Research Article

A Comparative Study on the Impact of Compost, Humate, and Silicate on the Nutritional Characteristics of Calcareous Soil Cultivated by Soybean

Dalal H. Sary and Rama T. Rashad*

Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Area code: 12112, P.O. Box: 175 El-Orman, Egypt.

Abstract | Two field experiments have been carried under the calcareous soil conditions during the summer seasons of 2018 and 2019. Their aim was to compare the effects of compost, K-humate, and K-silicate applied at 50% and 100% of the recommended dose (compost: 7.81 t ha^{-1}, potassium silicate: 16.67 L ha^{-1}, potassium humate: 15.63 kg ha^{-1}) on soil nutritional status regarding macro-nutrients (N, P, and K) and soybean yield and quality. Treatments were distributed in a randomized complete block design with three replicates. The study showed that soil applied K-H at 100% of the recommended dose has increased the available N (mg kg^{-1}) in soil significantly at a significance level of $P = .05$ by 77.78 % compared to the control. The 100 % application rate of compost showed the most significant increase in seed yield (kg ha^{-1}, 84.88%) followed by K-H (69.07%) then K-Si (67.39%) compared to the control. Also, compost at rate 100 % showed the most significant increase of protein and total N (~77.07%) followed by K-Si (~60.67%) then K-H (~ 17.69%). However, compost and K-Si have almost decreased the concentration (mg kg^{-1}) of Cu, Fe, Mn, Zn, and Si in soybean seeds significantly by increasing the application rate from 50 to 100 %. Potassium silicate was the most effective Si-source in this study due to its content of readily soluble Si in soil solution. Silicon uptake can partially control the availability and uptake of some nutrients from soil. Soil may be enriched by versatile advantages upon application of K-H and K-Si but the compost is still the most effective.

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***Correspondence** | Rama T. Rashad, Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Area code: 12112, P.O. Box: 175 El-Orman, Egypt; **Email:** rtalat2005@yahoo.com, Rama.mostafa@arc.sci.eg
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Introduction

Desert area at the west Nile Delta of Egypt has gained an interest to increase its agricultural sustainability and productivity. Reclamation projects and irrigation network covered about 23,000 hectares at the west of Nubaryia, Alex. Cairo desert road since 1969. Nevertheless, water-salt balance was altered over years by raised ground water table causing soil salinization. Water logging and salinization are major problems restrict the agricultural sustainability and productivity of the region (Khalifa and Beshay, 2015).

Geologically, the region is a part of Pleistocene limestone sediments of old marine formed by successive high sea level. Satellite image and soil survey studies revealed distinguishable categories of deteriorated surface soil. Soil mapping showed that non-saline calcareous loam deep soils represent 15.2% unit area (Khalifa and Morsy, 2007). Remote sensing and geographical information systems GIS techniques provided Land sat images of the cultivated land and surface water logging. Such degraded soils suffer from fertility problems and crop yield limiting factors (Amer and Moghanm, 2017).

Poor productivity of calcareous soils is often due to low organic matter and high $CaCO_3$ content that reduces nutrient availability (Ibrahim and Ali, 2018). Many techniques were studied to improve the nutritional status and crop yield of this type of soil (Eid *et al*., 2013). Fertigation by addition of humic substances to NPK fertilizer through drip irrigation system decreased leaching of N and K to deeper layer and, increased soil available P (Selim *et al*., 2010).

Humic substances (HS) are natural organic compounds have complex chemical structures originated from plants, peat, soil, and coals and can improve soil physically, chemically, and microbiologically (Ouni *et al*., 2014). Humates are salts of humic acids that are more soluble and active component of HS. Commercially available humates used in agriculture include K, Ca, B, and Na (Lyons and Genc, 2016).

Foliar application of HS is a common agricultural practice because of their hormone-like impact on growth promotion (Ouni *et al*., 2014) improve plant yield and quality (Mohsen *et al*., 2017). Commercial humates, especially K humate, are used as soil conditioners to enhance soil structure and water retention capacity (Karčauskienė *et al*., 2019). Iron-humates have been applied to soybean iron deficient plants to provide nutritional iron in calcareous soils (Cieschi *et al*., 2019).

Humic acid rich materials such as composts are in some cases better than humates that are easily leached by rainfall and irrigation. Compost is produced by controlled biological decomposition of organic material. It is used as an amendment to enhance soil chemical, physical, and biological properties due to its organic matter content. Compost is not a fertilizer but can reduce the required amount of fertilizer, efficient in improving plant growth and suppressing soil-borne plant pathogens (El-Mougy *et al*., 2014; Badar *et al*., 2015).

