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Impact of Humate Substances and Synthetic Polymers on Improving Quinoa Productivity and Soil properties

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ABSTRACT

Two field experiments were carried out in newly reclaimed land in private farm present at Village No. 7 in Minia Governorate, Egypt to evaluate the impact of humate substances, i.e., potassium humate and potassium fulvate as soil application at two levels (23.8 and 35.7 kg ha-1), and synthetic polymers, namely polyvinyl alcohol (PVA) and carboxymethyl cellulose (CMC) at rates of 2% and 4%. The results show that humate substances as soil application led to reduced soil pH, EC, ESP and soil bulk density in addition to increasing soil organic matter and soil fertility. Also, these soil ameliorations beside the synthetic polymers improved soil water retention. Vegetative growth and yield and yield components as well as protein percentage and yield in quinoa seeds showed significant response to the studied ameliorations, where humate substances and foliar spraying of carboxymethyl cellulose at high levels seem to be the best than the others. Furthermore, humate substances at high level gave the best net return of quinoa production. This means that it could be recommended to use the humate substances or foliar spraying of carboxymethyl cellulose at high rate to increase quinoa production and improve soil properties.

Keywords: Quinoa plants, humate substances, polymers, soil properties and yield.

Introduction

Quinoa (*Chenopodium quinoa* willd.) is a very old crop originated in Indean regions of America. It belonged to Amaranthaceae family, Chenopodiaceae subfamily and Chenopodium genus (Karina *et al*., 2014). Quinoa plant has a promoting endurance to many abiotic conditions (Farajzadeh *et al*, 2020). Gupta and Morya (2022) mentioned that quinoa planted for production and consumption in Europe, United State, Africa and Asia. It is cultivated in about 126×10^3 hectares that produce approximately 103×10^3 tones all over the world. Its seeds contain a boost level of protein and balanced of amino acids in comparison to wheat grains (El-Sherefl, 2020). Also, the seeds of quinoa are rich of some minerals such as K+, Ca^{+2}, Mg^{+2}, Zn^{+2}, Cu^{+2} and Fe^{+2} in addition to some important vitamins, e.g., Vit B1, B2, B3, Vit C, β-caroten, phenoliv compounds and essential amino acids (Mobeena *et al*., 2023). Furthermore, Jancurova *et al.,* (2009) mentioned that high content of carotenoids, phenolic and flavonoid compounds in quinoa seeds guarantes its high antimicrobial and antioxidant effects. Many authors reported that quinoa protein ameliorates the human immune system and increases protectionism against many disorders including malignancy (Farajzadeh *et al.,* 2020). Quinoa is namely “sweet” or bitter according to the saponin level, a great class of glycosides present in various plant parts (Carlson *et al.,* 2012). Saponin acts as antibiotic, insecticidal, fungicidal and therapeutic possessions.

Plant bio-stimulates such as humic substances consider good alternative materials for increased crops production as well as soil properties. Humic acid and fulvic acid are organic stimulants used for enhanced plant growth and improved soil fertility (El-Shaboury and Sakara, 2021). Humic acid consist of reactive crops including carboxyls, alcoholic, hydroxyls and phenolic (Abd-Elzaher *et al.,* 2022). Shahryari *et al.,* (2009) mentioned that humic substances, i.e., humates, humic acid and fulvic acids mainly consist of humus which formed from the decomposition of organic material and contain about 65-75% of organic matter. The positive effects of humic materials were stated by many authors. Kamh

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and Hedia (2018) indicated that nutrient uptake was enhanced due to humic materials application. Humic substances improve the permeability of the membranes, the activity of enzymes, activity of hormones in plant and H2O retention, consequently increased plant production (Jones *et al.,* 2007). Abd-All *et al.,* (2017) concluded that K-humate improve the soil criteria physically as well as chemically.

In arid and semi-arid zones, the rainfall rate is very low with an erratic arrangement. Therefore, it could be improved the water holding ability in soils with low H2O retention, in particular sand soil by using hydrophilic polymers which decrease water loss and improving water use efficiency. Furthermore, rapid infiltration of water far away from root-zone is accompanied by coarse-textured soil. Polymers have been used since long period as soil conditioners for H2O-retention elements. Such polymers considered as eco-friendly materials, such as carboxymethyl cellulose (CMC) and polyvinyl alcohol (PVA). (CMC) is a long-chain of macromolecule polymers and Na carboxymethyl cellulose. It is an anionic H_2O soluble polymer, which its application rate is low with low cost (Parvathy and Jyoth 2014). As regards to PVA, it is a synthetic hydrophilic polymer that's degraded with the help of the enzymes of bacteria. It has a great potential for absorbing water; therefore it has more effect in protecting the surface of soil at low application rate (Yasseen *et al.,* 2020).

