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Can Potassium, Amino Acids, and Yeast Foliar Applications Enhance Growth, Nutrient and Biochemical Contents of Peanut (*Arachis hypogaea*) Grown on a Calcareous Soil under Salinity Stress?

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PEANUT(*Arachis hypogaea*) is an important grain legume and, at the same time ,it can be considered among the oil crops that is widely cultivated in sandy soils of Egypt. The current research represents a trial towards its cultivation in a calcareous salt affected soil having a clay loam texture. These conditions are thought to be not suitable for growing peanut plant. Therefore, some treatments involved spraying plants with K in either humate or silicate forms whether applied solely or combined with amino acids and/or yeasts in a field investigation which was carried out for two consecutive seasons i.e.2022 and 2023. It has been shown that such treatments could affect significantly all plant growth indicators i.e. height of plant, number of branches per plant, weight of pods per plant and weight of seeds plant^{-1}. Also, the plant concentrations of the macro nutritive elements (N,P and K), micro nutritive ones (Fe, Mn and Zn) as well as some chemical compounds i.e., chlorophyll A, chlorophyll B and carotenoids in leaves of the peanut plant beside of its contents of protein, carbohydrates and oil in seeds responded positively and significantly to the aforementioned treatments. However, it is worthy to indicate that the effects of the silicate form surpassed that of the humate one and, at the same time, the yeasts enhanced the effect of the applied K more than the amino acids. The integration between K-silicate+amino acids+yeasts recorded the highest increases in macro and micro- nutrient concentrations in plants; hence raised significantly plant growth and productivity.

Keywords: K-humate; K-silicate; amino acids; yeast; peanut plant.

1. Introduction

Peanuts (*Arachis hypogaea)*, also known as groundnut or goober, are a type of legume crop (Taheri*et al*., 2024). It is widely grown in the tropical and subtropical areas (Rajyaguru*et al*., 2023). It can also be classified as an oil crop because of its high oil content (Singh *et al*., 2024). It is a moderately salt sensitive cultivar (Cui et al., 2018) that can be grown best in loose, well-drained, sandy loam soils (Tekulu and Berhe 2024). However, the current research represents a trial to cultivate peanut in a soil differs to a great extent to those previously mentioned i.e. a calcareous saline soil.

Soils characterized by substantial concentrations of calcium carbonate, which significantly affect their physical, chemical, and biological characteristics—especially regarding the availability of macro- and micronutrients—are designated as calcareous soils (Balba, 1995; Taalab *et al*., 2019). In their natural state, calcareous soils may also be impacted by elevated salt levels, a critical environmental factor that negatively influences the productivity of crop plants (Munns and Tester, 2008). This abiotic factor hinders overall plant

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growth by inducing ionic imbalances within plant tissues, as well as exerting osmotic and oxidative stresses that contribute to diminished nutrient uptake (Atta *et al*., 2023) and result in lipid peroxidation (Kanwal *et al*., 2024).

Almost 833 million hectares of arable soils in the world are influenced, to different extents, by either salinity or sodicity, which nearly covers just about 20% of the cultivated lands worldwide and 33% of the irrigated lands (Devkota et al. 2022). Salinity leads to the excessive buildup of soluble ions such as Na^+, Ca^{2+}, K^+, and Mg^{2+} in the root zone, as highlighted by Farid *et al*., 2020; Tester and Davenport (2003), Munns (2005), Atta *et al*. (2022a), Atta *et al.* (2022b) and El-Ramady *et al*., 2022), This accumulation reduces the solute potential (ψs) and, as a result, lowers the overall water potential (ψw) of the soil. To sustain water absorption and maintain turgor pressure under saline conditions, plants must ensure that their internal water potential (ψw) remains lower than that of the surrounding soil (Taiz et al., 2015).

Osmotic adjustment in plants under salt stress is mediated by the accumulation of osmolytes, such as organic acids, sugars, and amino acids, within plant cells. This process helps in lowering the water potential in plant tissues, enabling plants to absorb water from saline soils more effectively (Acosta-Motos *et al*., 2017; Ma et al., 2020; Munns et al., 2020a & b; Zhao et al., 2021). In salt-affected soils, excessive concentrations of Na^+ and Cl^- ions accumulate in plant tissues, leading to cytotoxicity. This can cause symptoms like leaf burn, stunted growth, and, in severe cases, plant death. Additionally, high Na^+ levels can disrupt the uptake of essential ions such as K^+, Ca^{2+}, and Mg^{2+} due to competitive interactions, potentially resulting in nutrient deficiencies (Munns and Tester, 2008; Atta et al., 2019; Yildiz et al., 2020; Atta et al., 2021). Nutrient absorption is influenced by both soil and water conditions, and salinity stress can hinder the movement of nutrients from the soil to the plant.

The gathering of salt deposits disturbs the water equilibrium within plants, thereby limiting their ability to absorb and utilize vital nutrients. This disturbance adversely affects cellular metabolic processes and diminishes the functionality of enzymes (Aslam et al., 2017). Elevated concentrations of Na^+ are frequently associated with a decrease in the availability of K^+. Therefore, it is imperative to maintain an appropriate cytosolic K^+ concentration, or to achieve K^+ homeostasis, to bolster plant resilience against salt stress (Shabala and Pottosin, 2014). The deleterious effects of Na^+ can also stem from its competition with K^+ for binding sites on K^+-dependent enzymes. Thus, the ratio of cytoplasmic Na^+ to K^+ may be of greater significance than the mere absolute concentration of Na^+ (Shabala and Cuin, 2008). .

