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Effect of Humic Acid Supplementation on Potato Yield, Nutritional Status and Nutrients Availability in Sandy Soil Fertilized with Different Rates of Mineral Fertilization

[1]Yasser A. El-Damarawy, [1]Khaled M. Abd El-Rheem and [2]Naglaa E. Khalafallah

[1]Soils and Water Use Dept., National Research Centre, Dokki, Giza, Egypt
[2]Soil and Water Department, Faculty of Agriculture, Tanta University, Egypt

Abstract: The research was carried out in the Agricultural Research Station, National Research Centre, El-Nubaria district, during the early growing season of summer 2020 to study the effect of humic acid addition (50 kg fed^{-1}) with NPK fertilizers (100%, 75% and 50% of N, P and K fertilizers) through drip irrigation system on mobility of NPK nutrients at three layers of soil (0-15, 15-30 and 30-45 cm), yield and nutrients content of potato plants grown on sandy soil. The obtained results indicate that the addition of humic acid to the full mineral fertilization greatly improved the marketable potato yield and its quality compared to the addition of the full mineral fertilization without the addition of humic acid. The use of humic acid with low rates of nitrogen, phosphate and potassium fertilization contributed a lot to obtaining a crop that is very close to that obtained by adding full mineral fertilization, which shows the important and effective role of humic acid when added at a rate of 50 kg fed^{-1} to increase the productivity of potato grown in the sandy soil. The addition of humic acid resulted in significant increase in nitrogen, phosphorous and potassium content of potato tubers with the addition of the recommended full mineral fertilization. Also, the reduction of different mineral fertilizers ratios applied to potato, did not affect the values of tubers content of the main essential nutrients of the plant when combined with humic acid. Humic acid had an effective role in the availability of nitrogen, phosphorous and potassium in the sandy soil, where with the addition of humic acid it greatly helped to facilitate these nutrients in the root zone of potato plants to translocate to aerial parts, and improve the nutritional status of potato tubers and increasing the fertility of sandy soil. In general, it can be said that the using of humic acid during drip irrigation with a reduction of mineral fertilization up to 75% can share in obtaining a high yield of potato tubers and nutrients (N, P and K) content in a balanced form.

Key words: Humic acid · Fertilization · Sandy soil · Drip irrigation · Yield · Nutrients content · Soil fertility

INTRODUCTION

Potato is the world's fourth largest food crop where it plays a paramount role as a master feed in the countries of Mediterranean Basin. The crop occupied an overall area about 1 million hectares which produced 28 million tons of tubers [1]. In Egypt, the amount of soil allocated for potato production represents about 20% of the total cultivated area. Export of Egyptian grown potatoes is a significant provenance of revenue, as potato represents over half of Egypt's net exports [2].

Humic acid contains many nutrients and it acts as an amendment to upgrade soil fertility. This boosts the availability of nutrients and consequently it augments plant outgrowth and yield. Humic acid particularly is used to mend or lessen the side effect of chemicals [3]. Humic acid is able to hold more wetness content that will increase the water use efficiency in the sandy soil. This may be attributed to the retention of water in the [4]. Soil implementation of humic acid significantly increased plant growth, photosynthetic pigments, total and marketable yield and tuber root quality of potato plants [5]. The increment of growth parameters and crop yields due to humic acid application may be attributed to that humic acid is an important component since it constitutes a stable fraction of carbon, thus regulating the carbon cycle and release of nutrients, including nitrogen, phosphorus, and sulfur, which decreasing the need for inorganic fertilizer for plant growth [6].

Corresponding Author: Yasser A. El-Damarawy, Soils and Water Use Dept., National Research Centre, Dokki, Giza, Egypt.

The purpose of this work aimed to determine the effect of application of humic acid along with different levels of mineral fertilizers on quantity and quality of yield and nutritional state of potato plants, as well as determined N, P and K availability under different layers of sandy soil.

MATERIAL AND METHODS

The research was carried out in the Agricultural Research Station, National Research Centre, El-Nubaria district, Egypt (latitude 30°8/ N, and longitude 30°16/ E, and mean altitude 21 m above sea level), during the early growing season of summer 2020 to study the effect of humic acid addition with NPK fertilizers through drip irrigation system on mobility of NPK nutrients at three layers of soil (0-15, 15-30 and 30-45 cm), yield and nutrients balance of potato plants (*Solanum tuberosum* L. Spunta cv.) grown on sandy soil.