The objective of such investigation was to improve the soil criteria of sand soil as well as its productivity of quinoa plant by using some chemical and synthetic conditioners.

2. Materials and Methods

Two field experiments in 2021/2022 and 2022/2023 seasons were carried out at private farm present at village No 8 in Minia Governorate, Egypt. The experimental soil was sand in texture having pH value of 7.8 and 7.8, EC value of 2.3 and 2.2 dSm^{-1}, organic matter 0.21 and 0.24 %, available N 1.9 and 2.0 mg kg^{-1}, available P 3.3 and 3.0 mg kg^{-1} and available K 20.5 and 21.2 mg kg^{-1} as well as bulk density 1.50 and 1.53 g cm^{-3}, field capacity 14.35 and 15.27%, wilting point 7.95 and 7.14 %, available water, 6.40 and 8.13%, respectively in the two seasons based on (A.O.A.C. (1995) for chemical and physical soil properties and Klute (1986) for water retention. During the first season, the soil consisted of sand, making up 89.96% of the particle size distribution. Silt and clay were present in much smaller amounts, with silt accounting for 7.53% and clay for 2.94%. The soil texture grade for this season was classified as sand. In the second season, the sand content decreased to 88.91%. The proportion of silt remained nearly constant at 7.47%. However, the clay content increased marginally to 3.62%. Despite these minor changes in the particle size distribution, the soil texture grade continued to be classified as sand.

The experimental design was totally randomized block in 4 replications in nine treatments, i.e. without conditioners (T1), 23.8 kg ha^{-1} potassium humate (KH) as soil application (T2), 35.7 kg ha^{-1} KH as soil application (T3), 23.8 kg ha^{-1} K fulvate (KF) as soil application (T4), 37.7 kg ha^{-1} potassium folvate (KF) as soil application (T5), polyvinyl alcohol (PVA) as soil application at rate of 2 % (T6), polyvinyl alcohol as soil application at rates of 4% (T7), carboxymethyl cellulose (CMC) as soil application at rates of 2% (T8) and carboxymethyl cellulose (CMC) as soil application at rate 4% (T9). Humate substances treatments were applied during land preparation, while (CMC) and (PVA) treatments were done by dissolving 12 or 24 kg from each materials in 600 liter water to produce 2 or 4% solution and applied by spraying on land surface.

Potassium humate contain 26 carboxyl groups (COOH), 34 phenoxyl groups (OH), 6 amino groups (NH_2), 7 nitrogen atonic and about 10% potassium, while potassium fulvate contain relatively low molecular weight and more oxygen.

Quinoa seeds, variety Misr 1 (received from Agricultural Research Center, Egypt) were planted at 23 and 27 November in the two seasons, respectively in plots. Each plot had 10 rows, 6 m in length and 3.5 m in width. The spacing between rows was 60 cm, while the distance between hills was 20 cm. After 120 days, the plants were harvested from each plots to determine grain and straw yields and converted to Mg ha^{-1}. Ten plants were randomized chosen from all plots to assess growth parameters (including the height of the plant, dry weight/plant and numbers of leaves in each plant) in addition to the yield components, i.e., numbers of panicles in each plant, 1000-seed weight(g) and seed yield/plant (g). Also, randomized samples from seeds were obtained to detect nitrogen concentration and converted to protein percentage and protein yield (kg ha^{-1}). After harvest, we took the surface soil sample (0-30 cm) from each plot were taken to detect some soil properties physically and chemically based on A.O.A.C (1995).

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The plants were fertilized with 215 kg N ha^{-1} as ammonium nitrate, 33.5percent in four equal doses before 1st, 2nd, 3rd and 4th irrigation. Also, 39 kg P_2O_5 ha-1 were added before sowing as calcium superphosphate (15.5 percent P_2O_5) and 57 kg K_2O ha^{-1} were added in 2 equal amounts, the 1st before sowing and the other before the 2nd irrigation. All the remaining cultural practices for quinoa plant growth were performed as in district.

Economic measurements, namely, total gross return, net return, return over variable costs, beneficial cost ratio and product prefit ratio were calculated as follows:
Gross return = seed yield (t ha^{-1}) × its price (3500 or 4000 L.E/t in both seasons, respectively) + straw yield (t ha^{-1}) × its price (100 or 150 L.E/t in both seasons, respectively).