The last 15 years introduced interesting studies about the impact of Si fertilization on the yield quantity and quality of cereals like soybean. Potassium silicate is a silica amendment of highly soluble potassium (K) and silicon (Si). It is approved by the USDA for conventional agriculture as a fertilizer compatible with sustainable agriculture. Foliar application of potassium silicates showed a bio-simulative effect under stress conditions for plants such as salinity (Bayat *et al*., 2013), water deficiency (Cruz *et al*., 2014), etc. Sodium meta-silicate (Na_2SiO_3) enhanced K use efficiency and ameliorated symptoms caused by deficiency in essential nutrients (Lee *et al*., 2010; Miao *et al*., 2010).

Soil application of Si-rich materials remains the most effective method that enhances Si uptake by plants and increased soybean yields by 7.5–13.6% (Liang *et al*., 2015). Application of potassium meta-silicate (K_2SiO_3, 12 kg ha^{-1}) has increased the concentration of K^+ in wheat shoots and grains (Artyszak, 2018). Fertilization by Si enhanced plant phosphorus (P) utilization (Agostinho *et al*., 2017).

Silicon in the soil is continuously removed via crop uptake and by leaching (NOSB TAP Review, 2003). Plant-available Si in soils can be depleted by continuous cultivation of some crops such as rice. Absorption through roots appeared to be the only Si-uptake mechanism by rice plants (Agostinho *et al*., 2017).

Soybean (*Glycine max* L.) is an important crop scientifically and agriculturally (Ouda *et al*., 2010). In Egypt, a decrease in the soybean production (tons) by 57.79% was from 1993 to 2008 due to biotic and abiotic factors negatively affecting production (El Agroudy *et al*., 2011; Khalil *et al*., 2011). Application of organic manure as well as foliar application of micronutrients (Fe, Zn, Mn and B) has enhanced the soybean yield and seed quality (Mekki and Ahmed, 2005; Abdel-Latif and El Haggan, 2014).

Field studies are required to match different soil conditioners with specific sandy soils and crops. The aim of this study is compare the impact of compost, potassium humate (K-H), and potassium silicate (K-Si) on the soybean crop cultivated under the calcareous soil conditions. Nutrient availability and uptake were estimated.

Materials and Methods

Area of the study

The field experiment has been carried out during the summer seasons of 2018 and 2019 at El-Nubaryia Agricultural Research Station (latitude of 30° 30°N longitude of 30° 20°E) Agricultural Research Center (ARC), Nubaryia, Egypt. The experimental area has an arid climate with cool winters and hot dry summers. Some properties of the experiment calcareous soil [Calcisol] (Khalifa and Beshay, 2015; FAO, 2014) are presented in Table 1.

Table 1: *Some characteristics of the experiment soil before cultivation.*

Particle size distribution (%)			
Sand	Silt	Clay	Texture class
44.95	28.1	23.5	Sandy Loam
$CaCO_3$ (%)	Organic matter % OM	pH†	Electrical conductivity EC (dS m^{-1})‡
33.66	4.13	8.3	0.31

† (1:2.5 soil : water suspension) ‡ (1:1 soil : water extract).

Materials used in the study and planting

The studied materials were applied to the experiment soil at two rates: 50% and 100% of the recommended dose that is for compost: 7.81 t ha^{-1}, potassium silicate: 16.67 L ha^{-1}, potassium humate: 15.63 kg ha^{-1}. Compost treatments 3.75 and 7.5 kg $plot^{-1}$ (3.91 and 7.81 t ha^{-1}, respectively) were mixed with surface soil a week before cultivation. Potassium humate was commercial K-humate powder 60%, K_2O-7% and potassium silicate was commercial liquid K_2SiO_3, K_2O– 10%, SiO_2– 25%. Potassium humate was applied as powder; 7.5 and 15 g $plot^{-1}$ spread on soil while solutions of K-silicate; 8 and 16 mL L^{-1} for plot was sprayed on soil 30, 60, and 90 days after cultivation. Some characteristics of the studied additives are presented in Table 2.

Table 2: *Some estimated properties of materials applied in the study.*

Material	pH‡	EC‡, dS m^{-1}	OC, %	Total, g kg^{-1}		
				N	P	K
Compost (C)	8.53	2.67	11.30	13.44	7.0	12.0
K-Silicate	7.00	7.00	-	-	-	98.0
K-Humate	7.40	19.05	16.89	20.20	12	62.0