Several strategies were proposed to help plants adapt with the undesired consequences of salt stress and ,at the same time, alleviate the influences of stress on plants; nevertheless, some of them raise environmental concerns. It would be better to search for long-term environmentally friendly strategies that can ensure satisfied and acceptable productivity of the saline soil while also do not damage the surrounding ecosystem. In saline environments, the high concentrations of Cl^- and Na^+, coupled with low levels of K^+ and Ca^{2+}, lead to variations in the Na^+/K^+ ratio within plants (Assaha *et al*., 2017). Silicon (Si) has been shown to alleviate ion toxicity caused by salinity (El-Ramady *et al*., 2023; Sári *et al*., 2023). It plays a beneficial role in enhancing K^+ uptake while reducing Na^+ absorption. Additionally, Si application may help mitigate the accumulation of Na^+ in plant roots (Filipiak *et al*., 2022).

Potassium is essential for a myriad of physiological functions, such as the regulation of stomata, the process of photosynthesis, the movement of photosynthates, the synthesis of polypeptides, meristematic growth, the activation of enzymes, charge equilibrium, osmoregulation, resistance to stress, and the enhancement of fruit quality (Epstein and Bloom, 2005; Johnson et al., 2022). It is imperative to maintain adequate potassium concentrations within plant tissues to ensure their viability in saline environments (Tester and Davenport, 2003). Extensive research has illustrated that potassium alleviates the adverse effects of salinity on plant development (Marschner, 1995; Sanjakkara *et al*., 2001) by influencing the K/Na ratio, which is regarded as a dependable measure of salt tolerance (Zhu, 2003). .

The present research constitutes a field trial conducted over two consecutive summer seasons in 2022 and 2023, aimed at investigating the following hypotheses: To what extent can the application of potassium (K) alleviate the detrimental effects of salinity on peanut plants cultivated in calcareous saline soil, and how do the associated anions of the applied K, specifically humate and silicate, influence plant growth (Hypothesis I)? Additionally, can the incorporation of amino acids and/or yeasts enhance the efficacy of the applied K on the growth of the cultivated peanut plants (Hypothesis II)?. This research is in accordance with the United Nations Sustainable Development Goal (SDG) 2: Zero Hunger, particularly target 2.4, which underscores the importance of sustainable food production and resilient agricultural methodologies. By investigating the effects of potassium, amino acids, and yeast foliar applications on peanut cultivation in calcareous saline soils, this study seeks to improve crop yield and nutrient efficiency, thereby contributing to global food security and sustainable agricultural practices.

2. Materials and methods

2.1. Materials of study

2.1.1. Soil of study

A calcareous salt-affected soil, situated at the Agricultural Research Station (Latitude 31° 13' 4.76" N and Longitude 29° 58' 26.94" E) in the Alexandria Governorate of Egypt, was selected for this study due to its calcareous characteristics and saline conditions. Prior to the cultivation of plants, a representative surface sample, extracted from a depth of 0-30 cm, was collected from the subject soil. This sample underwent air drying, was subsequently crushed using a wooden roller, and was then sieved through a 2 mm sieve. Following this process, the sample was analyzed to determine its physical and chemical properties, as detailed in the subsequent sections. Particle size distribution was analyzed using the international pipette method described by Klute (1986), with sodium hexametaphosphate employed as a dispersing agent. Soil pH was measured in a 1:2.5 soil-to-water suspension using a pH meter (ICM 71150). Electrical conductivity (EC) was assessed in the saturated soil paste extract using an EC meter (Orion Expandable Ion Analyzer EA920). Organic carbon content was determined through the modified Walkley and Black method, as detailed by Sparks et al. (1996). Calcium carbonate ($CaCO_3$) content was measured volumetrically using a Collins calcimeter (Jackson, 1973). Soluble cations (Ca^{2+} , Mg^{2+} , Na^+ , and K^+) and anions ($CO_3{}^{2-}$, $HCO_3{}^-$, and Cl^-) were analyzed in the saturated soil paste extract following the methods outlined by Sparks *et al.* (1996). Specifically, calcium and magnesium were determined using the versenate method, sodium and potassium were measured with a flame photometer (JENWAY PFP7), and carbonate ($CO_3{}^{2-}$) and bicarbonate ($HCO_3{}^-$) were quantified by titration with HCl. Sulfate ($SO_4{}^{2-}$) content was calculated by subtracting the total determined soluble anions from the total determined soluble cations. The results of these analyses are summarized in Table 1.

Table 1: Physical and chemical properties of the soil under investigation

Particle size distribution		**Chemical analysis**	
Coarse sand, %	12.58	pH:(1:2.5, soil:water suspension)	7.8
Fine sand, %	41.90	EC dS m^{-1} (in soil water paste extract)	6.47
Silt, %	23.01	O.M, mg kg^{-1}	24 .61
Clay, %	22.51	Available N, mg kg^{-1}	28.198
Soil textural class	clay loam	Available P, mg kg^{-1}	2 .189
$CaCO_3$ (g kg^{-1})	128.6	Available K, mg kg^{-1}	187.897

Soil pH was determined in soil:water (1:2.5) suspension, while EC was determined in soil paste extract

Potassium silicate anhydrous was procured from Agri WEET under the name of Bimko, while potassium humate was acquired from Green Fern Co. The amino acids were sourced from ORT SILVER, located in Turkey. The composition of the amino acids consists of Arginine at 5.50%, Aspartic acid at 7.50%, Alanine at 13.00%, Serine at 5.00%, Proline at 8.00%, Glycine at 19.00%, Glutamic acid at 8.00%, and Lysine at 5.20%. The yeast species Saccharomyces cerevisiae ATCC 287 (EMCC 69) was obtained from the Cairo Microbiological Resources Centre, affiliated with Ain Shams University.