Net return = gross return – total cultivation costs
Return over variable costs = gross return – variable cost
Beneficial cost ratio = gross return / total cultivation costs
Product profit ratio (%) = net return × 100 / gross return
L.E. (Egyptian pound) = about 0.06 and 0.04 US dollars in both seasons, respectively.

The collected results were subjected to analysis statistically according to Snedecor and Cochran (1980). Duncan's multiple range was utilized to compare the difference between treatment methods at the probability of 0.05.

3. Results

3.1. Physio-chemical soil properties

Physio-chemical characteristics particularly those related to structure and nutrient availability have high magnitude for the biological activities and plant growth. It include soil pH, EC, soil organic matter and bulk density. The impact of applied amelioration techniques on these soil properties after quinoa harvest are presented in Table 1 Regarding potassium humate or fulvate application, the data reveal that applying these amendments clearly ameliorated the studied physio-chemical criteria of the soil after quinoa harvest. These effectiveness were pronounced as the rate of humate substances increased. Comparing with control, added potassium humate or potassium fulvate at high rate decreased soil bulk density, soil reaction & salinity in addition to increased soil organic matter in both seasons.

Concerning the synthetic polymers, the data reveal that polyvinyl alcohol (PVA) and carboxymethyl celluse (CMC) at rates of 4% significantly improved soil bulk density only, while the other physio-chemical properties did not affect. The decrease in soil bulk density due to polymers application at rate of 4% reached 2.55 and 1.96 % over control in the two seasons, respectively.

Table 1: Effect of some humate substances and synthetic polymers on Physio-chemical soil properties.

Treatments	pH		EC (dSm^{-1})		Soil organic matter (%)		Bulk density (g cm^{-3})	
	2021	2022	2021	2022	2021	2022	2021	2022
T1	7.89	7.92	2.19a	2.27a	0.26b	0.28b	1.53b	1.53b
T2	7.84	7.85	2.13b	2.23b	0.32a	0.33a	1.59	1.58
T3	7.82	7.84	2.11c	2.21c	0.33a	0.35a	1.57	1.59
T4	7.84	7.89	2.15ab	2.25ab	0.30a	0.32a	1.59	1.58
T5	7.86	7.89	2.14b	2.24b	0.32a	0.34a	1.56	1.59
T6	7.87	7.93	2.17a	2.27a	0.27b	0.29b	1.56	1.55
T7	7.87	7.92	2.18a	2.28a	0.27ab	0.29ab	1.57	1.56
T8	7.88	7.91	2.18a	2.27a	0.27b	0.29b	1.53	1.55
T9	7.87	7.92	2.18a	2.28a	0.27b	0.29b	1.53	1.55

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Where,**T1**: without conditioners; **T2**: potassium humate, 23.8 kg ha^{-1}as soil application; **T3**: potassium humate, 35.7 kg ha^{-1}as soil application; **T4**: potassium fulvate, 23.8 kg ha^{-1}as soil application; **T5**: potassium fulvate, 37.7 kg ha^{-1}as soil application; **T6**: 2% polyvinyl alcohol as soil application; **T7**: 4% polyvinyl alcohol as soil application; **T8**: 2% carboxy- methyl cellulose as soil application; **T9**: 4% carboxymethyl cellulose as soil application.

3.2. Pore size distribution:

The most important indicator for improving soil properties is total porosity, especially in sand soil. In addition, the distribution of total porosity is a good indicator for water movement and water retention. Results in Table 2 show the impact of the studied ameliorations on total porosity and its distribution (calculated as percentage from total porosity). The results show that application of humate substances as soil application and synthetic polymers improved total porosity (TP) as well as slowly drainable pores (SDP) and water holding pores (WHP) and fine capillary pores (FCP), while it decreased the quick capillary pores (QCP). The highest improvement in distribution of soil pore size were recorded under application of humate substances at high level. The relative increasing of SDP % and WHP% due to application of high rate of KH were 118.6, 31.7 and 19.9% and 125.0, 29.7 and 13.3% when compared with control in the 1st season, respectively. The corresponding values in the 2nd season were 147.78 & 69.90% in the same respect.

Table 2: Effect of some humate substances and synthetic polymers on pore size distribution.

