, which gave the lowest values in this respect. Moreover, foliar spraying with a mixture of Zn and B significantly increased seed cotton yield/fed by 64.05 and 36.23% compared with the control treatment in the first and second seasons, respectively. The increase in seed cotton yield/feddan may be due to an increase in number of open bolls/plant, boll weight, lint% and seed index. The increase in productivity may be due to that the experimental soil sites in 2021 and 2022 seasons (Table 1), has low available Zn. Low solubility of zinc in soils rather than low total amount of Zn is the main reason for the general occurrence of Zn deficiency problem in crop plants (Cakmak, 2008). Similarly, the soil in the present investigation is low in boron and cotton plants needs a greater B as compared to most other field crops (Shorrocks, 1992). Thus, plant had the chance to bear more fruiting branches and consequently enhanced boll setting (Tables 3 and 4) and yield increase by foliar feeding with B compared to the control.

Concerning the number of unopen bolls/plant, the data in Tables 5 and 6 show that the same trend was obtained as found with open bolls in the first season where about 50% of the total bolls set/plant were not opened due to unfavourable weather in addition to severe infestation with boll worms and white fly. In the second season, the total number of total bolls set/plant produced 100% of open bolls.

In this concern, Ali *et al.* (2011) reported that foliar use of B improved bolls number, weight of boll and seed cotton yield compared to the control. Rashidi *et al*. (2011) found that bolls number, boll weight and seed cotton yield were increased due to foliar feeding with B. Eleyan *et al.* (2014) revealed that addition of B to cotton improved growth and seed cotton yield as well as earliness. Similarly, yield increase was the result of improved boll setting. Azeem *et al*. (2021) reported that the B foliar spray increased seed numbers and weight through activating flowering, simplifying the formation and growth of pollen tubes. Rabeh *et al.* (2021) added that Zn applied enhanced seed cotton yield compared with zero Zn treatment.

III-3. Effect of the interaction

The interaction significantly showed an additive effect on yield of seed cotton per feddan and its components (open bolls number, weight of boll (g), yield of seed cotton (g/plant), earliness index (%), seed index (g) and lint%) in both seasons (Tables 5 and 6). HA application to the soil and foliar spraying with a mixture of Zn and B was superior in this respect. However, untreated soil with amendments combined with foliar application with water (the control) recorded the lowest values in this concern in both seasons.

The variation in the seed cotton yield/feddan between the two seasons, with the low yield in the first season is mainly due to severe infestation with boll worms and white fly, unsuitable weather factors such as high temperature and humidity in the air at the end of the season which resulted in not opening of about 50% of the total bolls set/plant and decreased in boll weight compared to the second season, where the total number of total bolls set/plant produced 100% of open bolls and heavier boll weight (Tables 3, 4, 5 and 6).

VI-Fiber Properties

VI-1. Effect of soil treatments addition

Significant additive effects for humic acid and sulphur soil application were observed for fiber length and micronaire reading in both seasons (Tables 7 and 8), in favour of HA addition. In addition, the data show that no significant differences due to these treatments for fiber length uniformity index and fiber strength in the two seasons of study. Similarly, results were reported by Görmüş (2014) who found that plants that received 30 kg sulphur ha^{-1} recorded the highest uniformity of fiber length, fiber strength and the concentration of sulphur in the leaf. Tucker (1999) reported that application of sulphur to the soil led to an increase in quality of fiber. Sharma *et al.* (2000) reported that the addition of S increased span length and uniformity ratio. El-Ashmouny *et al.* (2017) found that the implementation of S improved micronaire by 4.5 %.

VI-2. Effect of foliar feeding with zinc and/or B

Differences between foliar spraying with Zn and/or B and without application (control) were not significant for micronaire value and fiber length uniformity index (%) and were significant for fiber length and fiber strength in the two growing seasons (Tables 7 and 8), in favour of foliar spraying with a mixture of Zn and B. In this concern, it was reported that B is necessary to achieve high fiber quality. The major function of B is in the elongation of cotton fibre and prohibits callusing of the fibre (Birnbaum *et al*., 1974). It also plays an important role in the transport of sugars. It forms polyhydroxy compounds with components of cell wall to increase their cohesion. Rashidi *et al*. (2011) studied the effect of foliar feeding with B on cotton fibers and found that length and fineness of cotton fibers were improved by foliar feeding with B.

VI-3. Effect of the interaction

Significant additive effects were showed in the interaction treatments on value of micronaire and fiber strength in the two growing seasons (Tables 7 and 8). HA application to the soil and foliar feeding with a mixture of Zn and B twice was superior in this regard.

CONCLUSION

It could be concluded that addition of humic acid to the soil interacting with a mixture of Zn and B as foliar feeding twice alleviated the harmful effects of calcareous soil in El-Nubaria region and counteracted its harmful effects on cotton productivity of cultivar Super Giza 94.

Table 7: Effect of some soil treatments addition and foliar feeding with zinc and/or boron as well as their interactions on fiber traits of Super Giza 94 cotton variety in 2021 season.