2.2. Experimental procedures

A field experiment utilizing a randomized complete block design was conducted over two consecutive growing seasons, 2022 and 2023, to achieve the objectives of the present study. The experimental design incorporated the following treatments: control treatment (T1), potassium humate applied at a concentration of 2.0 g L^{-1} (T2), potassium humate at 2.0 g L^{-1} combined with amino acids at 2.0 g L^{-1} (T3), potassium humate at 2.0 g L^{-1} in conjunction with yeast extract at a rate of 2 mL L^{-1} (T4), potassium humate at 2.0 g L^{-1} mixed with both amino acids at 2.0 g L^{-1} and yeast extract at 2 mL L^{-1} (T5), potassium silicate at a concentration of 5.0 g L^{-1} (T6), potassium silicate at 5.0 g L^{-1} combined with amino acids at 2.0 g L^{-1} (T7), potassium silicate at 2.0 g L^{-1} alongside yeast extract at 2 mL L^{-1} (T8), and potassium silicate at 5.0 g L^{-1} blended with both amino acids at 2.0 g L^{-1} and yeast extract at 2 mL L^{-1} (T9). .

The investigational unit area was 10.5 m^2 comprising of 5 ridges; 0.6 m apart and 3.5 m long and each treatment was replicated three times. Four seeds of peanut plant (*Arachish ypogaea*) were sown in hill by hand on one side of each ridge on May the 15^{th}, then the seedlings were thinned to two per hill 15 days after planting (DAP). Phosphorus, nitrogen and potassium fertilizers were applied to all plots at the recommended rates: Ammonium nitrate (33.5% N) was added at a rate of 143 kg N ha^{-1}. Monocalcium super phosphate (15.5% P_2O_5) was added at a rate of 480 kg ha^{-1}. Potassium sulfate (48 %K_2O) was applied at a rate of 120 kg K ha^{-1}. In this concern, each of the nitrogen and potassium fertilizers was applied in two equal doses, i.e. 15 and 30 DAP, while calcium super phosphate was added during soil preparation

All prescribed agricultural practices were executed throughout the two seasons of the study. The plants received irrigation via flooding on twelve occasions during each season, utilizing tap water and drainage water alternately for the irrigation process. The characteristics of these two water sources are detailed in Table 2. At the time of harvest, a random sample of five plants was collected from each plot to evaluate various growth parameters, including plant height, the number of branches per plant, the weight of pods per plant, as well as the weight of seeds per plant. .

Table 2. Properties of the drainage and tap water that were used alternately for irrigation of the peanut plants

Source	pH	EC	Soluble ions, $mmol_c$ L^{-1}						
		dS m^{-1}	Na^+	Ca^{2+}	Mg^{2+}	K^+	Cl^-	HCO_3^-	SO_4^{2-}
Drainage water	7.80	9.85	60.24	16.30	7.16	14.80	32.14	35.90	30.46
Tap water	7.80	0.91	2.9	6.9	5.4	4.8	13.7	6.5	4.2

2.3. The plant analyses

Samples of the collected plant materials were dried in an oven at 70°C for 72 hours, ground using a Willy Mill, and then digested with H_2SO_4 -H_2O_2 according to the method described by Parkinson and Allen (1975). Portions equivalent to 0.2 g of dried plant leaves and seeds were used for analysis. The total contents of macro- and micronutrients in the plant digests were determined as follows: nitrogen (N) was measured using a micro-Kjeldahl apparatus, phosphorus (P) was quantified spectrophotometrically using a UV/Vis spectrophotometer (JENWAY 6405), and potassium (K) was analyzed using a flame photometer (JENWAY PFP7). Micronutrients (Zn, Fe, Mn, and Cu) were determined in the plant digest using an Atomic Absorption Spectrophotometer (Perkin-Elmer 372).

Photosynthetic pigments, including chlorophyll a, chlorophyll b, and carotenoids, were measured spectrophotometrically 45 days after planting, following the method recommended by Metzner et al. (1965). Oil content in the seeds was determined using the standard method outlined by AOAC (1990). Total carbohydrate percentage was assessed according to Dubois et al. (1956), and protein content in peanut seeds was determined using the standard method described by AOAC (1990).

2.4. Statistical analyses

Collected data were statistically analyzed using the SPSS program. Analysis of variance (ANOVA) and Duncan’s test were applied at a 0.05 probability level to evaluate the significance of the results.

3. Results

*3.1. **Treatments and growth parameters of peanut plant grown on a calcareous saline soil***

Fig. 1 reveals that all the applied amending treatments exerted significant increases on all the studied growth parameters i .e. plant height, No of branches plant^{-1},weight of pods plant-^{1} and weight of seeds plant^{-1}. The effect of the applied K-humate or K-silicate solely seemed to be the lowest among the other amending treatments. Such effects seemed more pronounced upon association with either the amino acids or yeast. Nevertheless, the association between the K-humate and the amino acids together with the yeasts resulted in the highest corresponding values of all the above mentioned growth parameters. Generally, the increases occurred in all the above mentioned growth parameters owing to K-silicate were significantly higher than the corresponding ones of K-humate. This finding was true whether the K-silicate was applied solely or combined with the amino acids and/or yeasts.