Treatments	Total porosity %		Pore size distribution							
			Quickly drainable pore (QDP) %		Slowly drainable pore (SDP) %		Water holding capacity (WHP) %		Fine capacity pores (FCP) %	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T1	36.5c	35.4c	31.55	30.74	0.86c	0.80c	3.00c	2.96c	1.09c	0.90
T2	39.1a	38.6a	31.90	30.52	1.89b	2.86b	3.98ab	4.02ab	1.31a	1.22a
T3	38.3b	37.6b	31.18	30.75	1.88b	1.80b	3.95ab	3.84b	1.25ab	1.21a
T4	39.1a	38.3a	31.92	30.46	1.90b	1.78b	4.00ab	4.86a	1.28a	1.16a
T5	38.3b	37.6b	31.20	30.92	1.88b	1.80b	3.97ab	3.82b	1.22b	1.02b
T6	39.3a	38.9a	31.60	30.41	2.35a	2.30a	4.00ab	4.95a	1.35a	1.26a
T7	39.6a	38.7a	31.54	30.40	2.72a	2.91a	4.11a	4.25ab	1.25ab	1.11ab
T8	39.7a	38.6a	31.50	30.13	2.78a	2.75a	4.08ab	4.66a	1.30a	1.09ab
T9	39.9a	39.5a	31.58	30.71	2.75a	2.90a	4.26a	4.82a	1.28a	1.03b

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Where,**T1**: without conditioners; **T2**: potassium humate, 23.8 kg ha^{-1}as soil application; **T3**: potassium humate, 35.7 kg ha^{-1}as soil application; **T4**: potassium fulvate, 23.8 kg ha^{-1}as soil application; **T5**: potassium fulvate, 37.7 kg ha^{-1}as soil application; **T6**: 2% polyvinyl alcohol as soil application; **T7**: 4% polyvinyl alcohol as soil application; **T8**: 2% carboxy- methyl cellulose as soil application; **T9**: 4% carboxymethyl cellulose as soil application.

3.3. Soil fertility

Data concerning the impact of humic substances and synthetic polymers on soil fertility in term of soil available nitrogen, phosphorus and potassium following quinoa harvesting are shown in Table 3. The data clearly show that humic substances application increased N, P and K availability. It might be arranged the impact of these conditioners on nutrient availability on the descending order as follow: K humate at high rates > K fulvate at high rates > K humate at low rate > K fulvate at low rate. Noteworthy, the influence of humate substances increased as its rate increased. Potassium humate seem to be more pronounced in its effect on soil fertility than potassium fulvate.

3.4. Vegetative growth

Table 4 shows a significant role of humic substances and synthetic polymers on plant height, dry weight/plant as well as numbers of leaves/plant when compared with control. In this respect, the tallest, heaviest plant and highest numbers of leaves/plant were obtained under humate substances in the both seasons. It’s crucial to observe that humate substances at high rates, particularly potassium humate surpassed the others. Also, carboxy methylcelluse at rate of 4% is the best polymers in its effect on quinoa growth.

Table 3: Effect of some humate substances and synthetic polymers on Soil fertility.

Treatments	Soil available N (ppm)		Soil available P (ppm)		Soil available K (ppm)	
	2021	2022	2021	2022	2021	2022
T1	2.35b	2.80b	4.28c	4.30c	17.36c	22.57c
T2	3.10a	3.87a	6.60b	8.61b	40.05c	38.13
T3	2.22a	3.05a	8.81a	9.96a	55.12a	53.05a
T4	3.08a	3.80a	6.55b	8.57b	39.13c	36.27c
T5	3.18a	3.91a	8.69a	9.69a	46.36b	43.72b
T6	2.37b	3.02b	4.30c	4.30c	28.12c	32.71c
T7	2.38b	2.81b	4.29c	4.31c	27.39c	33.03c
T8	2.37b	2.81b	4.29c	4.33c	27.92c	32.13c
T9	2.35b	2.83b	4.28c	4.33c	28.05c	32.71c

Table 4: Effect of some humate substances and synthetic polymers on Vegetative growth.

Treatments	Plant height (cm)		Dry weight plant (g)		No. of leaves/plant	
	2021	2022	2021	2022	2021	2022
T1	29.3f	31.2e	21.5f	22.8f	108.7g	111.2g
T2	38.5c	40.3c	29.4cb	31.1b	143.1cb	146.3cb
T3	41.7a	43.7a	32.0a	33.7a	155.0a	157.3a
T4	35.2ed	39.2c	26.8e	28.5d	131.6e	136.2e
T5	39.3b	42.1b	29.9b	31.0b	145.2b	147.7c
T6	34.4ed	37.5d	26.3e	27.7e	127.7f	130.2f
T7	36.9d	39.2c	28.2d	29.8c	137.2d	139.7d
T8	36.5d	39.1c	28.4d	30.0c	136.7d	139.6d
T9	39.9b	42.0b	30.6b	31.9b	148.3b	150.7b

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Where,**T1**: without conditioners; **T2**: potassium humate, 23.8 kg ha^{-1}as soil application; **T3**: potassium humate, 35.7 kg ha^{-1}as soil application; **T4**: potassium fulvate, 23.8 kg ha^{-1}as soil application; **T5**: potassium fulvate, 37.7 kg ha^{-1}as soil application; **T6**: 2% polyvinyl alcohol as soil application; **T7**: 4% polyvinyl alcohol as soil application; **T8**: 2% carboxy- methyl cellulose as soil application; **T9**: 4% carboxymethyl cellulose as soil application.