Treatments / Traits		Fiber fineness	Fiber strength	Fiber length (mm)	Length uniformity index (%)
A- Soil treatments addition					
a_1-Control		3.59	10.04	30.45	84.65
a_2-Sulphur addition		4.04	10.00	32.31	84.79
a_3-Humic acid addition		4.08	10.10	32.96	84.76
LSD at 5%		0.14	NS	0.64	NS
B- Foliar feeding with zinc and/or boron					
b_1-Control		3.70	9.95	31.37	84.92
b_2- 2 g chelated zinc/L		3.92	10.02	31.83	84.72
b_3- 2 g chelated boron/L		3.93	10.07	32.10	84.92
b_4-(b_2+ b_3)		4.05	10.15	32.33	84.38
LSD at 5%		NS	0.06	0.49	NS
A×B Interaction					
a_1	b_1	3.35	9.90	29.60	85.10
	b_2	3.60	10.05	30.10	85.35
	b_3	3.65	9.95	30.75	84.10
	b_4	3.75	10.25	31.35	84.05
a_2	b_1	3.85	9.75	32.25	85.00
	b_2	4.05	10.00	32.25	84.00
	b_3	4.05	10.25	32.55	85.75
	b_4	4.20	10.00	32.20	84.40
a_3	b_1	3.90	10.20	32.25	84.65
	b_2	4.10	10.00	33.15	84.80
	b_3	4.10	10.00	33.00	84.90
	b_4	4.20	10.20	33.45	84.70
LSD at 5%		0.19	0.11	NS	NS

NS: not significant.

Table 8: Effect of some soil treatments addition and foliar feeding with zinc and/or boron as well as their interactions on fiber traits of Super Giza 94 cotton variety in 2022 season.

Treatments \ Traits		Fiber fineness	Fiber strength	Fiber length (mm)	Length uniformity index (%)
A- Soil treatments addition					
a_1-Control		3.57	10.00	30.40	84.10
a_2-Sulphur addition		3.91	10.03	32.52	84.83
a_3-Humic acid addition		4.10	10.10	33.00	84.76
LSD at 5%		0.16	NS	0.66	NS
B- Foliar feeding with zinc and/or boron					
b_1-Control		3.67	9.85	31.33	84.42
b_2- 2 g chelated zinc/L		3.82	10.00	31.81	84.53
b_3- 2 g chelated boron/L		3.92	10.05	32.20	84.57
b_4-(b_2+ b_3)		4.01	10.27	32.57	84.73
LSD at 5%		NS	0.07	0.50	NS
A×B Interaction					
a_1	b_1	3.3	9.80	29.80	84.00
	b_2	3.55	10.00	30.00	84.10
	b_3	3.6	10.00	30.60	84.10
	b_4	3.81	10.20	31.20	84.20
a_2	b_1	3.7	9.80	32.09	84.70
	b_2	3.86	10.01	32.40	84.90
	b_3	4.01	10.05	32.60	84.70
	b_4	4.06	10.25	33.00	85.00
a_3	b_1	4.01	9.95	32.09	84.55
	b_2	4.06	10.00	33.02	84.60
	b_3	4.16	10.10	33.40	84.90
	b_4	4.16	10.35	33.50	85.00
LSD at 5%		0.21	0.12	NS	NS

NS: not significant.

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استخدام بعض المعاملات السمادية لتقليل الأثر السلبي للأراضي الجيرية على إنتاجية القطن المصري

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الملخص العربي

أجريت تجربة حقلية في مزرعة محطة بحوث النوبارية - مركز البحوث الزراعية-مصر خلال موسمي ٢٠٢١، ٢٠٢٢ لدراسة استجابة صنف القطن المصري سوبر جيزة ٩٤ لإضافة حمض الهيوميك والكبريت (إضافة أرضية للتربة) مقارنة بعدم الإضافة والرش بالزنك المخلب والبورون المخلب (إضافة ورقية مرتان) مقارنة بمعاملة الكنترول واستخدم تصميم القطع المنشقة مرة واحدة في ثلاث مكررات لتنفيذ التجربة.

وأوضحت أهم النتائج أن إضافة حمض الهيوميك للتربة وكذلك الرش الورقي بخليط من الزنك المخلب والبورون المخلب مرتان أدى إلى زيادة معنوية في صفات النمو، وعدد نقاط الإثمار الكلية، ومجموع اللوز الكلى العاقد / نبات، والنسبة المئوية لعقد اللوز ومحصول القطن الزهر للفدان ومكوناته وطول التيلة بينما خفض معنويا النسبة المئوية لتساقط اللوز في الموسمين. كما أدى إضافة حمض الهيوميك للتربة الى زيادة معنوية في نعومة التيلة مع انخفاض معنوي لعقدة أول فرع ثمري في الموسمين، وأعطت معاملة الرش الورقي بخليط من الزنك المخلب والبورون المخلب زيادة معنوية في متانة التيلة في الموسمين.

وقد أوضحت معاملات التفاعل ان الإضافة الأرضية لحمض الهيوميك مع الرش الورقي بالزنك المخلب اعطت أطول النباتات بينما أعطت الإضافة الأرضية لحمض الهيوميك مع الرش الورقي بخليط من الزنك المخلب والبورون المخلب مرتان زيادة معنوية في عدد الأفرع الخضرية / النبات، وعدد اللوز الكلي العاقد / النبات، ومحصول القطن الزهر/ الفدان ومكوناته، ونعومة ومتانة التيلة في الموسمين كما أعطت زيادة معنوية في النسبة المئوية لعقد اللوز وعدد الأفرع الثمرية/ النبات، وانخفاض معنوي في النسبة المئوية لتساقط اللوز في الموسم الأول وهذا التفاعل كان أكثر كفاءة في تحسين إنتاجية صنف القطن المصري سوبر جيزة ٩٤ مع تقليل التأثيرات الضارة للتربة الجيرية في منطقة النوبارية على القطن.