Planting was carried out on the 1st of June (2018 and 2019) in four ridges per plot. Three soybean seeds (Giza 111 variety) were hand-sown in each hole along the ridge. The twenty-one plot (3.2 m × 3 m = 9.6 m^2 plot area, 4 ridges) received the recommended dose of the NPK fertilizer (Before planting, calcium superphosphate (15.5% P_2O_5- 200 kg ha^{-1}) was applied during seedbed preparation. Potassium sulfate (48% K_2O- 75 kg ha^{-1}) was applied 21 days after planting. Urea (46% N - 90 kg N ha^{-1}) was divided in two equal doses prior to the 1st and 2nd irrigations). Different treatments including a control (without additives) were distributed in a randomized complete block design (RCBD) with three replicates. The cultivated area of study was irrigated 30, 60, and 90 days after sowing. The change in soil moisture (ΔSM, %) due to application of compost, K-H, and K-Si was estimated 48 h after irrigation by core method (Black, 1982) and calculated according to the Equations 1 and 2:

$$\text{Soil moisture (SM, \%)} = \frac{Wet weight of soil sample - Dry weight of soil sample}{Dry weight of soil sample} \times 100 \quad ....(1)$$

$$\Delta SM\ (\%) = SM\ after\ irrigation - SM\ before\ irrigation \quad ....(2)$$

Soil and plant sampling

At harvest, representative soil and plant samples from all experimental plots were randomly selected and air-dried to estimate the following characteristics: Plant height (cm), number of branches/and number of pods per plant, number of seeds per plant, 100-seed weight (g), seed yield $plant^{-1}$ (g), shelling (%), and seed yield (t ha^{-1}) have been calculated based on the seed yield per plot area and the mean of the two seasons was recorded.

Analysis of soil and plant samples' content of N, P, and K

The soil available N, P, and K were extracted by 1% K_2SO_4, 0.5 N $NaHCO_3$, and 1 N NH_4OAc (pH 7.0), respectively (Black, 1965; Jackson, 1973). Soybean seeds were dried at 70°C for 48 h and ground. A half gram of the ground seeds was wet digested using the acid mixture (1:1 $H_2SO_4/HClO_4$) (Chapman and Pratt, 1961). Total concentrations of N, P and K in plant and soil extracts were estimated by distillation using Kjeldahl apparatus, colorimetrically by the UV-Vis. Spectrophotometer and by flame photometer, respectively. Protein percentage in seeds was calculated as the N (%) × 6.25. Concentrations of Cu, Fe, Mn, Zn, and Si in seeds' extract were measured by the ICP Spectrometry (ICP-*Ultima 2 JY* Plasma).

Statistical analysis

The statistical significance (LSD) of the treatments effect was estimated by the one-way analysis of variance (ANOVA) (Gomez and Gomez, 1984). Calculations were carried out at a significance level *P*= *.05* using the Co-State Software Package (Ver. 6.311), a product of Cohort software Inc., Berkley, California.

Results and Discussion

Availability of macronutrients in soil

Results in Table 3 indicate that applied K-H at 100% of the recommended dose has increased soil available N (mg kg^{-1}) significantly at a significance level of $P = .05$ depending on the LSD value by 77.8% compared to the control. Non-significant increase by 36.7% and 22.2% was observed for K-H (rate 50%) and K-Si (rate 100%) treatments, respectively. Non-significant decrease in the available N in soil was observed for compost and K-Si treatments by 11.1% and 22.2% at application rate 50%, respectively. Non-significant variation was observed for the soil available P and K (mg kg^{-1}) under the effect of different treatments. However, maximum increase in available P was due to compost at rates 50 and 100% by 54.6% and 36.4%, respectively. Minimum decrease by 45.4% was recorded for K-Si at the rate 50%. Maximum increase in the soil available K can be observed from Table 3 for compost treatments by 23.8% compared to the control. While minimum decrease was due to K-H at rate 50% by 20.6%.

Table 3: *Soil available NPK after harvesting.*

Treatment	Application rate	Available (mg kg^{-1})		
		N	P	K
	Before planting	13.44^{c*}	4.00^{a}	293.00^{ab}
	Control	20.16^{bc}	7.33^{a}	293.07^{ab}
Compost	50%	17.92^{bc}	11.33^{a}	362.87^{a}
	100%	20.16^{bc}	10.00^{a}	362.87^{a}
K-H	50%	27.55^{ab}	8.00^{a}	232.60^{b}
	100%	35.84^{a}	6.33^{a}	293.07^{ab}
K- Si	50%	15.68^{bc}	4.00^{a}	344.27^{a}
	100%	24.64^{abc}	8.67^{a}	335.00^{a}
$L.S.D_{5\%}$		12.32	7.62	91.07
Significance of factors		*	ns	ns