3.5. Yield components

Table 5 represent the response of yield components of quinoa plants. As regard to response of numbers of panicles/plant, numbers of seeds/panicle, 1000-seed weight and seed yield /plant to the studied conditioners. The data show that the greatest values of these parameters were recorded for the plants treated with humate substances and the synthetic polymers. The quinoa yield components increased as the level of the studied conditioners increase. Application of humic substances and carboxymethyl celluse at high rates seem to be more pronounced on increasing yield component parameters. The relative increment of such parameters due to added 35.7 kg potassium humate reached to 6.9, 38.3, 41.5 and 87.5 % over without conditioner, respectively in the 1st season. The corresponding increases in the 2nd season were 35.0, 14.1, 41.3 and 97.7 % in the abovementioned respect.

3.6. Quinoa productivity

The quinoa productivity, i.e. seed yield, straw yield in addition to biological yield as influenced by the studied conditioners are given in Table 6. The data indicate that seed and/or straw yields showed significant changes by soil conditioners application when compared with controls. The greatest values of quinoa yields resulted when treated the soil with potassium humate and carboxymethyl cellulose at higher rates (1.83, 2.55 and 4.38 t ha^{-1} for humate substances and 1.57, 2.44 and 4.01 t ha^{-1} for carboxymethyl cellulose in the first season, respectively). Similar findings recognized in the 2nd season). It's worthy to notice that the role of soil conditioners on quinoa yields have the same trends as its effect on physio-chemical properties, soil fertility, vegetative growth and yield components of quinoa as

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mentioned before. Additionally, the effect of soil conditioners on quinoa yields increased as its level increase. Moreover, the effect of potassium humate or carboxymethyl cellulose are superior on quinoa yields than potassium fulvate or polyvinyl alcohol, respectively.

Table 5: Effect of some humate substances and synthetic polymers on Yield components.

Treatments	Number of seeds/panicles		Number of panicles/plant		1000-seed weight (g)		Seed yield/plant (g)	
	2021	2022	2021	2022	2021	2022	2021	2022
T1	297.3c	302.9c	12.0d	12.8d	3.01e	3.03e	12.0g	12.8f
T2	309.1a	313.4a	14.5ba	17.2b	3.80b	3.85b	17.2d	21.5c
T3	317.9a	321.4a	16.6a	18.5a	4.26a	4.28a	22.5a	25.3a
T4	303.6b	307.5b	13.3c	14.6c	3.54c	3.57c	14.4e	15.6e
T5	312.8a	316.6a	15.1ba	18.1a	3.66b	3.87b	17.7c	21.9c
T6	302.5b	306.8b	13.1c	14.2c	3.42dc	3.47dc	13.7f	14.5e
T7	305.2b	307.9b	14.2c	16.7b	3.70c	3.74c	15.2e	15.5e
T8	309.5a	312.8a	14.5ba	15.0c	3.76b	3.81b	16.4e	17.6d
T9	315.3a	316.6a	15.5a	18.3a	4.01a	4.16a	19.7b	24.1b

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Where,**T1**: without conditioners; **T2**: potassium humate, 23.8 kg ha^{-1}as soil application; **T3**: potassium humate, 35.7 kg ha^{-1}as soil application; **T4**: potassium fulvate, 23.8 kg ha^{-1}as soil application; **T5**: potassium fulvate, 37.7 kg ha^{-1}as soil application; **T6**: 2% polyvinyl alcohol as soil application; **T7**: 4% polyvinyl alcohol as soil application; **T8**: 2% carboxy- methyl cellulose as soil application; **T9**: 4% carboxymethyl cellulose as soil application.

Table 6: Effect of some humate substances and synthetic polymers on Quinoa productivity.

