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Effect of Nano, Bio and Organic Fertilizers on Some Soil Physical Properties and Soybean Productivity in Saline Soil

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Authors' contributions

This work was carried out in collaboration among all authors. Author KAS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAE and AKAF managed the analyses of the study. Author KAF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out at Khaled Ibn El-waleed village, Sahl El-Hussinia, El-Sharkia Governorate, Egypt, during two summer seasons 2019 and 2020 to study the effect of NPK nanofertilizers, biofertilizers and humic acid combined with or without mineral fertilizers different at rates on some soil physical properties and soybean productivity and quality under saline soil conditions. The treatments consisted of: NPK-chitosan, NPK-Ca, humic acid, biofertilzer and control (mineral NPK only). In both seasons, the experiment was carried out in a split plot design with three replicates. The results indicated a significant increase in the soybean yield parameters as compared to control. There was also a significant increase in dry and water stable aggregates in all treatments as compared to control. The treatment NPK-Chitosan was the best in improving dry and stable aggregates. Also, hydraulic conductivity and total porosity values were significantly increased in all treatments due to increase in soil aggregation and porosity that led to increase in values of hydraulic conductivity. Values of bulk density were decreased, the lowest values of bulk density were found in NPK-chitosan treatment as a result of the high concentration of organic matter resulted from NPK-chitosan is much lighter in weight than the mineral fraction in soils. Accordingly,

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the increase in the organic fraction decreases the total weight and bulk density of the soil. Concerning soil moisture constants, all treatments significantly increased field capacity and available water compared to control. This increase was due to improvement of the soil aggregates and pores spaces which allowed the free movement of water within the soil thereby, increasing the moisture content at field capacity.

Keywords: Nano chitosan; humic acid; bio fertilizer; saline soil.

1. INTRODUCTION

Soil salinity is the foremost factor causing land degradation. The high concentrations of salinity affect crop growth due to osmatic stress influence where it limits the spread of roots to soil solution uptake thereby, causing negatively influences on crop quality [1]. The northern parts of the Nile Delta are suffering from increasing the salinization soils, where, climate factors increase salinization and beside other factors, such as groundwater [2]. Improving salt affected soils may be achieved using different practices such as sub soiling, mole drain, soil amendments, farm manure and biofertilizer. These previous practices are important tools for improving crop productivity and soil properties in salt affected soils at the North Delta [3].

Chitosans are non-toxic, biocompatible, biodegradable, and friendly to the environment and have a great potential for agricultural application. Chitosan enhances growth and crop yield due to their bioactivities to plants such as stimulating growth of plants, seed germination, enhancing nutrient uptake, and antibacterial and antifungal activity [4]. Therefore, in this work chitosan nanoparticles were selected to use as nanomaterial for loading NPK with the idea of applying both bioactive effects of chitosan nanoparticles and NPK macronutrients to crops.

NPK nanofertilizer was prepared by loading nitrogen (N), phosphorous (P) and potassium (K) into chitosan nanoparticles [5]. Nanofertilizer as a new technology and a suitable substitution for traditional chemical fertilizer in agricultural practice, it can prevent the soil and water pollution by gradual and controlled release of nutrients into the soil and subsequently on the plant [6]. Nanoparticles increased water absorption by the seeds, increased nitrate reductase enzyme concentration, promoted seed antioxidant system, reduced antioxidant stress by reducing H_2O_2, superoxide radicals, and malonyldialdehyde content, and increased some enzymes such as superoxide dismutase, ascorbate peroxidase, guaiacol peroxidase and catalase activities Feizi et al. [7]. Nano NPK fertilizers increased the N, P and K absorbed by the plants along with the absorbed water and the production plants increased [8]. Nanofertilizer was significant increased on the yield of fresh seeds, yield of dry seed, the number of seeds/bush, the number of green pods, the number of mature pods, the number of pods/ bush, the yield of pod, total biomass, harvest index and the weight of 100 seeds of pea plants [9]. Humic acid reduces soil erosion by increasing the cohesive forces of the very fine soil particles. It improves the soil structure and improves physical properties of soil by increasing the exchange capacity and buffering qualities, promoting the chelation of many elements and making these available to plants.

Humic substances have been widely used as plant growth promoters to improve the yield of agricultural crops [10]. Humic substances (HS), which include humic acid is among the most complex and biologically active organic matter compounds in the soil and are known to stimulate both plants and microbial activities through a number of mechanisms (e.g. through humic extracts of leonardite, compost or other organic fertilizer) [11]. Hussain et al., [12] indicated that humic acids are important soil components, as they can improve physical properties of soils. Soil organic matter is responsible to increase the water holding capacity of farm soil [13]. Humic acid application led to improve soil fertility and increase nutrients availability, enhance plant growth, yield, and decrease the harmful effect of stresses through various mechanisms inside plants and soil [14] Humic acid application on soybean significantly increased Fe, Mn and Zn uptake and reduced the influence of the salt stress on soybean plant [15]. El-Shafey and Zein El-Dein [16] studied the effect of foliar and soil addition of humic acid on soybean yield and growth parameters. They added it by rates 5 kg/fed and 5 g/L for soil and foliar application, respectively. They deduced a significant increase in all yield parameters as plant height, weight of pods/plant, weight of seeds/plant, weight of 100 seeds and weight of seeds (ton/fed.) in the treated plots as compared to the untreated ones.