**The footnotes (a–h) indicate the non-significance ranges for the different treatments.*

Since all treatments have received equal doses from NPK fertilization according to recommendations, variation in the available N, P, and K (mg kg^{-1}) in soil can be attributed to the effect of the studied additives. Two factors affect nutrient availability for plant that is soil nature and amendment properties. The studied soil is sandy clay loam of medium texture. Solubilized nutrients are not quickly leached and can be kept within soil until a reasonable time before loss. Compost and K-H can produce additional N; P and K nutrients in soil as well as K-Si can add K. Although compost has lower NPK content (g kg^{-1}) than K-H, its application has increased the soil available P and K more than K-H and K-Si. This may be due to the slow decomposition and slow release of nutrients behaviour of compost in soil. Both K-H and K-Si are water-soluble salts more leachable away from root zone compared to the compost. Therefore, available P and K in soil was lower concentration for K-H and K-Si treatments. Lower available N in soil can be caused by more N uptake from compost being biocompatible by the microorganisms' activity. Humate moieties solubilized from K-H may be retained or adsorbed by some soil particles after K-H dissolution in soil solution, which increased available N in soil but decreased N uptake by plant compared to the compost. Potassium silicate treatments were almost free of additional N or P, but played a role in their availability in soil from routine fertilization and uptake by plant. Chemical similarity between phosphate ($H_2PO_4^-$) and silicate ($H_3SiO_4^-$) ions may play a role in phosphorus (P) utilization by plant and in soil. Some competition between $H_2PO_4^-$ and $H_3SiO_4^-$ ions for specific soil sorption sites may occur, in which adsorbed $H_2PO_4^-$ is displaced by $H_3SiO_4^-$ and then became available for plant uptake (Agostinho *et al*., 2017). The presence of Si and P in the soil may create a synergistic effect on soil Al, Mn, and As (Gonzalo *et al*., 2013; Mihara *et al*., 2017).

Yield components and characteristics of soybean

Soil application of compost, K-H, and K-Si in the present study resulted in significant increase in the estimated yield parameters of soybean crop compared to the control and to each other (Table 4). Increasing application rate from 50 to 100% of the recommended dose increased the plant length (cm), number of shoots, number of pods, seed yield (kg ha^{-1}), 100-seed wt. (g), and shelling (%). Most significant increase in the plant length (cm) was by 40.9 and 39.5% recorded for compost and K-Si at the rate 100%, respectively. The least significant increase was by 19.2% for K-H at the rate 50%. Also, the 100% application rate of compost showed the most significant increase in the number of shoots (81.6%) and pods (123%), seed yield (kg ha^{-1}, 84.9%) 100-seed wt. (g, 45.9%), and shelling (%, by 50.4%) compared to the control. The next most significant increase in the number of shoots (71.3%), seed yield (kg ha^{-1}, 69.1%) and shelling (%, by 16.5%)

Table 4: *Yield and some yield components and characteristics.*

Treatment	Application rate	Plant length (cm)	No. of shoots	No. of pods	Seed yield (kg ha^{-1})	100-seed wt. (g)	Shelling (%)
	Control	66.66^{d*}	2.72^{b}	33.33^{c}	1475.84^{f}	11.55^{b}	58.79^{c}
Compost	50%	80.00^{c}	3.22^{b}	36.33^{bc}	1920.62^{e}	11.54^{b}	59.22^{c}
	100%	93.89^{a}	4.94^{a}	74.33^{a}	2728.53^{a}	16.85^{a}	88.41^{a}
K-H	50%	79.44^{c}	3.11^{b}	46.89^{bc}	2403.32^{c}	12.27^{ab}	54.34^{d}
	100%	84.33^{bc}	4.66^{a}	48.89^{bc}	2495.22^{b}	12.57^{ab}	68.50^{b}
K- Si	50%	87.22^{abc}	3.22^{b}	36.33^{bc}	2291.06^{d}	10.98^{b}	53.65^{d}
	100%	93.00^{ab}	3.22^{b}	52.22^{b}	2470.40^{bc}	11.21^{b}	58.78^{c}
L.S.D $_{5\%}$		8.75	0.60	18.46	79.88	4.59	2.69
Significance of factors		***	***	**	***	ns	***

** The footnotes (a–h) indicate the non-significance ranges for the different treatments.*

was observed for K-H followed by K-Si (67.4%) at the 100 % application rate as indicated by Table 4.

This behavior can be attributed to the organic nature of compost and K-H, which is rich in biocompatible nutrients readily available for absorption by plant compared to inorganic K-Si limited to available K and Si. Compost succeeded more than K-H due to its slow release of nutrients. Additionally, soil application of the studied amendments affects the role of soil during the cultivation season. Compost can improve water movement through soil; enhance soil chemical, physical, and biological properties due to its organic matter content (Krull *et al.*, 2012; Darlington, 2014; El-Mougy *et al.*, 2014; Badar *et al.*, 2015). Soil may be enriched by versatile advantages upon application of K-H and K-Si but still compost is the most effective. Humates and silicates enhance soil structure and water retention capacity, activate beneficial soil microbes, and deactivate toxic metals (Agostinho *et al.*, 2017; Karčauskienė *et al.*, 2019). Studies referred to that yield components of soybean enhanced by Si application (Artyszak, 2018).