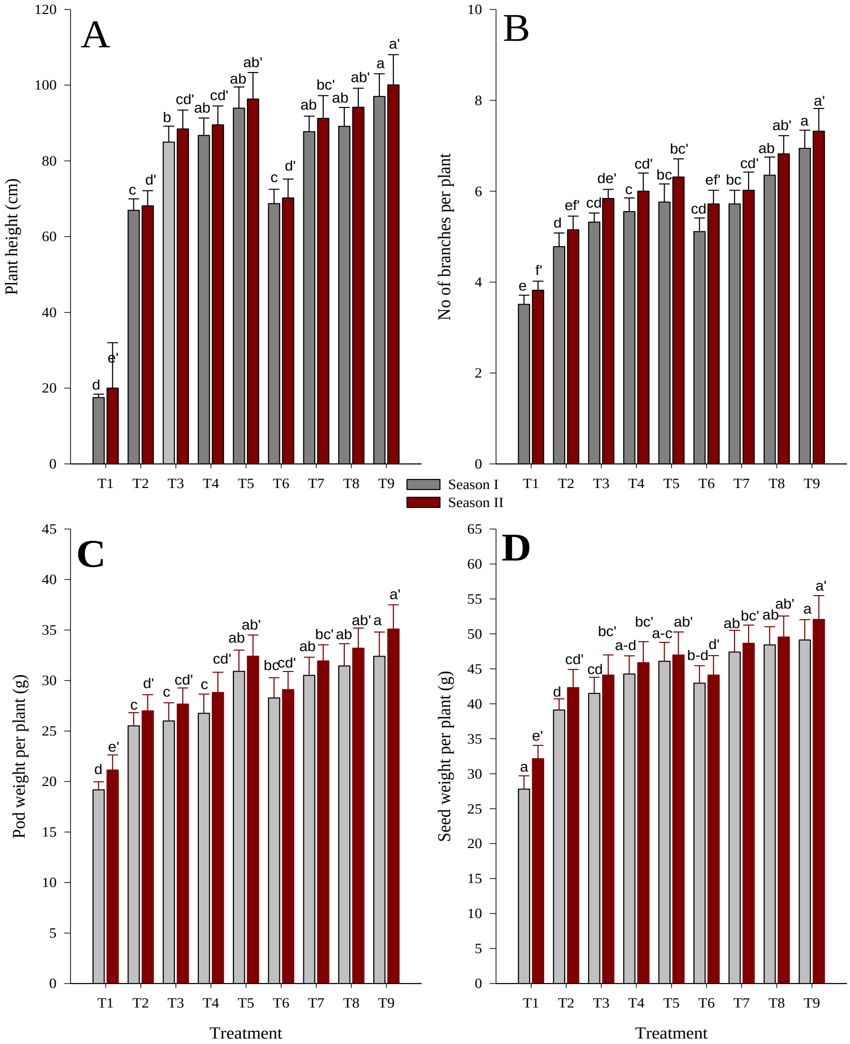

Fig. 1. Effects of the foliarly applied K- humate and K-silicate without or with amino acids and / or yeasts on growth parameters (mean±stdev)of peanut plant grown in a calcareous saline soil. N.B.control (T1), K-humate (T2), K-humate+amino acids (T3), K-humate+yeast (T4), K-humate+amino acids+yeast (T5), K-silicate (T6), K-silicate+amino acids (T7), K- silicate +yeast (T8), K-silicate +amino acids+yeast (T9). Similar letters indicate no significant variations among treatments

*3.2. **Treatments and nutrient contents in plant leaves***

Data illustrated by Fig.2 show that all the nutritive element contents in the leaves of peanut plant increased significantly due to the applied treatments versus the control treatment. Concerning the solely applied K-humate or K-silicate, significant increases occurred in N, P, K, Fe, Mn and Zn concentrations in leaves of the peanut plants, yet these effects were further enhanced due to their association with either amino acids or yeasts. Moreover, the association of the K-humate or K-silicate with both the amino acids and the yeasts resulted in the highest values of all the studied macro and micronutrients in leaves of the peanut, especially T9.