Biofertilizers are organic, bio-degradable as well as contain micro-organisms, provide nutrients viz., N, P, K and other nutrients, antibiotics, hormones like auxins, cytokinins, vitamins which enrich root rhizosphere. The benefits of bio-fertilizers are as follows : Reduce the use of chemical fertilizers, reduce environmental pollution, increase the validity of nutrients and easily absorbed, excretion of doping substances for growth, improve the physical, chemical and biological properties of the soil, Excretion of some antibiotics that is resistant to some plant diseases, bio-fertilizers are not costly and even poor farmers can make use them, microorganisms convert complex organic material to simple compounds that plant can easily take up and finally enhance root proliferation due to release of growth promoting hormones [17].

Soybean (*Glycine max L.*) is a strategic crop plant grown to obtain edible oil and forage. It has a high sensitivity to soil. Water salinity is one of the biggest problems with soybean crop [18]. Soybeans, including processed soybean products such as good nutritional quality for adult humans, including a high content of proteins (40-50%), lipids (20-30%) and carbohydrates (26-30%), with more than 85% of proteins consisting of β-conglycinin and glycinin [19]. This work is to evaluate of NPK nanofertilizers carried on Ca^{2+} and chitosan, NPK, biofertilizers and humic acid combined with or without NPK mineral fertilizers different rates on some soil physical properties and soybean productivity under saline soil conditions.

2. MATERIALS AND METHODS

A field experiment was carried out at Khaled Ibn El-waleed village, Sahl El-Hussinia , El-Sharkia Governorate, Egypt, during two summer seasons 2019 and 2020, to study the evaluation of NPK Nanofertilizers, biofertilizers and humic acid combined with or without mineral fertilizers at different rates on some soil physical properties and soybean productivity and quality under saline soil conditions. The studied location lies between 32°/00 to 32° / 15, N latitude and 30° / 50 to 31°/ 15 E, longitude. Soil sample from surface (0 - 30 cm) was taken , air-dried , ground good mixed , sieved through a 2 mm sieve kept and analyzed the physical and chemical soil properties before sowing and after soybean productivity according to the methods described by Klute [20], Page et al. [21] and Cottenie et al. [22]. The main physical and chemical properties before planting were recorded in Table 1.

In both seasons (2019 and 2020), the experiment was carried out in a split plot design with three replicates. All farming processes were carried out before planting. Addition of calcium super phosphate (15.5% P_2O_5) was applied at rates (0, 15, 25 and 31 kg P_2O_5/fed) alone or mixed with bio-fertilizers *Bacillus megatherium* for dissolving phosphate. Humic acid was applied at rate 20 kg/fed during the soil tillage before sowing. The individual and the combined three bio-fertilizers namely radiobacter strain as a salt tolerant rhizobacteria (Salt Tolerant PGPR), N_2 fixed with or without urea (46% N) at rates (0, 10, 20, 40 kg N /fed) after 31, 45 and 65 days from planting and *Bacillus circulans* (enhancing potassium availability) combined with or without mineral potassium sulphate (48% K_2O) fertilizer at rates (0, 15, 30 and 75 kg K_2O /fed) after 31 and 45 days from planting. Bio-fertilizer Production Unit, Department of Microbiology, Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt.

NPK nanofertilizer nanoparticles were obtained by polymerization of methacrylic acid (MAA) in chitosan (CS) solution in a two-step process according to Hasaneen et al. [23]. Nitrogen, phosphorus and potassium (NPK) were loaded on the Ca-PMAA nanoparticles using the following concentrations 500, 60, 400 ppm respectively (100% concentration stands for 500 ppm of N, 60 ppm of P and 400 ppm of K in both nano and normal NPK solutions and other concentrations were made from these stock solutions). The NPK nano-fertilizer was applied after 30, 45 and 65 days from planting.

The area of each experimental unit plot was 50 m^2 which divided into rows with 50 cm. Soybean (*Glycine max L.*) cultivar Giza 35 supplied by Field Crop Res. Inst. ARC, were sown on the 25th of May 2019, and 2020. Three to four of coated seeds were sown in hole with 3 cm depth. The distance between each two holes was 20 cm. After 30 day of sowing, the plant of each hole was thinned to one plant.

Soybean varieties were harvested on 25 September 2019 and 22 September 2020 and the following characters were recorded: Plant height, No. of pods/plant, weight of pods/plant (g), weight of seeds/plant (g), weight of 100 seeds (g), weight of pods (ton/fed) and weight of seeds (ton/fed).