Impact of compost, K-H and K-Si applied to soil on the total N, P, and K content of soybean

Results obtained for N, P, and K availability as affected by compost, K-H, and K-Si applied to soil may be reflected in the total N, P, and K content of soybean seeds. Significant increase was observed in Table 5 for the total N and in turn in protein (%), while non-significant variation was observed for total P and K compared to the control. Compost at rate 100% showed the most significant increase of protein and total N (~77.1%) followed by K-Si (~ 60.7%) then K-H (~ 17.7%). Compost also showed the maximum increase in seeds' total P by 4.9% and total K by 2.7% compared to the control. Soil application of K-H and K-Si decreased but non-significantly the total P in soybean seeds. This may be due to P leaching loss affected by humate and silicate moieties. Additional K content of K-H and K-Si could not increase the total K in seeds significantly.

Table 5: *Total content of N, P, and K in soybean seeds.*

Treatment	Application rate	Protein (%)	Seeds (g kg^{-1})		
			N	P	K
	Control	25.62^{d*}	40.99^{c}	7.77^{ab}	9.95^{ab}
Compost	50%	40.31^{abc}	64.50^{ab}	7.68^{ab}	9.88^{b}
	100%	45.36^{a}	72.58^{a}	8.15^{a}	10.22^{a}
K-H	50%	29.68^{cd}	47.48^{bc}	6.90^{b}	9.96^{ab}
	100%	30.15^{bcd}	48.24^{bc}	7.17^{ab}	9.85^{b}
K- Si	50%	34.71^{abcd}	55.54^{abc}	7.28^{ab}	9.99^{ab}
	100%	41.16^{ab}	65.86^{ab}	7.22^{ab}	10.05^{ab}
L.S.D $_{5\%}$		11.16	18.44	1.13	0.33
Significance of factors		*	*	ns	ns

**The footnotes (a–h) indicate the non-significance ranges for the different treatments.*

Concentration (mg kg^{-1}) of micronutrients in soybean seeds

Table 6 shows a significant (at $P= .05$) variation in the concentration (mg kg^{-1}) of micronutrients in soybean seeds affected by the studied treatments compared to the control. For compost and K-Si, increasing the rate of application from 50 to 100% almost decreased the concentration (mg kg^{-1}) of Cu, Fe, Mn, Zn, and Si in soybean seeds significantly. Oppositely, increasing K-H application rate from 50 to 100% increased the seeds' content (mg kg^{-1}) of Cu, Fe, Mn, and Zn; but decreased total Si (mg kg^{-1}). Among treatments, K-Si at 100% application rate resulted in the most significant decrease in seeds' Fe (by 16.8%) and the most significant increase in seeds' Si (by 50.7%). On the other hand, K-H at same rate showed the most significant increase in seeds' Fe (by 21.2%) and the most significant decrease in seeds' Si (by 28.1%).

Table 6: *Concentration (mg/kg) of micronutrients in soybean seeds for different treatments.*

Treatment	Application rate	Seeds (mg/kg)				
		Cu	Fe	Mn	Zn	Si
	Control	26.8^{a*}	371.3^{b}	65.5^{a}	60.6^{a}	198.9^{e}
Compost	**50%**	21.6^{ab}	348.3^{c}	61.2^{ab}	59.8^{ab}	221.9^{c}
	100%	20.8^{b}	324.5^{d}	51.8^{de}	54.3^{c}	214.3^{d}
K-H	**50%**	18.5^{b}	324.2^{d}	48.4^{e}	47.0^{d}	237.1^{b}
	100%	22.3^{ab}	450.0^{a}	58.7^{bc}	55.1^{bc}	143.1^{f}
K- Si	**50%**	18.3^{b}	354.2^{c}	58.2^{bc}	53.9^{c}	299.8^{a}
	100%	18.5^{b}	308.9^{e}	54.9^{cd}	52.4^{c}	220.4^{cd}
L.S.D $_{5\%}$		5.21	8.27	5.71	5.21	6.72
Significance of factors		*	***	***	**	***

**The footnotes (a–h) indicate the non-significance ranges for the different treatments.*

This observed behaviour could be explained by the effect of two main factors: (1) chemical nature of compost, K-H, and K-Si, and (2) enhanced absorption of Si by soybean seeds. It has been well defined that HS bear miscellaneous chelating groups (carboxylic, phenolic and alcoholic) in soil solution able to bind to soil mineral surfaces. They can form metal complexes, oxidize/reduce elements, control root uptake of micronutrients by plants and microorganisms, and fix some heavy metals. Humic substances in compost and K-H improve nutrient uptake and decrease the uptake of toxic elements such as Cd, Cu, Pb, as studied previously (Ouni *et al*., 2014). Difference between compost and K-H may be caused by the direct chelating action of soluble humate ligands produced from dissolution of K-H that increase micronutrients absorption by plant. Organo-metallic complexes of Cu, Fe, Mn, Zn absorbed by soybean seeds may compete for Si absorption and hence decrease Si concentration in seeds in case of K-H.