Treatments	Seed yield (t ha^{-1})		Straw yield (t ha^{-1})		Biological yield (t ha^{-1})	
	2021	2022	2021	2022	2021	2022
T1	0.85g	0.90g	1.70f	1.81e	2.65f	2.82g
T2	1.35c	1.71c	2.34b	2.44b	3.69c	4.18d
T3	1.83a	2.02a	2.55a	2.68a	4.38a	4.70a
T4	1.13f	1.20e	2.14e	2.28d	3.27e	3.52ef
T5	1.41c	1.66c	2.38b	2.47b	3.79c	4.66c
T6	1.09f	1.15fe	2.11e	2.21d	3.21e	3.36ef
T7	1.20e	1.24e	2.24d	2.38cb	3.44cd	3.68e
T8	1.31dc	1.41d	2.30cd	2.41cb	3.56cd	3.81e
T9	1.57b	1.91b	2.44b	2.55b	4.01b	4.46b

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Where,**T1**: without conditioners; **T2**: potassium humate, 23.8 kg ha^{-1}as soil application; **T3**: potassium humate, 35.7 kg ha^{-1}as soil application; **T4**: potassium fulvate, 23.8 kg ha^{-1}as soil application; **T5**: potassium fulvate, 37.7 kg ha^{-1}as soil application; **T6**: 2% polyvinyl alcohol as soil application; **T7**: 4% polyvinyl alcohol as soil application; **T8**: 2% carboxy- methyl cellulose as soil application; **T9**: 4% carboxymethyl cellulose as soil application.

3.7. Quinoa quality

Table 7 represent the impact of some soil amelioration on seed quinoa quality, namely, nitrogen content, protein percentage and protein yield. The data show significant differences among the studied amelioration for seed quality. The highest values of N (%) and protein (%) and protein yield were determined for plants amended with humate substances at high levels and 4% carboxymethyl cellulose, while the lowest values of them are produced under without soil conditioners.

Table 7: Effect of some humate substances and synthetic polymers on Quinoa quality.

Treatments	N (%) in grains		Protein (%) in grains		Protein yield (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022
T1	2.26c	2.28c	14.13c	14.25c	120.10i	128.25i
T2	2.37a	2.40a	14.81a	15.00a	199.94d	256.50d
T3	2.49a	2.53a	15.56a	15.81a	284.75a	319.36a
T4	2.34ab	2.37ab	14.63ab	14.81ab	167.35g	177.72g
T5	2.45a	2.47a	15.31a	15.44a	215.87c	256.30c
T6	2.35ab	2.38ab	14.69ab	14.88ab	160.12h	171.12h
T7	2.35ab	2.38ab	14.69ab	14.88ab	176.28f	184.51f
T8	2.36ab	2.39ab	14.75ab	14.94ab	193.23e	210.65e
T9	2.43a	2.45a	15.19a	15.31a	238.48b	292.42b

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Where,**T1**: without conditioners; **T2**: potassium humate, 23.8 kg ha^{-1}as soil application; **T3**: potassium humate, 35.7 kg ha^{-1}as soil application; **T4**: potassium fulvate, 23.8 kg ha^{-1}as soil application; **T5**: potassium fulvate, 37.7 kg ha^{-1}as soil application; **T6**: 2% polyvinyl alcohol as soil application; **T7**: 4% polyvinyl alcohol as soil application; **T8**: 2% carboxy- methyl cellulose as soil application; **T9**: 4% carboxymethyl cellulose as soil application.

3.8. Economic analysis

To investigate the economic analysis of quinoa production, partial budget was used, which include net return, return over variable costs, beneficial cost ratio and product profit ratio. The data in Table 8 represent the general cultivation costs and variables cost, while data in Tables 9a and 9b show the pudjet analysis as affected by the studied treatments.

Table 8: The quinoa costs (L.E.)

General cost	First season	Second season
Rent of land	7140	7380
Preparation of land	1098	1145
Seeds	430	480
Sowing	830	920
Thinning and hoeing	3330	3570
Irrigation	950	1070
Weed control	950	1050
fertilization	2000	2100
Harvesting	9500	10000
Drying	1070	1190
Packing and translocation	1700	1850
Human management	3000	3500
Total	31995	34255
Variables cost:		
T1	0.0	0.0
T2	4284	4760
T3	8568	9520
T4	4284	4760
T5	8568	9520
T6	3000	3600
T7	6000	7200
T8	3000	3600
T9	6000	7200

Table 9a: Effect of humate substances and synthetic polymers on some economic measurements of quinoa production (first season).