Table 1. Some properties of the studied soil before planting

PH (1:2.5)	**EC $ds.m^{-1}$**	**O.M (%)**	**Particle size distribution**				
			Coarse sand (%)	**Fine sand (%)**	**Silt (%)**	**Clay (%)**	**Textural Class**
8.12	10.48	0.62	6.87	12.91	33.17	53.94	Clay
H.C $cm.h^{-1}$	B.D $g.cm^{-3}$	T.P (%)	Soil moisture constants (%)				
			F.C	W.P		A.W	
0.022	1.30	50.98	25.12	11.02		14.10	
Dry aggregates diameters (mm)							
10-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.063		<0.063
40.32	18.50	12.03	4.67	7.04	8.17		9.27
Wet aggregates diameters (mm)							
10-2	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.063		Total (TSA)
9.02	10.12	10.81	5.16	2.56	2.71		40.38

Particle size distribution was carried out by the pipette method described by Gee and Bauder [24] using sodium hexameta phosphate as a dispersing agent. Soil bulk density, total porosity, field capacity and stability of dry aggregates were determined according to the method of Richards [25]. Water aggregates stability was estimated using the wet sieving technique described by Yoder [26] and modified by Ibrahim [27]. The determination of soil moisture equilibrium values was carried out according to the methods described by Richards and Weaver [28] and Richards [29]. Wilting point (W.P) was determined according to Stakman and Vanderhast [30].

Data were statistically analyzed according to Gomez and Gomez [31].

3. RESULTS AND DISCUSSION

3.1 Soil Aggregation

The volume of solid soil particles and the pore volume influences air balance and root penetration ability. Soil structure is defined by size and spatial distributions of particles, aggregates and pores in soils. As a general fact, the more soil structure is compacted, the more unfavorable are the soil conditions for plant growth. The aggregates categories studied in this work are of the following diameters (mm): 10-2, 2-1, 1-0.5, 0.5-0.25, 0.25-0.125, 0.125-0.063 and < 0.063, they can be expressed as follows: very large, large, medium, sub-medium, small, very small and extremely small, respectively. Dry aggregation covered the 7 categories, but wet aggregation (because of its nature) covered the 6 categories.

3.1.1 Dry stable aggregates

It is clear from the distribution fractions of dry stable aggregates (Table 2), that the dominant diameters were 10-2 and 2-1 mm, while 0.50-0.25 and <0.063 mm recorded the lowest weights in most of the studied samples. Concerning treatments of soil amendments, there was a slight increase in weights of 10-2, 2-1 and 1-0.5 mm diameters in all treatments than control. The treatment of NPK-chitosan caused the highest increase and bio treatment induced the least increase. While all treatments caused a slight decrease in weights of 0.50-0.25, 0.25-0.125, 0.125-0.063 and <0.063 mm diameters as compared to control. Humic acid reduces soil erosion by increasing the cohesive forces of the very fine soil particles that led to composition of more stable aggregates and improve the soil structure and physical properties of the soil.

3.1.2 Water stable aggregates

The values of water stable aggregates (WSA %) as well as distribution of aggregates size fractions are shown in Table (3). It can be deduced that, the mean values of aggregates having diameters between 2 to 1 and 1 to 0.5 mm were slightly higher than the other aggregates fraction diameters in most of the treatments understudy. Concerning treatments of soil amendments, data showed that values of total water stable aggregates were increased in all treatments understudy compared to control. The highest increase in values of total water stable aggregates was observed in the treatment NPK-chitosan compared to other treatments and control. The polymeric nature of chitosan helped in increasing soil aggregate stability by improving the volume of drainable pores [32]. The organic matter produced from humic acid and biofertilizer aid to glues the tiny soil particles together into larger water stable aggregates, increasing bio pores spaces which increase soil air circulation necessary for growth of plants and microorganisms. Similar results were obtained by Rasool et al. [33] who concluded that, the application of organic matter in saline soil promotes flocculation of clay minerals, which is essential for the aggregation of soil particles and play an important role in erosion control. These results are in agreement with those of Tejada and Gonzalez [34] and Tejada et al. [35] who found that organic matter acts as a cementing factor, necessary for flocculated soil particles to form stable aggregates. Soil aggregation is one component of soil structure. Mycorrhizal fungi contribute to soil structure [36]. This direct access will influence the formation of soil aggregates, because soil carbon is crucial to form organic materials necessary to cement soil particles.