Soybean shows a high response to Si application because it is a Si-accumulator plant; with Si-transporters facilitate uptake and distribution of Si between leaves and grains (Cruz *et al*., 2014; Rashad and Hussien, 2018). In the present study, soil application of compost, K-H and K-Si showed a highly significant increase in seeds' content of Si (mg kg^{-1}) compared to the control. Potassium silicate was the most effective Si-source in this study due to easily soluble Si in soil solution produced by K-Si dissolution. Silicon may partially control the availability and uptake of some nutrients (Schaller *et al*., 2017; Greger *et al*., 2018).

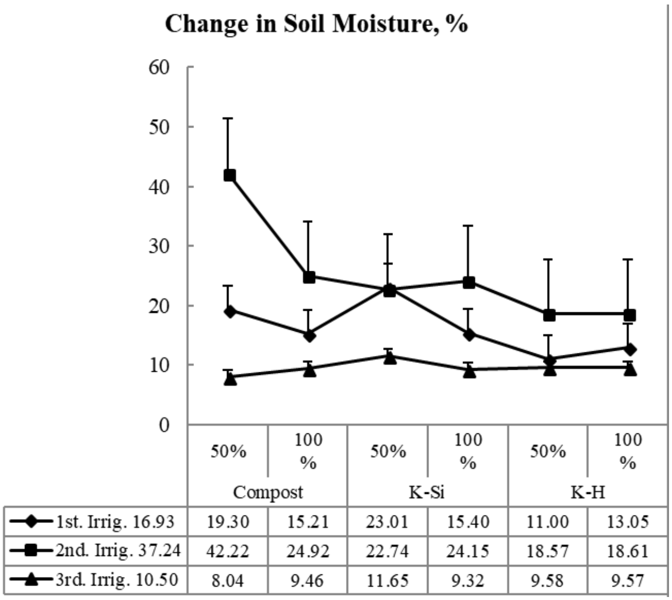

Figure 1: *Change in the soil moisture (%) after irrigation under the effect of the studied amendments.*
**Error bars represent standard deviation values SD = 3.98, 9.21 and 1.11 for 1st, 2nd and 3rd irrigation, respectively.*

Soil moisture change (%)

Results for the three irrigations were plotted in Figure 1. Soil moisture (%) for all applications increased from first irrigation to the second irrigation that showed the maximum ΔSM (%) then decreased to minimum in the third one. Compost maximized ΔSM (%) followed by K-Si. It may be due to the swelling of compost particles and silicate moieties. Soil structure improved by soil applications perhaps includes expanded voids and pores which entrap water that is consumed by plant during its growth step.

Conclusions and Recommendations

Compost showed the most significant increase in soil available (mg kg^{-1}) and seed total (g kg^{-1}) nitrogen, seed yield (kg ha^{-1}) and seed protein (%), and soil moisture (%) after irrigation compared to the control, K-H and K-Si. Potassium silicate resulted in the most significant increase in concentration (mg kg^{-1}) of Si in soybean seeds being a Si-source. The studied amendments mitigated the uptake of Cu, Fe, Mn, Zn, and Si by soybean seeds in a variable manner. Compost can be considered the most effective for soybean cultivation in calcareous soil compared with K-H and K-Si.

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Novelty Statement

It is the optimization of the calcareous soil status to optimize its crop production by utilization of eco-friendly fertilizers like compost, K-humate and K-silicate. In addition, it is to differentiate between the three fertilizers regarding soybean yield and quality in calcareous soil.

Author's Contribution

This work was carried out in collaboration between all authors: DHS and RTR. Both authors designed the study and designed the experimentation. The author DHS followed up the field-work. The author RTR managed the laboratory analyses of the study, literature survey, performed the statistical analysis and drafted the manuscript. All authors read and approved the final manuscript.

Compete of interest

The authors declare that they have no conflict of interest.

References

Abdel-Latif, E. and M.A. El-Haggan. 2014. Effect of micronutrients foliar application on yield and quality traits of soybean cultivars. Int. J. Agric. Crop Sci., 7(11): 908-914.