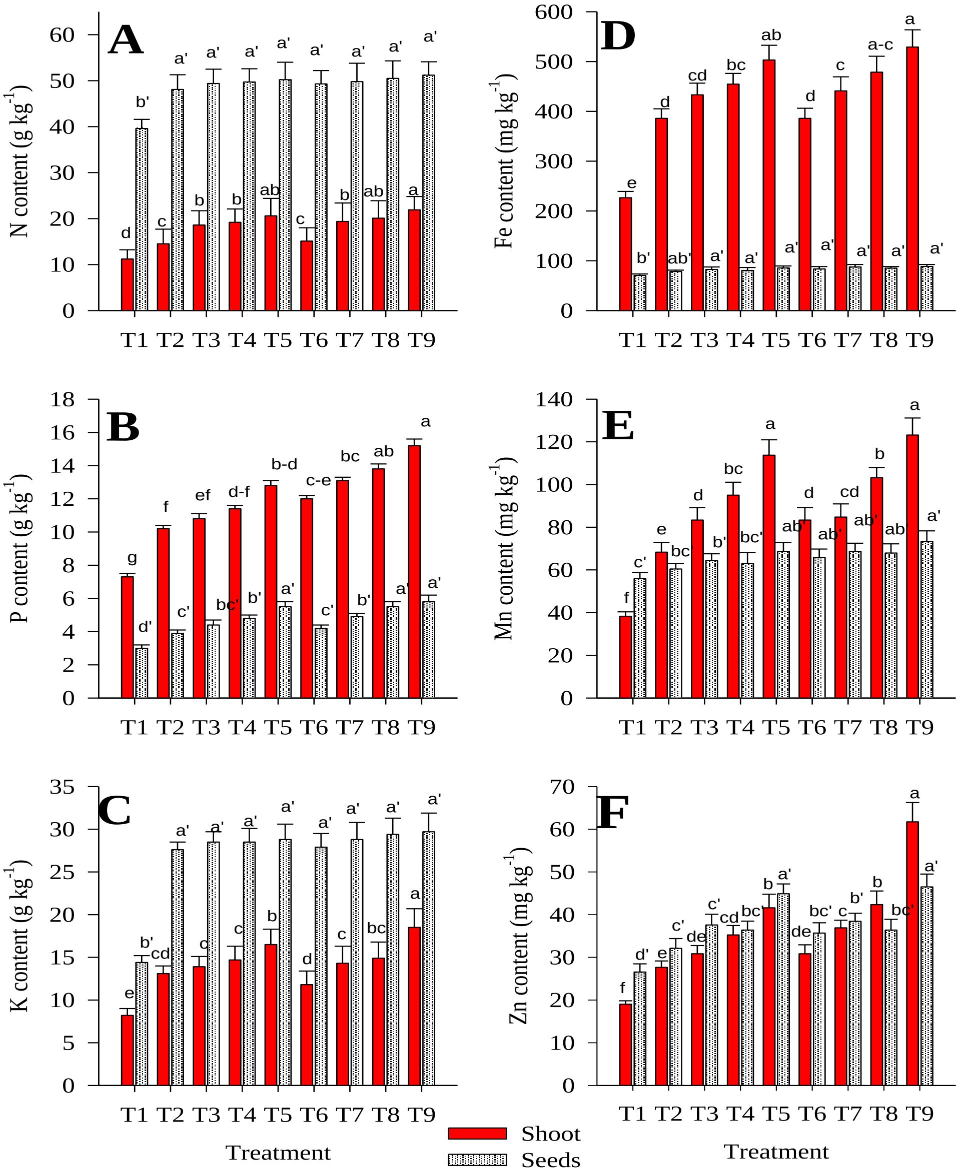

Fig. 2. Effect of the foliarly applied K-humate and K- silicate without or with amino acids and / or yeasts on macro and micronutrients contents (mean±stdev)in leaves and seeds of peanut plant grown in a calcareous saline soil during the first season. See footnote Fig 1. Similar letters indicate no significant differences among treatments at the 0.05 probability level, as determined by Duncan's test.

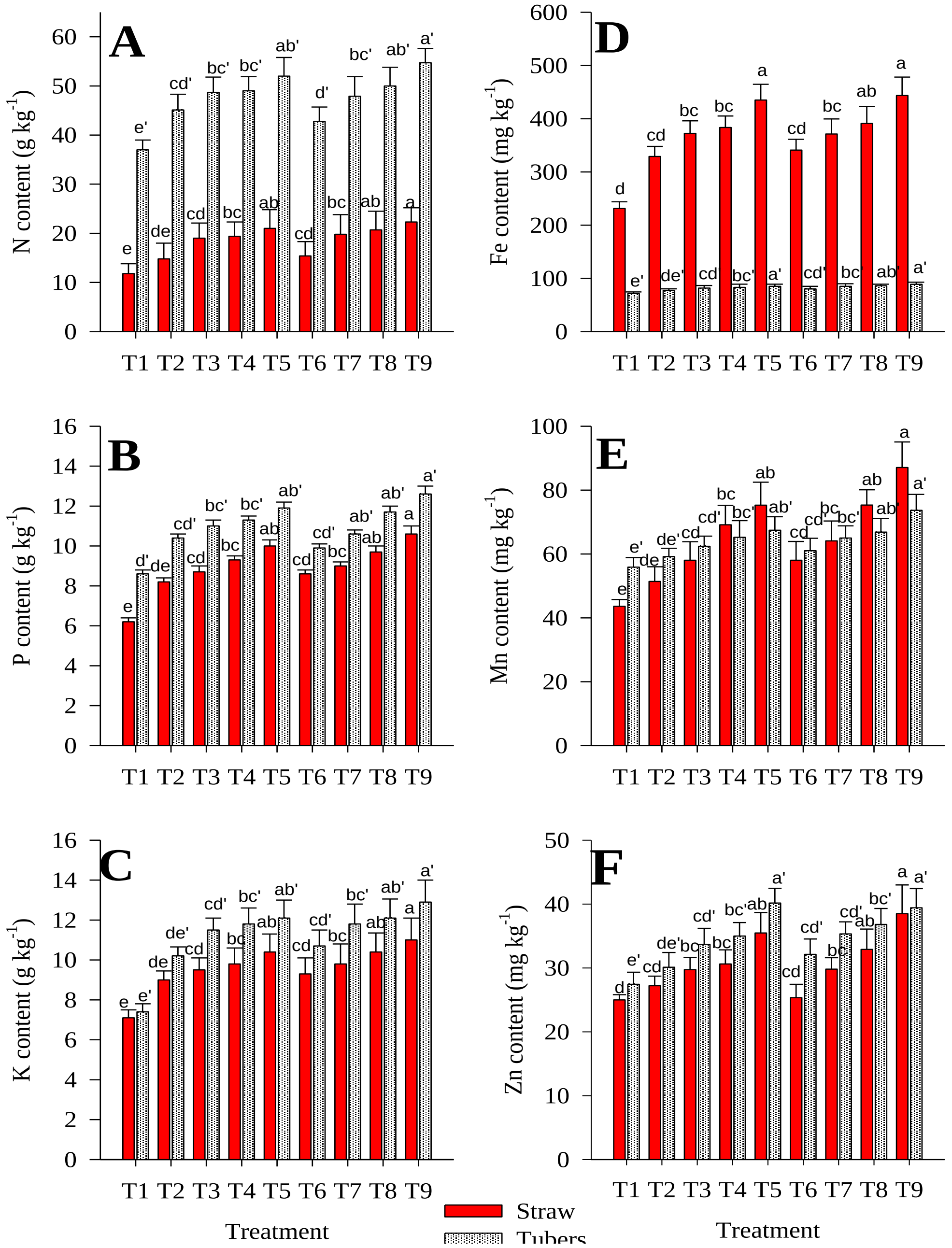

Fig. 3. Effect of the foliarly applied K-humate and K- silicate without or with amino acids and / or yeasts on macro and micronutrients contents (mean±stdev)in leaves and seeds of peanut plant grown in a calcareous saline soil during the second season. See footnote Fig 1. Similar letters indicate no significant differences among treatments at the 0.05 probability level, as determined by Duncan's test.