3.2 Hydraulic Conductivity, Bulk Density and Total Porosity

Hydraulic conductivity refers to the rate at which water flows through soil. For instance, soils with well-defined structure contain a large number of macro pores, cracks, and fissures which allow for relatively rapid flow of water through the soil. The ability of soil to transmit water depends on the porosity and the arrangement of soil particles. Data presented in Table 4 indicated that, the values of soil hydraulic conductivity coefficient are ranged between 0.021 and 0.063 $cm.hr^{-1}$. All treatments understudy significantly affected such character compared to control. While there was no significant increase concerning the used rates of mineral fertilizers. It is clear from the values of H.C, that the treatment NPK-Chitosan had the highest values followed by NPK-Ca, then humic acid, while bio-treatment had the lowest H.C values. This may be attributed to that the higher organic matter content in the treated plots improved soil aggregates and macropores that led to increase in the rate the water flows through soil profile and hence increasing H.C values.

Concerning bulk density, it can be concluded that all treatments significantly decreased bulk density as compared to control. The best treatment in decreasing values of bulk density was NPK-chitosan. These results are confirmed with those of Brown and Cottone [37], who observed that addition of organic and biofertilizers influences soil structure in a beneficial way by lowering soil density as a result for the admixture of low density organic matter into the mineral soil fraction. In addition, the organic fraction is much lighter in weight than the mineral fraction in soils. Accordingly, the increase in the organic fraction decreases the total weight and bulk density of the soil.

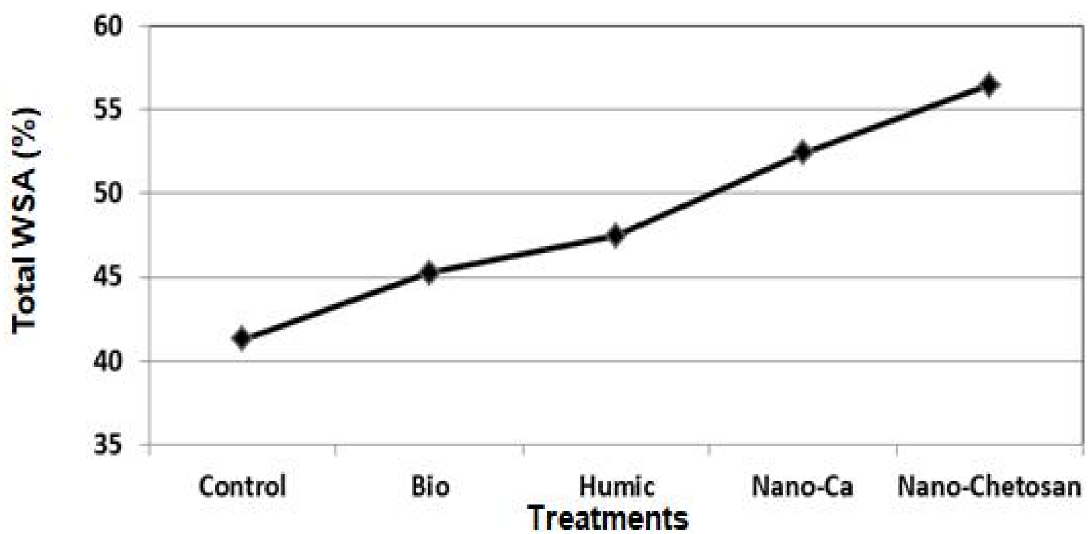

Fig. 1. Relationship between the treatments and total water stable aggregates

Table 2. Distribution fractions (%) of dry stable sieved aggregates (average of two seasons) as affected by the studied treatments

	Rates of NPK (kg/fed)	> 2 mm	2-1	1-0.5	0.5-0.25	0.25- 0.125	0.125- 0.063	< 0.063
Control	0+0+0	39.24	17.81	8.56	6.53	7.64	10.42	9.80
	10+15+15	40.26	19.10	9.47	5.78	6.32	9.75	9.32
	20+25+30	40.56	18.34	11.83	4.68	6.98	8.63	8.98
	40+31+75	41.16	18.90	10.15	5.61	6.17	9.20	8.81
	Mean	40.31	18.54	10.00	5.65	6.78	9.50	9.23
Bio-fertilizer	0+0+0	42.56	19.20	12.28	4.34	5.62	6.82	9.18
	10+15+15	42.41	20.28	12.75	4.81	4.67	6.71	8.37
	20+25+30	44.02	19.61	11.92	5.03	4.51	7.11	7.80
	40+31+75	43.93	19.86	12.84	4.92	4.90	6.54	7.01
	Mean	43.23	19.74	12.45	4.78	4.93	6.80	8.09
Humic acid	0+0+0	43.72	19.72	11.10	5.26	5.32	7.10	7.78
	10+15+15	44.50	20.46	12.41	4.31	4.68	6.28	7.36
	20+25+30	44.81	20.98	13.72	4.82	5.70	6.04	3.93
	40+31+75	45.32	21.51	12.98	5.02	5.62	7.12	2.43
	Mean	44.59	20.67	12.55	4.85	5.33	6.64	5.38
NPK Nano Ca	0+0+0	44.10	21.73	12.32	3.28	5.00	5.02	8.55
	10+15+15	45.52	22.06	14.61	4.16	3.62	4.31	5.72
	20+25+30	46.75	23.54	14.48	4.35	4.04	5.21	1.63
	40+31+75	47.14	22.93	14.50	3.93	4.71	5.44	1.35
	Mean	45.88	22.57	13.98	3.93	4.34	5.00	4.31
NPK Nano Chitosan	0+0+0	47.48	24.32	12.56	2.92	4.15	3.56	5.01
	10+15+15	48.13	25.18	12.35	3.16	3.82	4.12	3.24
	20+25+30	50.21	24.04	13.62	3.20	2.26	3.83	2.84
	40+31+75	50.72	23.28	14.06	3.31	3.32	3.10	2.21
	Mean	49.14	24.21	13.15	3.15	3.39	3.65	3.33