Agostinho, F.B., B.S. Tubana, M.S. Martins and L.E. Datnoff. 2017. Effect of different silicon sources on yield and silicon uptake of rice grown under varying phosphorus rates. Plants, 6: 35. https://doi.org/10.3390/plants6030035

Amer, R. and F. Moghanm. 2017. Remote sensing for detection and monitoring of the cropland water logging in arid and semi-arid regions. 20th Int. Water Technol. Conf., IWTC20, Hurghada, 18-20 May: 264-276

Artyszak, A., 2018. Review effect of silicon fertilization on crop yield quantity and quality. A Literature Review in Europe. Plant, 7: 54. https://doi.org/10.3390/plants7030054

Badar, R., B. Batool, A. Ansari, S. Mustafa, A. Ajmal and S. Perveen. 2015. Amelioration of salt affected soils for cowpea growth by application of organic amendments. J. Pharmacogn. Phytochem, 3(6): 87-90.

Bayat, H., M. Alirezaie, H. Neamati and A.A. Saadabad. 2013. Effect of silicon on growth and ornamental traits of salt-stressed Calendula (*Calendula officinalis* L.). J. Ornament. Plants, 3(4): 207-214.

Black, C.A., 1982. Methods of soil analysis. Soil Sci. Soc. Am., Inc. Pub., Madison, Wisconsin, USA.

Black, C.A., 1965. Methods of soil analysis. Part 2, Series 9, Am. Soc. Agron. Inst. Publ., Madison, WI. pp. 894-1372.

Chapman, H.D. and R.E. Pratt. 1961. Methods of analysis for soil, plants and water. Department of Soil and Plant Nutrition, California Univ, U.S.A.

Cieschi, M.T., A.Y. Polyakov, V.A. Lebedev, D.S. Volkov, D.A. Pankratov, A.A. Veligzhanin, I.V. Perminova and J.J. Lucena. 2019. Eco-friendly iron-humicnano fertilizers synthesis for the prevention of iron chlorosis in soybean (*Glycine max*) grown in calcareous soil. Front. Plant Sci., 10: 413. https://doi.org/10.3389/fpls.2019.00413

Cruz, M.F.A., F.Á. Rodrigues, A.P.C. Diniz, M.A. Moreira and E.G. Barros. 2014. Soybean Resistance to *Phakopsorapachyrhizi* as Affected by Acibenzolar-S-Methyl, Jasmonic Acid and Silicon. J. Phytopathol., 162: 133–136. https://doi.org/10.1111/jph.12170

Darlington, W., 2014. Compost. A Guide for evaluating and using compost materials as soil amendments. Consultant Soil and Plant Laboratory, Inc., Orange Office, (714): 282-8777, seen on 16 Feb. 2014.

Eid, A.R., B.A. Bakry and M.H. Taha. 2013. Effect of pulse drip irrigation and mulching systems on yield, quality traits and irrigation water use efficiency of soybean under sandy soil conditions. Agric. Sci., 4(5): 249-261. https://doi.org/10.4236/as.2013.45036

El Agroudy, N., S. Mokhtar, E.A. Zaghlol and M. El-Gebaly. 2011. An economic study of the production of soybean in Egypt. Agric. Biol. J. N. Am., 2(2): 221-225. https://doi.org/10.5251/abjna.2011.2.2.221.225

El-Mougy, N.S., M.M. Abdel-Kader and F. Abdel-Kareem. 2014. Application of commercial composts and/or *Trichoderma Harzianum* for controlling lupine root rot disease under field conditions. Int. J. Eng. Inn. Technol., 4(2): 68-73.

FAO, 2014. World reference base for soil resources. A framework for international classification, correlation, and communication, Soil Taxonomy, Food and Agriculture Organization of the United Nations, Rome, Italy.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. John Wiley and Sons, New York, NY, USA. pp. 8–20.

Gonzalo, M.J., J.J. Lucena and L. Hernández-Apaolaza. 2013. Effect of silicon addition on soybean (*Glycine max*) and cucumber (*Cucumis sativus*) plants grown under iron deficiency. Plant Physiol. Biochem., 70: 455-461. https://doi.org/10.1016/j.plaphy.2013.06.007

Greger, M., T. Landberg and M. Vaculík. 2018. Silicon influences soil availability and accumulation of mineral nutrients in various plant species. Plants, 7(41): 1-16. https://doi.org/10.3390/plants7020041

Ibrahim, S.M. and A.M. Ali. 2018. Effect of potassium humate application on yield and nutrient uptake of maize grown in a calcareous soil. Alex. Sci. Exch. J., 39(3), July-September 2018. https://doi.org/10.21608/asejaiqjsae.2018.10601

Jackson, M.L., 1973. Soil Chemical Analysis, Prentice-Hall, Inc., Englewood Califfs, New Jersy, USA. pp. 429–464.