Treatments	Variable costs (L.E ha^{-1})	Total cultivation cost (L.E ha^{-1})	Gross return (L.E ha^{-1})			Net return (L.E ha^{-1})	Return over variable costs (L.E ha^{-1})	Beneficial cost ratio	Product profit margin ratio (%)
			Seeds	Straw	Total				
T1	0.0	31995	34000	170	34170f	2175f	34170e	1.07f	6.37f
T2	4284	36279	54000	234	54234c	17955c	49950c	1.80a	33.11c
T3	8568	40563	73200	255	73455a	32892a	64887a	1.81a	44.78a
T4	4284	36279	45200	214	45414e	9135e	41130d	1.25e	20.11e
T5	8568	40563	56400	238	56638c	16075d	48070c	1.40d	28.38d
T6	3000	34995	43600	211	43811l	8816j	40811j	1.25i	20.12i
T7	6000	37995	48000	224	48224e	10229e	42224d	1.27e	21.21e
T8	3000	34995	52400	230	52630cd	17635c	49630c	1.50c	33.51c
T9	6000	37995	62800	244	63044b	25049b	57044b	1.66b	39.73b

Table (9b): Effect of humate substances and synthetic polymers on some economic measurements of quinoa production (second season).

Treatments	Variable costs (L.E ha^{-1})	Total cultivation cost (L.E ha^{-1})	Gross return (L.E ha^{-1})			Net return (L.Eha^{-1})	Return over variable costs (L.E ha^{-1})	Benefic-ial cost ratio	Produc t profit margin ratio (%)
			Seeds	Straw	Total				
T1	0.0	34255	43200	271.5	43471.5^{g}	9216.5^{g}	43471.5^{g}	1.27^{d}	21.20^{g}
T2	4760	39015	76950	366.0	77316.0^{d}	38301.0^{c}	72556.0^{c}	1.98^{a}	49.54^{c}
T3	9520	43775	90900	402.0	91302.0^{a}	47527.0^{a}	81782.0^{a}	2.09^{a}	52.05^{a}
T4	4760	39015	54000	342.0	54342.0^{ef}	15327.0^{f}	49582.0^{f}	1.39^{c}	28.20f
T5	9520	43775	74700	370.5	75070.5^{c}	31295.5^{d}	65550.5^{d}	1.71^{b}	41.69^{d}
T6	3600	37855	51750	331.5	52081.5^{l}	14226.5^{l}	48481.5^{l}	1.38^{i}	27.32^{k}
T7	7200	41455	55800	357.0	56157.0^{e}	14702.0^{f}	48957.0^{f}	1.35^{c}	26.18^{f}
T8	3600	37858	63450	361.5	63811.5^{e}	25953.5^{e}	60211.5^{e}	1.69^{b}	40.67^{e}
T9	7200	41455	85950	382.5	86332.5^{b}	44877.5^{b}	79132.5^{b}	2.08^{a}	51.98^{b}

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of $\leq$.0.05

Where,**T1**: without conditioners; **T2**: potassium humate, 23.8 kg ha^{-1}as soil application; **T3**: potassium humate, 35.7 kg ha^{-1}as soil application; **T4**: potassium fulvate, 23.8 kg ha^{-1}as soil application; **T5**: potassium fulvate, 37.7 kg ha^{-1}as soil application; **T6**: 2% polyvinyl alcohol as soil application; **T7**: 4% polyvinyl alcohol as soil application; **T8**: 2% carboxy- methyl cellulose as soil application; **T9**: 4% carboxymethyl cellulose as soil application.

The data reveal that potassium humate application at level of 35.7 kg ha^{-1} and carboxy methyl cellulose at rate of 4 % gave highest values of the studied economic measurements, i.e., gross return (73455 and 63044, L. E./ha), net return (32892 and 25049, L.E./ha), return over variable costs (64887 and 57044, L.E./ha), beneficial cost ratio (1.81 and 1.66), and product profit margin ratio (44.78 and 39.73 %) in first season, respectively. Same trends were obtained in the second season.

On the other hand, the quinoa plants without, humat substances or synthetic polymers gave the lowest ones (34170 and 434715, L.E./ha; 2175 and 9216.5 L.E./ha; 34170 and 43471.5, LE./ha; 1.07 and 1.27; and 6.37 % and 21.20 % in both seasons, respectively). This results indicates the profitability of quinoa crop and the need to expand the cultivation of this crop to reduce the food gap of wheat production and maximize the farmers incomes.

The profitability of cultivated quinoa to improving the net return of farmers than other crops was reported by many investigators, such as Khalil (2018).

4. Discussion

Due to the rapid human population, the gap between the production of cereal crops and its consumption in Egypt increased. Therefore, the intensive agriculture and best land using; especially saline and sand soil are also increased. Using natural and synthetic substances such as humate substances or polymers to improved sand soil and its production in sustainable and economic approach are most important practices.