Table 3. Distribution fractions (%) of water stable sieved aggregates (average of two seasons) as affected by the studied treatments

	Rates of NPK (kg/fed)	> 2 ml	2-1	1-0.5	0.5-0.25	0.25- 0.125	0.125- 0.063	Total
Control	0+0+0	9.32	11.41	10.18	5.52	2.02	2.78	41.23
	10+15+15	8.76	10.26	11.74	5.03	2.45	2.64	40.88
	20+25+30	7.91	10.83	10.33	7.24	3.41	1.52	41.24
	40+31+75	9.03	9.56	12.13	6.21	2.57	2.28	41.78
	Mean	8.76	10.52	11.10	6.00	2.61	2.31	41.28
Bio-fertilizer	0+0+0	5.83	12.53	12.62	7.04	3.47	2.57	44.06
	10+15+15	6.32	13.25	9.67	8.12	3.79	3.63	44.78
	20+25+30	7.16	11.91	11.68	9.41	4.02	2.32	46.50
	40+31+75	7.52	10.21	10.63	9.84	3.96	3.47	45.63
	Mean	6.71	11.98	11.15	8.60	3.81	3.00	45.24
Humic acid	0+0+0	6.11	13.08	12.41	8.15	2.36	3.21	45.32
	10+15+15	10.82	12.78	9.83	8.56	2.53	2.94	47.46
	20+25+30	6.74	13.50	12.88	7.95	2.63	3.92	47.62
	40+31+75	8.46	11.92	13.84	9.06	3.52	2.64	49.44
	Mean	8.03	12.82	12.24	8.43	2.76	3.18	47.46
NPK Nano Carrier Ca	0+0+0	11.20	8.86	10.20	10.31	5.65	4.14	50.36
	10+15+15	9.40	13.16	10.82	9.53	4.46	5.26	52.63
	20+25+30	7.72	14.46	10.71	9.92	4.37	6.40	53.58
	40+31+75	10.32	13.30	11.25	8.12	4.69	5.38	53.06
	Mean	9.66	12.45	10.75	9.47	4.79	5.30	52.41
NPK Nano Carrier Chitosan	0+0+0	5.26	10.51	11.58	15.93	6.92	4.21	54.41
	10+15+15	9.30	12.41	10.15	12.61	5.42	6.23	56.12
	20+25+30	13.21	12.16	9.04	11.32	5.52	6.25	57.50
	40+31+75	12.06	13.32	10.45	13.04	4.31	4.61	57.79
	Mean	9.96	12.10	10.31	13.23	5.54	5.33	56.46

Total soil porosity is a special formula which explains the relationship between both the soil real and bulk densities. On the other hand, it is an index of the relative volume of pores in soil. As a general pattern, data of total soil porosity was closely followed the opposite trend of soil bulk density regarding the effect of all studied treatments, where the lower soil bulk density, the higher total soil porosity was observed. Data in Table 5 showed that total soil porosity was increased and the maximum increase was found in the soil treated with NPK-chitosan compared to other treatments and control. These results are in agreement with those of Zhou et al. [38] who found that organic matter increases the portion of meso- and macro-pores because of an improved aggregation and stabilization of soil significantly initiated by various soil organisms. Macroaggregates are mainly stabilized by fungal hyphen, fine roots, root hair and microorganisms with a high portion of easily degradable polysaccharides [39].

3.3 Soil Moisture Characteristics

Soil field capacity, wilting point and available water are considered the three main soil moisture constants. The amount of water available to plant depends on two factors: the quantity of water that is able to infiltrate into the soil and the quantity of water that the soil is able to hold onto. Field capacity and available water holding capacity are influenced by the particle size, structure and content of OM. However, clay soils, due to its higher matric potential and smaller pore size will generally hold significantly more water by weight than sandy soils. It can be deduced from the data in Table 5 that all treatments significantly increased field capacity and available water compared to control, while these parameters did not significantly affected by the used mineral fertilizers rates. The best addition improved field capacity and available water was NPK-Chitosan, followed by NPK-Ca then organic and bio. This significance increase in field capacity and available water may be attributed to the increase in organic matter which indirectly contributes to soil texture via increased soil faunal activity leading to improve the soil aggregation and porosity which ultimately increased the number of macro-pores and thus, infiltration rates. The organic matter was found contributing to the stability of soil aggregates and pores through the binding properties of organic material. These results are in agreement with those of Malik et al. [40], who found that increase in soil organic matter content led to higher values for field capacity due to improvement of the soil aggregates and pores spaces which allowed the free movement of water within the soil thereby, increasing the moisture content at field capacity.