Figs 2 and 3 obviously reveal that K-humate was of significant effects on increasing N, P, K, Fe, Mn and Zn contents in seeds of the peanut plant grown in a calcareous saline soil. K-humate application caused the least significant increases in all the seed element contents under study. Application of the amino acids enhanced the effects of the applied K-humate, while application of the yeasts with the K-humate was of relatively more higher effects on the levels of these elements in plants. However, co-application of the amino acids and the yeasts together with the K-humate maximized the effects on the studied elements. The application of the K-silicate whether solely or combined with the amino acids and or the yeasts seemed to be of more significant effects than the K-humate and its associated amending treatments on seed contents of the elements under study.

3.3. Effects of the K-humate or K-silicate foliarly applied solely or combined with amino acids and /or yeasts on some chemical compound contents of the peanut plant grown in a calcareous saline soil

The results illustrated by Fig.4 reveal that the investigated amending treatments significantly enhanced the levels of chlorophyll A, chlorophyll B, and carotenoids in the leaves, as well as the protein, carbohydrate, and oil contents in the seeds of peanut plants cultivated on calcareous saline soil. These improvements highlight the potential of the treatments to mitigate the adverse effects of salinity and enhance both physiological and nutritional attributes of the plants. In all cases, the effects of the applied K-humate although were significant on the aforementioned compounds, yet such effects seemed higher upon the co-application of the K-humate and the amino acids. However,the combined application of K-humate together with the amino acids and the yeasts maximized the content values of these chemical compounds in peanut plant.

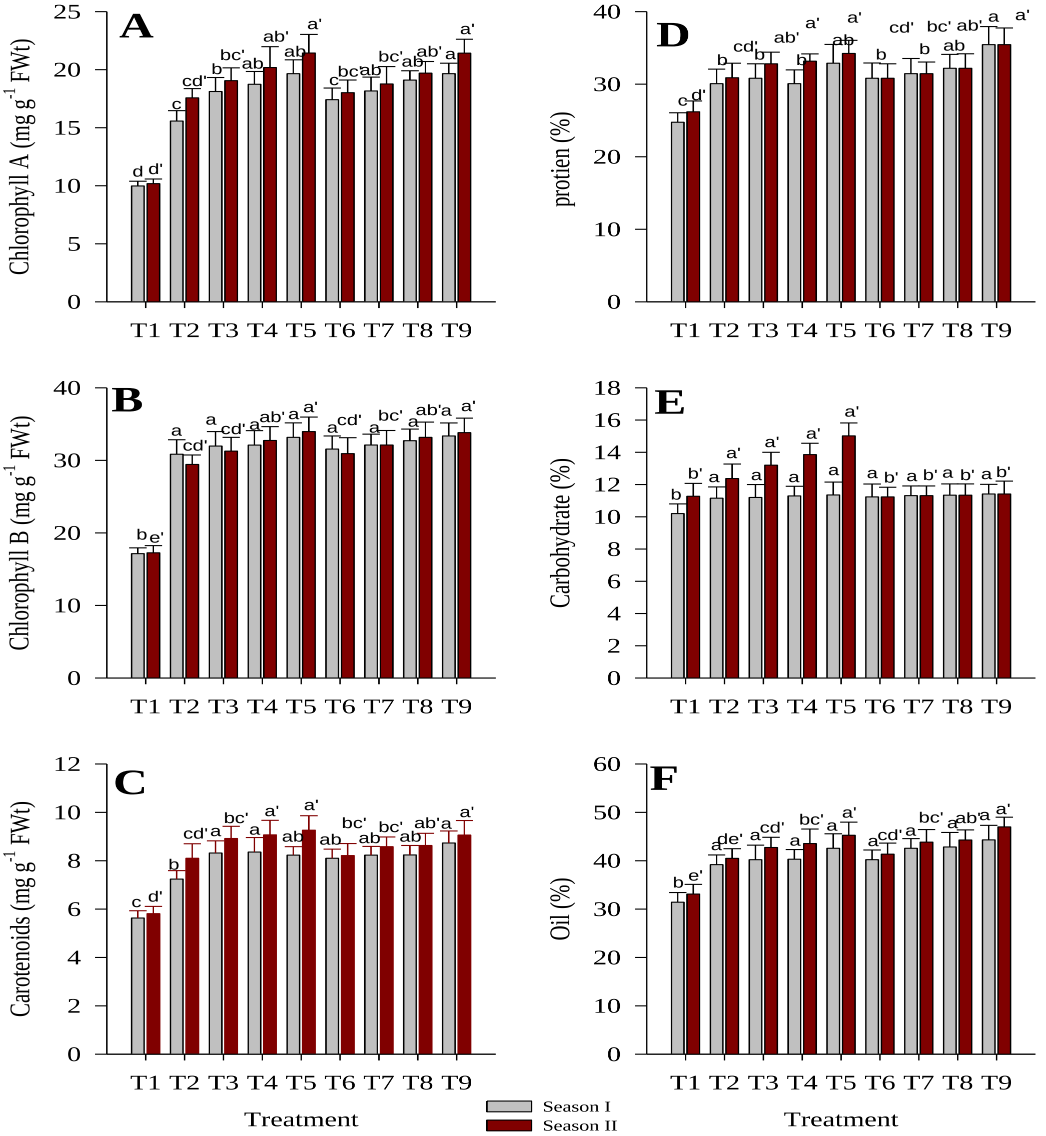

Fig. 4. Effects of the foliarly applied K- humateand K-silicate without or with amino acids and / or yeasts on chlorophyll A, chlorophyll B, carotenoids in leaves as well as on protein, carbohydrates and oil of seeds peanut plant (mean±stdev) grown in a calcareous saline soil. See footnote Fig 1. Similar letters indicate no significant differences among treatments at the 0.05 probability level, as determined by Duncan's test.