On basis of our results, the physical and chemical soil properties after quinoa harvest, i.e. bulk density, soil pH, soil salinity and soil organic matter were positively affected by application of humate substances. The helpful influence of humate substances on physico-chemical soil properties may be resulted in significant increase in soil bulk density and organic matter. Also, the positive role of humic substances on ameliorated soil pH might be attributed to the carboxyl, phenolic and hydroxyl groups that produce hydrogen ion in soil (Khattak *et al.,* 2013). Additionally, Ding *et al.* (2021) reported that the decomposition of organic matter in humic materials led to release H+ ions, hence reduce soil pH. Also, the positive effect of humic elements on physio-chemical soil properties might be explained by the enhanced soil aggregation, consequently reduced soil bulk density & salinity (Abd-Elzaher *et al.,* 2022). In this corncern, Abd-Elzaher *et al.* (2022) stated that the promotive effect of humate substances on increasing N, PO4 and K in soil led to raising soil organic matter. Comparable findings were documented by Ullah *et al.* (2020) and Yoldas *et al.* (2020). However, synthetic polymers decreased bulk density only when compared with control. The better influence of polymers on soil bulk density may be due to these substances contain many groups of (-OH-) and (-COONa+) which covered on surface of soil particles and aggregates, hence reduce soil bulk density (Wang *et al.*, 2019). Such outcomes are in accordance with data documented by Yasseen *et al.* (2020).

Total porosity, slowly drainable pores and water holding pores were increased, while fine pores decreased by application of the studied conditioners. Hegab *et al.* (2022) stated that application of potassium humate or potassium fulvate improved soil structure that resulted in improving soil porosity and H2O movement in soil. These results are in line with those obtained by Agbna *et al.* (2017) for potassium humate and polymers, respectively.

Application of humate substances resulted in increased in soil available N,P and K in soil after harvest. The potential impact of humic substances on nutrient availability might be explained by its influence on enhanced the soil microorganisms, in turn increased nutrient cycling as well as its effect on reducing soil pH (Osman and Rady, 2012). In addition, El-Shaboury and Sakara (2021) reported that potassium humate and fulvate increased nutrient availability by its impact on improvement of soil structure and soil microbial population. such findings are comparable with what demonstrated by Mohamed and El-Hamed (2020) and Sary and Hamed (2021).

Quinoa growth in terms of growth parameters, yield components and grain and straw yields were positively responded to humate substances and polymers application, where as levels of conditioners increased those parameters increased. The potential influence of humate substances might be explained by increased chlorophyll content, enhanced the respiration processes and growth hormones, and improved plant membrane penetrating capacity, beside it improves physio-chemical soil properties and biological activity (Osman *et al.,* 2017). As for the promotive effect of polymer materials, Stefan *et al.* (2022) stated that polymers are capable of retaining great amounts of H2O and nutrient substances and releasing the nutrients in addition to H_2O slowly to plant requirement. Zainescu *et al.* (2011) demonstrated that synthetic polymers enhanced soil quality via prevention of forming crust in the duration between seedling and emergence, improving soil permeability by formation a stable aggregates and enhancing the resistance to soil erosion by water or air. These findings are the same as the findings demonstrated by those by Osman *et al.* (2017) and Sarhan and Abd El-Gayed (2017), Sary and Hamed (2021), Awwad *et al.,* (2022) and El-Shabaury and Sakara (2022) for humate substances and Yasseen *et al.,* (2020), Zein El-Abdeen (2018), Alkhasha (2019) and Zhang *et al.,* (2022) and Karipcin (2023) for polymer materials.

Amended quinoa plant with the studied conditioners led to improve its quality in term of N and protein percentage grains. The promotive effect of soil amelioration on seed quality is mainly because of its impact on physio-chemical properties and soil fertility along with seed yield as discussed earlier in addition, Ding *et al.* (2021) illustrated that humate substances enhanced oxygen uptake for biosynthesis of protein enzyme that stimulate the production of protein structural as well as carrier. Moreover, Stefan *et al.* (2022) stated that polymer materials affected quinoa quality by its action on soil microorganisms which degraded to supply more nutrients, consequently promoted nutrient uptake by plants. The results we reported are in accordance with findings concluded by many workers, such as Sary and Hamed (2021) for humate substances and Aly *et al.* (2016) and Stefan *et al.* (2022) for polymer materials.

5. Conclusion

From the obtained results of this investigation, under newly reclaimed land with slightly salinity it could be recommended to using potassium humate as soil application at rate of rats of 37.7 kg ha^{-1} or 4% carboxymethyl cellulose to improve physio-chemical soil properties and soil fertility in addition to quality and quantity of quinoa.

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