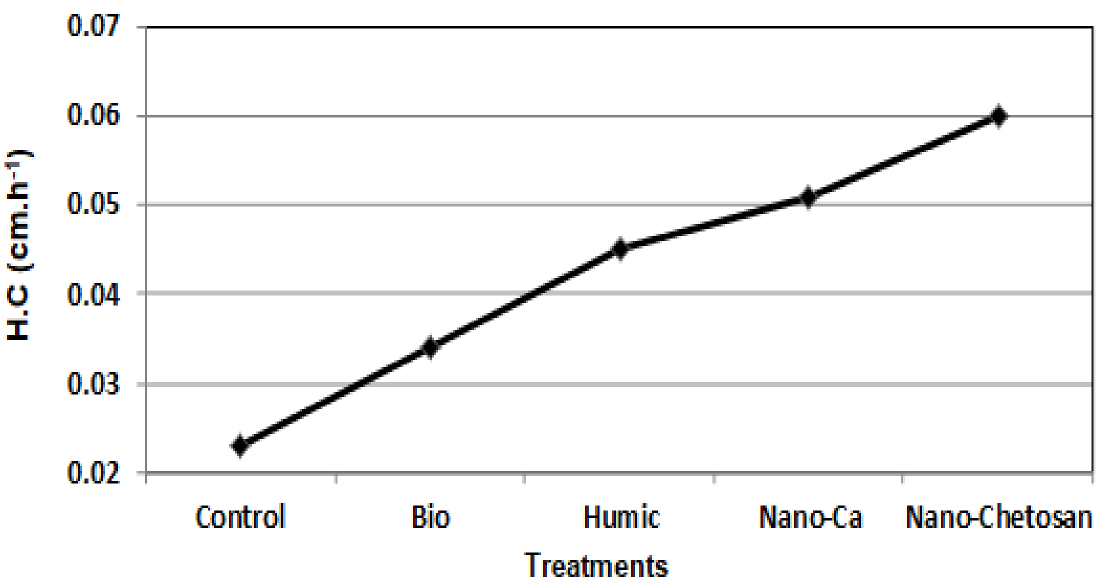

Fig. 2. Relationship between the treatments and hydraulic conductivity

Table 4. Hydraulic conductivity, bulk density and total porosity in the studied soil as affected by different treatments

	Rates of NPK (kg/fed)	H.C ($cm.h^{-1}$)	B.D (g/cm^3)	T.P (%)
Control	0+0+0	0.021	1.30	51.12
	10+15+15	0.022	1.32	50.62
	20+25+30	0.024	1.32	52.04
	40+31+75	0.025	1.31	51.95
	Mean	0.023 e	1.31 d	51.43 d
Bio-fertilizer	0+0+0	0.031	1.28	51.21
	10+15+15	0.033	1.26	53.02
	20+25+30	0.034	1.25	54.58
	40+31+75	0.036	1.25	54.70
	Mean	0.034 d	1.26 c	53.38 c
Humic acid	0+0+0	0.042	1.24	52.61
	10+15+15	0.043	1.23	54.14
	20+25+30	0.046	1.21	55.38
	40+31+75	0.048	1.21	55.91
	Mean	0.045 c	1.22 b	54.51 b
NPK Nano Carrier Ca	0+0+0	0.046	1.23	54.32
	10+15+15	0.050	1.20	54.80
	20+25+30	0.053	1.18	55.58
	40+31+75	0.054	1.19	56.27
	Mean	0.051 b	1.20 b	55.24 b
NPK Nano Carrier Chitosan	0+0+0	0.057	1.16	56.22
	10+15+15	0.059	1.15	56.64
	20+25+30	0.062	1.13	57.49
	40+31+75	0.063	1.13	58.36
	Mean	0.060 a	1.14 a	57.18 a
	L.S.D (0.05)	A= 0.004 M= ns A*M= ns	A= 0.026 M= ns A*M= ns	A= 0.92 M= ns A*M= ns