Similar trends were shown by the applied K-silicate whether it was applied solely or combined with the amino acids and /or the yeasts. Nevertheless, the corresponding values of each of the chemical compounds in leaves as well as in seeds in case of application of K-silicate surpassed those attained due to the applied K-humate and its associated amino acids and the yeasts.

4. Discussion

4.1. Effects of the foliar application of K-humate or K-silicate solely or combined with amino acids and /or yeasts on growth parameters of peanut plant grown in a calcareous saline soil

All additives raised significantly the growth parameters of peanut plant, especially the combined ones with superiority for K-silicate treatments versus K-humate ones. Comparable results were reported by Meena et al.(2018), who reported that supplementary applications of potassium could counteract the salinity stress and consequently improved salinity tolerance in terms of plant growth parameters (plant height, branches, root length and weight beside of the Na^{+}: K^{+} ratio in the different plant parts). There is no doubt that K is an essential nutrient for plant growth. This could be attributed to its importance in regulating membrane potential, cellular homeostasis and confirming stable protein synthesis (Romheld, 2010; Chakraborty et al.,2016; Yang et al .2019). Moreover, it is an activator of more than 60 enzymes, besides it affects substance transport, osmotic regulation, and stress resistance (Johnson *et al*., 2022). In abiotic stress, this nutrient lowers the osmotic potential in root stele, and this is essential for maintaining turgor pressure, which drives solute transportation in xylem and regulates plant's water balance (Hauser and Horie, 2010).

K-humate is utilized commonly as a plant bio-stimulant and a good natural supply due to its potentiality to increase soil content of the organic matter , regulate osmotic potential (Farid et al., 2023), improve nutrition status (Farid et al., 2018 & 2021), enhance carbohydrate transformation, stimulate plant progress, and enhance the water use efficiency of a plant (Hasanuzzaman et al.2018, Ibrahim et al., 2018)**.** The accumulation of proline in plant tissues is the consequence of spraying plants with the K-humate, besides K activates antioxidant enzymes which take part in scavenging ROS (El-Beltagi et al., 2023)

Silicon is another noteworthy exogenous material can play a multifunctional role in promoting plant vigor and confirming maintainable yield under salinity stress (Zargar et al., 2019; El-Ghamry *et al*., 2021). It is a beneficial nutrient for plants, e.g. it enhances growth parameters and consequently increases yield (Khan et al., 2019). It can, therefore , be regarded as “multitalented” element (Wu et al.2015; Zargar et al.,2019). In stressed conditions, silicate salts minimize the oxidative damage while modify metabolic and biochemical pathways in plants and this, in turn, increases plant growth (Alabdallah et al., 2024). Likewise, Kandil et al. (2019) reported that potassium silicate (K-silicate) application enhanced yield, yield components, and quality of soybean under environmental stress conditions. Additionally, Gomaa et al. (2020) and Gomaa et al. (2021b) demonstrated that foliar application of K-silicate significantly improved growth, yield, grain characteristics, and water use efficiency (WUE) in maize.

Amino acids, which are organic nitrogen polymers, serve as the building blocks for proteins and enzymes (Shokunbi et al., 2012) and are recognized as potent plant growth bio-regulators (Pessarakli et al., 2015). Moreover, they play a role in increasing the biosynthesis of non-protein nitrogenous compounds, such as pigments, vitamins, coenzymes, purines, and pyrimidine bases (Buchanan et al., 2015). Results obtained herein indicate that application of amino acids with either K humate or K silicate improves plant growth parameters beyond those attained for application of these salts solely. Similar results indicate that foliar addition of amino acids enhanced all growth parameters of bean plants under salinity stress (Sadak et al., 2015). This effect seems to be dependent on amino acid concentration, in which the highest concentration of the amino acids is more effective on plant growth parameters and yield under abiotic stresses (Sadak et al., 2023).

Usage of yeast became of great interest because of its ability to mitigate salinity stress indirectly via “secretion of volatile organic compounds and/or antifungal agents (Ruspi et al., 2025) beside of its positive effects as sources of several nutrients supplied by its foliar application (Babaousmail et al., 2022). Many research studies proved that yeasts promote in a direct way or indirectly growth of roots in the rhizosphere (Nassar et al., 2005; El-Tarabily and Sivasithamparam, 2006; Cloete et al., 2009).

4.2. Effects of of the foliar application of K-humate, K-silicate, amino acids, and yeasts on nutrient content in peanuts grown in calcareous saline soil

Fig 2 reveals the significant impacts of foliar application of each of K-humate and K-silicate, whether they were applied solely or in combinations with amino acids and/or yeasts, on increasing the concentrations of macro- (N, P, and K) and micronutrients (Fe, Mn, and Zn) in both leaves and seeds of peanut plants grown in the calcareous saline soil. The application of potassium (K), regardless of its source, could significantly increase concentrations of macro- and micro-nutrients within leaves and seeds. These findings stand in well agreement with those of Elbaalawy et al. (2018), who indicated that applied K could significantly increase the concentrations of N, P, K Fe, Mn, and Zn in peanut seeds for plants grown on a saline sandy soil in Egypt. Likewise, Abd El-Mageed et al. (2023) showed that applied K resulted in higher contents of N, P and K in wheat plant as compared with the control treatment.