Potato pieces were cultivated on 15 February 2020. Spacing between plants in rows were 0.25 m. Soil samples i.e. 0-15, 15-30 and 30-45 cm were collected by auger and these were air-dried, crushed and passed through a 2-mm sieve and preserved for analyses. Some physical and chemical properties at different depths of El-Nubaria soil illustrated in Table (1) according to Cottenie [7].

Mineral fertilizers were 4 treatments as follow; the first treatment was 100% of recommended chemical NPK fertilizer dose (according to the Egyptian Ministry of Agriculture recommendations 200 kg N, 45 kg P_2O_5 and 85 kg K fed^{-1}).

Three treatments of mineral fertilization were added (100%, 75% and 50% of N, P and K fertilizers), and one dose of humic acid (50 kg fed^{-1}) was added to them through drip irrigation system. The chemical analysis of humic acid is shown in Table (2).

After 115 days from cultivation, a random sample of three plants from each treatment was chosen and prepared for chemical analysis. Fresh tubers yield was calculated as (ton fed^{-1}). Specific gravity of tubers was calculated as (g cm^{-3}) according to the methods described by Smith [8]. The starch content was calculated according to the formula of Burton [9]:

Table 1: Some physical and chemical properties at different depth of the soil used

Soil properties		Soil depth (cm) 0-15	15-30	30-45
Particle size distribution (%)	Sand	92.32	93.0	95.02
	Silt	5.68	4.56	3.33
	Clay	2.00	2.44	1.65
	Texture	Sandy soil	Sandy soil	Sandy soil
$CaCO_3$ (%)	2.11	2.14	1.70	
$pH_{(1:2.5\ soil\ suspension)}$	7.80	7.70	7.70	
EC (dS m^{-1})	1.60	1.92	2.69	
Soluble caions (mmol L^{-1})	Ca^{++}	6.02	8.96	12.2
	Mg^{++}	3.97	3.16	5.44
	Na^{+}	3.64	5.20	6.48
	K^{+}	2.37	1.88	2.82
Soluble anions (mmol L^{-1})	CO_3^{--}	-	-	-
	HCO_3^{-}	0.64	0.64	0.64
	Cl^{-}	4.10	7.82	14.9
	SO_4^{--}	6.02	10.74	11.36
Available nutrients mg kg^{-1}	N	32.2	28.5	16.4
	P	4.05	4.00	3.05
	K	88.6	58.5	46.1

Table 2: Chemical analysis of humic acid used

			N	P	K	Fe	Zn	Mn
pH	EC dS m^{-1}	Organic mater %	%			mg kg^{-1}		
7.82	0.85	65	2.00	0.18	5.50	425	266	114

Starch (%) = 17.546 + 199.07(specific gravity - 1.0988)

where:

$$\text{Specific gravity (g cm}^{-3}) = \frac{\text{weight in air}}{\text{weight in air - weight in water}}$$

To determine N, P and K concentrations in tuber tissues of potato, samples were taken from each plot, dried at 70° and grounded using stainless steel equipments. From each sample 0.2 g was digested using 5 cm^3 from the mixture of sulfuric (H_2SO_4) and perchloric ($HClO_4$) acids (1:1) as described by Cottenie [10]. After potato harvesting, soil samples were taken at three depths of 0-15, 15-30 and 30-45 cm, respectively. The same procedures of soil analysis before cultivation were carried out to study NPK distribution at three soil depths under investigated treatments as mentioned by Hesse [11].

RESULTS AND DISCUSSION

The results in Table (3) indicate the effect of the experimental treatments on the quantity and quality of the potato plants. The injection of humic acid at the rate recommended by the previous experiments of other researchers such as [12, 13]. Humic acid added in this experiment (50 kilo per feddan) to be a good factor in improving the quantity and quality of the resulting yield of potato plants when it was combined with the recommended full mineral fertilization and compared with the control treatment. With the addition of humic acid to potato plants, the amount of the total yield as well as the marketable yield increased from 16.1 to 18.2 and 15.1 to 17.0 ton fed^{-1}, respectively, with an increase of 13 and 12.5% for each, respectively. In the same context, the addition of humic acid led to an improvement in the quality of the potato crop, as the value of protein, starch, and the specific gravity increased compared to the control treatment.