A= Amendments treatments; M= Mineral NPK treatments

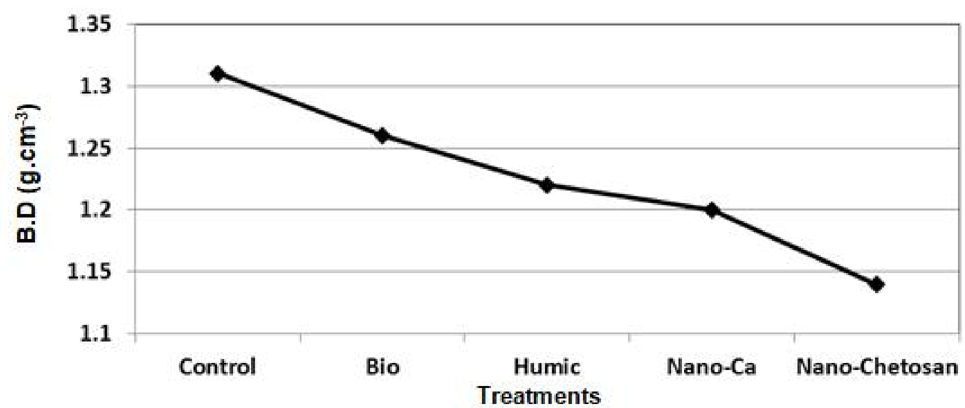

Fig. 3. Relationship between the treatments and bulk density

3.4 Effect of the Used Treatments on Soybean Yield Parameters

It is clear from the data of yield parameters as shown in Table 6, that the used treatments significantly increased all of the growth parameters as compared to control. The best treatments affected these parameters were NPK-chitosan and NPK-Ca followed by humic acid and bio fertilizer. Concerning plant height, the best treatments were NPK-Ca and NPK-chitosan, followed by bio fertilizer then humic acid with means 60.27, 57.80, 55.61 and 54.88 cm, respectively. While for weight of pods/plant and weight of seeds/plant, the trend was NPK-chitosan > NPK-Ca > bio fertilizer > humic acid > control with mean values 64.52 , 64.23 , 54.16 , 47.84 and 28.52 g for weight of pods/plant, and 30.35, 28.99 ,25.78, 22.49 and 14.81 g for weight of seeds/plant, respectively. Concerning weight of pods (ton/fed), the best treatment was bio fertilizer followed by NPK-Ca with means 1.010 and 0.936 ton/fed for bio fertilizer and NPK-chitosan, respectively. The same trend was recorded for weight of seeds (ton/fed) with mean values 0.782 and 0.782 ton/fed for bio fertilizer and NPK-Ca, respectively.

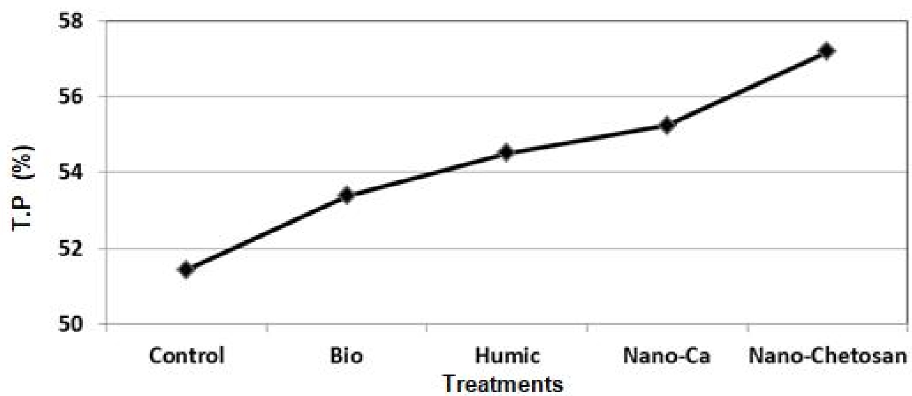

Fig. 4. Relationship between the treatments and total porosity

Table 5. Soil moisture constants in the studied soil as affected by the treatments

	Rates of NPK (kg/fed)	Soil moisture constants (%)		
		Field capacity	Wilting point	Available water
Control	0+0+0	25.86	11.25	14.61
	10+15+15	24.27	10.91	13.36
	20+25+30	26.42	12.38	14.04
	40+31+75	26.74	11.64	15.10
	Mean	25.82 d	11.55 d	14.28 e
Bio-fertilizer	0+0+0	28.36	13.82	14.54
	10+15+15	30.33	15.17	15.16
	20+25+30	31.81	14.84	16.97
	40+31+75	30.76	15.63	15.13
	Mean	30.32 c	14.87 c	15.45 d
Humic acid	0+0+0	32.05	16.73	15.32
	10+15+15	33.82	16.59	17.23
	20+25+30	33.61	17.83	15.78
	40+31+75	34.97	16.21	18.76
	Mean	33.61 b	16.84 b	16.77 c
NPK Nano Carrier Ca	0+0+0	32.59	16.31	16.28
	10+15+15	35.19	17.08	18.11
	20+25+30	36.96	17.16	19.80
	40+31+75	37.08	18.34	18.74
	Mean	35.46 b	17.22 b	18.23 b
NPK Nano Carrier Chitosan	0+0+0	39.52	18.31	21.21
	10+15+15	39.76	19.28	20.48
	20+25+30	41.61	20.53	21.08
	40+31+75	42.23	20.95	21.28
	Mean	40.78 a	19.77 a	21.01 a
	L.S.D (0.05)	A= 1.96 M= ns A*M= ns	A= 1.17 M= ns A*M= ns	A= 0.83 M= ns A*M= ns