Karčauskienė, D., R. Repšienė, D. Ambrazaitienė, I. Mockevičienė, R. Skuodienė and G. Šiaudinis. 2019. A complex assessment of mineral fertilizers with humic substances in an agro ecosystem of acid soil. Zemdirbyste-Agric., 106(4): 307–314. https://doi.org/10.13080/z-a.2019.106.039

Khalifa, M.E.A. and I.M. Morsy. 2007. Land use planning at mechanical farm Sector-west of Nubaryia using Parametric models. J. Agric. Env. Sci. Alex. Univ., 6(2): 159-175.

Khalifa, M.E.A. and N.F. Beshay. 2015. Soil classification and potentiality assessment for some rain fed areas at west of Matrouh, Northwestern Coast of Egypt. Alex. Sci. Exch. J., 36: 4. https://doi.org/10.21608/asejaiqjsae.2015.2940

Khalil, N.A., D.S. Darwish, S.A. Safina and S.A. Ferozy. 2011. Effect of environmental conditions on the productivity of soybean in Egypt. Egypt. J. Plant Breed., 15(3): 33–43.

Krull, E.S., J.O. Skjemstad and J.A. Baldock. 2012. Grains research and development corporation (GRDC) Project No. CSO 00029. Residue Management, Soil Organic Carbon and Crop Performance - Functions of Soil Organic Matter and the Effect on Soil Properties, seen on 28 Dec. 2012.

Lee, S.K., E.Y. Sohn, M. Hamayun, J.Y. Yoon and I.J. Lee. 2010. Effect of silicon on growth and salinity stress of soybean plant grown under hydroponic system, Agroforest Sys., 80: 333–340. https://doi.org/10.1007/s10457-010-9299-6

Liang, Y., M. Nikolic, R. Bélanger, H. Gong, A. Song. 2015. Effect of silicon on crop growth, yield and quality. In Silicon in Agriculture; Springer Science + Business Media: Dordrecht, The Netherlands, pp. 209–224. https://doi.org/10.1007/978-94-017-9978-2_11

Lyons, G. and Y. Genc. 2016. Review commercial humates in agriculture: Real substance or smoke and mirrors? Agronomy, 6: 50. https://doi.org/10.3390/agronomy6040050

Mekki, B.B. and A.G. Ahmed. 2005. Growth, yield and seed quality of soybean (*Glycine max* L.) as affected by organic, bio fertilizer and yeast application, Res. J. Agri. Biol. Sci., 1(4): 320-324.

Miao, B-H., X-G. Han and W-H. Zhang. 2010. The ameliorative effect of silicon on soybean seedlings grown in potassium-deficient medium. Ann. Bot., 105: 967–973. https://doi.org/10.1093/aob/mcq063

Mihara, C., X. Chang, Y. Sugiur, S. Makabe-Sasakid and A. Watanabe. 2017. Relationship between plant-available silicon and reducible iron in irrigated paddy soils. Soil Sci. Plant Nutr., 63(1): 67–74. https://doi.org/10.1080/00380768.2016.1278560

Mohsen, A.A.M., S.Kh.A. Ibraheim and M.K. Abdel-Fattah. 2017. Effect of potassium humate, nitrogen bio fertilizer, and molybdenum on growth and productivity of garlic (*Allium sativum* L.). Curr. Sci. Int., 6(1): 75-85.

NOSB TAP Review Compiled by UC SAREP,

2003. National organic standards board technical advisory panel review compiled by University of California Sustainable Agriculture Research and Education Program (UC SAREP) for the USDA National Organic Program. Potassium Silicate for use in crop production. September 4, 2003.

Ouda, S.A., M.A. Shreif and R. Abou Elenin. 2010. Simulation of the effect of water stress on soybean Yield and water use efficiency, 14th Int. Water Technol. Conf., IWTC 14, Cairo, Egypt. pp. 395-406.

Ouni, Y., T. Ghnaya, F. Montemurro, Ch. Abdelly and A. Lakhdar. 2014. The role of humic substances in mitigating the harmful effects of soil salinity and improve plant productivity. Int. J. Plant Prod., 8 (3): 353-374.

Rashad, R.T. and R.A. Hussien. 2018. Studying the solubility, availability, and uptake of silicon (Si) from some ore minerals in the sandy soil, Sains Tanah J. Soil Sci. Agroclimat., 15(2): 69-82. https://doi.org/10.15608/stjssa.v15i2.21430

Schaller, J., M.J. Hodson and E. Struyf. 2017. Is relative Si/Ca availability crucial to the performance of grassland ecosystems? Ecosphere., 8(3): 1-11. https://doi.org/10.1002/ecs2.1726

Selim, E.M., A.S. El-Neklawy and S.M. El-Ashry. 2010. Beneficial effects of humic substances on soil fertility to fertigated potato grown on sandy soil. Libyan Agri. Res. Cent. J. Int., 1(4): 255-262.