Through the results in Table (3), it is also clear that the addition of humic acid at a rate of 50 kg per feddan with reduced rate up to 75% of the recommended doses, potato yield gave results similar to the yield obtained when adding full mineral fertilization, but without adding humic acid, which indicates that the use of humic acid reduced the amounts of mineral fertilization by 25% without decreasing the quality and quantity of the potato crop planted in sandy soil. Such effect may be due the promotive role of humic acid in improving the crop without any shortage. Moreover, the rationalization of mineral fertilizers use, and thus rationalizing expenditures and reducing environmental pollution for nitrogen, phosphate and potash fertilizers.

The increment of growth parameters and yield of all crops due to humic acid addition may be attributed to that humic acid is an substantial component since it constitutes a fixed fraction of carbon, thus regulating the carbon cycle and release of nutrients, which detraction the need for inorganic fertilizer for plant growth. Humic acids stimulate plant growth by the assimilation of main nutrients, enzyme activation and protein synthesis [14]. Suh *et al*. [15] treated potato with humic acid applied to the soil and demonstrated improvements in soil properties, and fresh tuber weight and size. Selim *et al*. [16] observed that the addition of humic acid with the recommended amount of the integrated mineral fertilization greatly improved the quantity and quality of the potato crop that was grown in sandy soil, compared to the addition of mineral fertilization without adding humic acid with it.

The results obtained in Table (4) showed the activating and effective effect of adding humic acid with different rates of mineral fertilization on increasing and improving the nitrogen, phosphorous and potassium content of potato tubers. The addition of humic acid at a rate of 50 kg per feddan with the full fertilization of the recommended mineral fertilizers raised the efficiency of these fertilizers, so the concentration values of the three main elements inside the potato tubers increased compared to the mineral fertilizers without adding humic acid. Application of the reduced amount of mineral fertilization, the addition of humic acid greatly helped to not significantly decrease the nitrogen, phosphorous and potassium content of potato tubers.

Therefore, it can be said that the use of low amounts of NP fertilization (50% of the recommended amount) did not affect the potato tubers content of both nutrients, while 75% of potassium fertilization should be used so as not to affect the potato tubers content of potassium, all of this becomes clear with the addition of humic acid with mineral fertilization for all three elements.

Sharif *et al*. [17] also showed addition of humic acid increased N accumulation over control with no significant differences within the treatments of different levels of humic acid applied. The enhanced uptake of phosphorous in plants with application of humic acid is mainly due to the increased availability of phosphate in the soil [18]. Manas Denre *et al*. [19] mentioned that the increase in the concentration of humic acid addition with mineral fertilization led to an increase in phosphorous content

Table 3: Effect of adding humic acid with different rates of mineral fertilization on the quantity and quality of potato yield

	Tuber yield quantity (ton fed^{-1})			Tuber yield quality		
Treatments	Total	Marketable	Unmarketable	Specific gravity (g cm^3)	Starch (%)	Protein (%)
100 %	16.1	15.1	1.0	1.05	11.4	10.8
100 % + HA	18.2	17.0	1.2	1.07	13.5	11.5
75 % + HA	16.2	15.1	1.1	1.10	14.4	10.7
50 % + HA	13.3	12.1	1.0	1.08	13.8	10.4
$L.S.D_{0.05}$	2.10	2.02	0.60	0.03	1.80	0.12

Table 4: Effect of adding humic acid with different rates of mineral fertilization on N, P and K content of potato tuber

	Nutrients content		
	N	P	K
Treatments	%		
100 %	1.84	0.22	2.89
100 % + HA	2.20	0.26	2.95
75 % + HA	1.95	0.21	2.94
50 % + HA	1.71	0.21	2.82
$L.S.D_{0.05}$	0.22	0.01	0.30

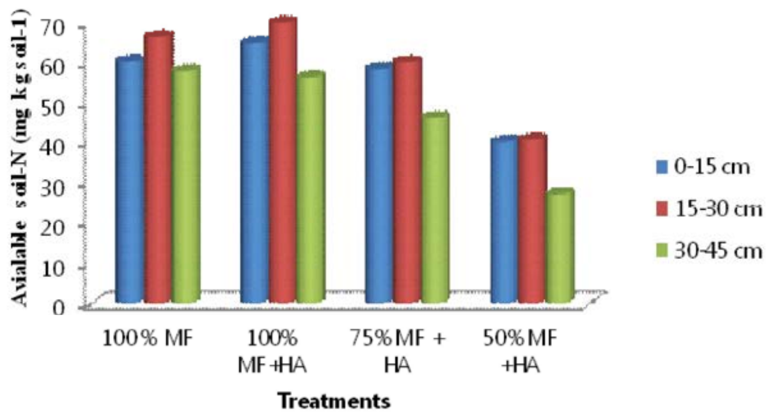

Fig. 1: Available soil- N (mg kg $soil^{-1}$) at different soil depth as affected by humic acid and different rates of mineral fertilizers