A= Amendments treatments; M= Mineral NPK treatments

Table 6. Soybean productivity as affected by all treatments

Amendments Treatments	Rates of NPK (kg/fed)	Plant height (cm)	No. of Pods	Weight of pods/plant (g)	Weight of seeds/plant (g)	Weight of 100 seeds (g)	Weight of pods (ton/fed)	Weight of seeds (ton/fed)
Control (Mineral)	0+0+0	38.52	22.89	12.60	9.10	5.88	0.395	0.238
	10+15+15	45.62	52.90	22.40	13.84	6.33	0.846	0.587
	20+25+30	47.24	56.67	33.96	16.90	7.12	0.894	0.665
	40+31+75	49.88	70.88	45.10	19.39	7.83	0.944	0.734
	Mean	45.32 e	50.84 e	28.52 e	14.81 e	6.79 e	0.770 e	0.556 e
Bio fertilizers	0+0+0	45.19	35.00	26.46	16.70	8.07	0.859	0.589
	10+15+15	55.32	69.00	55.49	26.87	7.50	0.968	0.793
	20+25+30	59.80	80.00	59.45	28.01	10.98	1.025	0.834
	40+31+75	62.14	95.00	75.23	31.55	6.98	1.186	0.912
	Mean	55.61 c	69.75 c	54.16 c	25.78 c	8.38 d	1.010 a	0.782 a
Humic acid	0+0+0	48.95	32.00	25.71	14.20	8.68	0.860	0.569
	10+15+15	53.24	66.00	43.00	17.93	9.70	0.889	0.695
	20+25+30	56.88	76.00	55.20	27.54	11.50	0.975	0.769
	40+31+75	60.46	90.00	67.43	30.30	10.76	0.998	0.815
	Mean	54.88 d	66.00 d	47.84 d	22.49 d	10.16 c	0.931 c	0.712 d
NPK Nano carrier Ca	0+0+0	52.41	40.00	32.56	15.62	11.91	0.849	0.579
	10+15+15	59.35	84.00	64.87	29.20	12.76	0.885	0.790
	20+25+30	62.41	89.00	73.80	35.30	14.20	0.989	0.825
	40+31+75	66.89	98.00	85.70	35.83	12.88	1.020	0.892
	Mean	60.27 a	77.75 a	64.23 b	28.99 b	12.94 a	0.936 b	0.772 b
NPK Nano carrier chitozan	0+0+0	50.45	39.00	32.70	20.66	12.30	0.833	0.570
	10+15+15	57.95	80.00	60.96	28.65	14.12	0.871	0.783
	20+25+30	60.33	85.00	75.43	34.38	13.16	0.955	0.815
	40+31+75	62.48	95.00	89.00	37.69	9.10	0.998	0.885
	Mean	57.80 b	74.75 b	64.52 a	30.35 a	12.17 b	0.914 d	0.763 c
	L.S.D (0.05)	A= 0.014 M= 0.011 A*M=0.028	A= 0.71 M= 0.64 A*M=1.42	A= 0.32 M= 0.29 A*M= 0.65	A= 0.045 M= 0.042 A*M=0.093	A= 0.011 M= 0.008 A*M=0.023	A= 0.08 M= 0.05 A*M=0.15	A= 0.06 M= 0.04 A*M=0.11

A= Amendments treatments; M= Mineral NPK treatments

These results are in agreement with those obtained by El-Shafey and Zein El-Dein [16] who deduced a significant increase in all yield parameters of soybean as plant height, weight of pods/plant, weight of seeds/plant, weight of 100 seeds and weight of seeds (ton/fed.) in humic acid treated plots as compared to the untreated ones. Similar results were obtained by Nguyen et al. [4] who elucidated that chitosan enhances growth and crop yield due to their bioactivities to plants such as stimulating growth of plants, seed germination, enhancing nutrient uptake, and antibacterial and antifungal activity. Moreover, chitosan nanoparticles have also a positive effect on biophysical aspects and growth of crops.

4. CONCLUSION

Addition of NPK nanofertilizers, biofertilizers and humic acid led to improvement in soil physical properties and soybean productivity under saline soil conditions. The hydraulic conductivity and total porosity values were increased in all treatments due to increase in soil aggregation and porosity that led to increase in values of hydraulic conductivity. Values of bulk density were also decreased due to that the high concentrations of organic matter resulted from these additions are much lighter in weight than the mineral fraction in soils, that causes a decrease in the total weight and bulk density of the soil. Also, all of the applied treatments increased field capacity and available water compared to control. This increase was due to improvement of the soil aggregates and pores spaces which allowed the free movement of water within the soil thereby, increasing the moisture content at field capacity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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