In case of K-humate, Mahdy et al. (2021) found that application of K-humate significantly increased the concentrations of N, K, P, and Ca in faba bean plants while, at the same time, decreased the Na content. Probably this occurred owing to the functional groups of the humate which chelates the micronutrients such as Fe and Zn and convert them from sparingly soluble hydroxides into more available ones (Stevenson, 1994). Moreover, humic substances can improve cell membrane functions and hence promote nutrient uptake (Azari et al., 2012), beside of its action as hormone-like substances that improve growth and development of plants (Nardi et al., 1996). Additionally, K-humate is characterized by its high contents of the macronutritive (N, P, K) and the micronutritive elements (Mo, Cu, Zn, B, Co, Mg) which could increase nutrient contents in peanut plants (El-Hashash et al., 2022).

K-silicate plays a dual role in enriching plant with the nutritive elements through its content of K whose role has been discussed above beside of its content of Si which can be considered as “multitalented” element that improves soil conditions and enhances nutrient concentrations (e.g., N, P, K) in plants (Dong et al., 2018). Thus, potassium silicate (K-silicate) can be regarded as a high-quality fertilizer that supports sustainable and environmentally friendly agricultural practices. Its ability to enhance plant growth, yield, and stress tolerance while improving resource use efficiency makes it a valuable tool for promoting ecological balance and sustainable farming (Wu et al., 2015, Zagar et al.,2019). Addition of amino acids and/or yeasts were of pronounced enhancing effects on either K-humate or K-silicate where such additions improved the nutritional status of peanut plants, with superiority for K-silicate treatments. Amino acids are growth bio-regulators (Pessarakli et al., 2015) beside being a source of N and hormone precursors (Zhao, 2010; DeLille et al., 2001; Maeda and Dudareva, 2012) that enhanced plant defence mechanisms against abiotic and biotic stresses (Teixeira et al., 2017). Thus, amino acids create favorable environmental conditions for growth of plant. Yeast metabolites e.g. cytokinin, and auxin stimulate growth of plants and consequently their development (Kowalska et al., 2022). In summary, yeasts play a vital role in agricultural production by promoting crop growth, enhancing stress resistance, and improving the quality and storage properties of agricultural products.

4.3. Effects of the foliar application of K-humate or K-silicate solely or combined with amino acids and /or yeasts on some chemical compound contents of the peanut plant grown in a calcareous saline soil

All the amending treatments under study raised plant biochemical components i.e.—chlorophyll A, chlorophyll B, and carotenoids in leaves, beside of protein, carbohydrates, and oil in seeds. Moreover, combining either of K- amendments with amino acids and/or yeasts maximized their influences, resulting in increased concentrations of each of chlorophyll A, chlorophyll B, carotenoids in the leaves, beside of higher protein, carbohydrate, and oil contents in the plant seeds. According to these results, it can be deduced that application of these amending materials were of helpful effects on mitigating salinity stress, improving soil health, and consequently boosting the plant's biochemical composition.

Potassium (K) content in both K-humate and K-silicate seemed to play critical roles in different metabolic processes in plants due to its essentiality for photosynthesis, protein synthesis, enzyme activation, and stomatal function (Hawkesford et al., 2012). In addition, it supports fixation of nitrogen and ensures proper nitrogen partitioning to meet the demands of active sinks, e.g. reproductive parts and nodules, simultaneously (Almeida et al., 2015), while, at the same time, it plays a key role in hormone balance, including the regulation of auxine, a hormone vital for plant growth (Rubio et al., 2009).

Silicon (Si), which is the other component of the K-silicate, contributes to plant growth by strengthening stress resistance (Xiao et al., 2022). It is particularly of obvious beneficial effect under stressful conditions, as it helps improve plant resilience and nutrient uptake (Liang et al., 2007). Together, the combined effects of potassium and silicon as a K-silicate amending material, along with the synergistic contributions of amino acids and yeasts, create favourable environmental conditions for the peanut plant to thrive, even under salinity stress conditions, ultimately leading to improved biochemical and physiological outcomes.

Conclusions

Peanut plant (***Arachis hypogaea***) is an important grain legume ; however, its cultivation in a saline soil is adversely affected by salt stress The current research hypothesized that potassium in the form of humate or silicate could be a suitable solution under saline stress of the soil and the results obtained herein confirm that K-salts increased significantly all the plant growth indicatorsi.e of plant, number of branches per plant weight of pods per plantand weight of seeds per plant.Also,these salts raised plant contents of the macro - (N,P and K) and micronutrients (Fe,Mn and Zn) as well as some chemical compounds in leaves i.e. chlorophyll A, chlorophyll B and carotenoids beside of its contents of protein, carbohydrates and oil in seeds. In particular, there was superiority for K-silicate versus K-humate in this concern. Overall, these findings confirm the 1st hypothesis. The use of amino acids and/or yeasts recorded further significant enhance in the nutritional status of plants and their growth and productivity. In this concern, the integration between K-silicate+aminoacids+yeast recorded the highest increases and this support the 2nd hypothesis.

We suggest that future researches should try more promising amending materials to restrict the deleterious effect of salinity stress on the plant grown on such soils . Soils of more areas are expected to be salt-affected due to bad management of soil and bad quality of the irrigation water. Therefore, good farm management involving application of suitable, safe and cheap amendments to soil or plant might become necessity in the close future.

Declarations

Ethics approval and consent to participate

Consent for publication: The article does not include any content that could be considered unlawful, defamatory, or in violation of the terms and conditions outlined in the agreement. It adheres to ethical and legal standards, ensuring compliance with all relevant guidelines.

Availability of data and material: The datasets and materials generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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