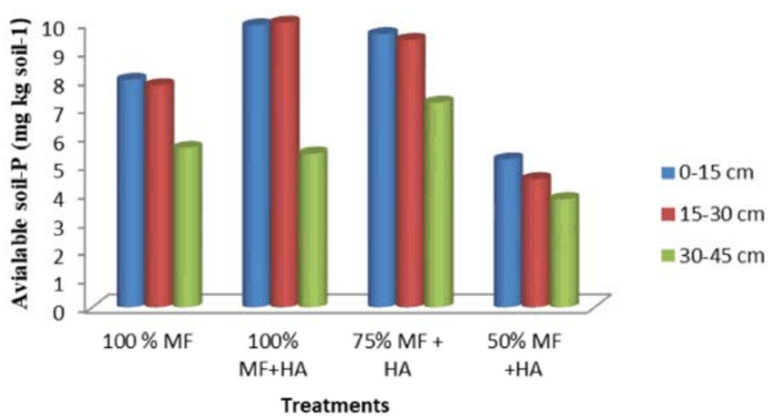

Fig. 2: Available soil- P (mg kg $soil^{-1}$) at different soil depth as affected by humic acid and different rates of mineral fertilizers

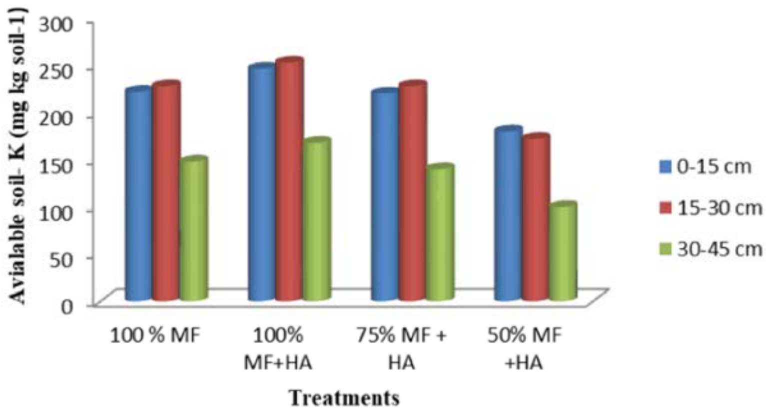

Fig. 3: Available soil- K (mg kg soil^{-1}) at different soil depth as affected by humic acid and different rates of mineral fertilizers

inside the garlic plant compared to the control treatment (not adding humic acid). Rosolem *et al*. [20] reported that using humic acid to sandy soil led to increasing K content in plant tissues. Application of humic acid increased availability of potassium in soil, it can be prevents of precipitation, ions fixation and nutrients leaching in soil [21].

A sight of the following Figures (1), (2) and (3), it could noticed that addition of different treatments had a significant effect on soil N, P and K available at three soil layers i.e., 0-15, 15-30 and 30-45 cm, respectively after potato harvesting. The highest available N was 70 mg kg soil^{-1} observed with addition of humic acid to 100% NPK at 15-30 cm soil depth. While the lowest value of available nitrogen was in the lower region (30-45 cm), which proves the efficiency of humic acid in binding the nitrogen element in the root spreading region and preventing its leakage to the far areas of the potato plant roots, which increases the efficiency of nitrogen fertilizer use.

It was found that the addition of humic acid to the complete mineral fertilization (100 %) made the phosphorous element more available in the soil compared to the control treatment (100 % mineral fertilizers without humic acid addition). In fact, using 75% of the mineral fertilization with the addition of humic acid also increased the easy amount of phosphorus, and thus the amount of phosphate fertilization added to potato plants was saved, in the region of diffusion of the roots, which allows increasing the absorption of phosphorous.

Addition of humic substances to mineral fertilizers maximized available K in soil and when humic acid injected with 100%NPK fertilizer, available K values were 250, 260 and 180g kg soil^{-1} higher more than application of 100% NPK fertilizer at all soil layers.

Increase in N, P and K as a result of humic acid addition may be attributed to the improving in soil nutrients retention and enhancing soil microbial activity which works to convert the organic from of nutrients to mineral form [22]. Zaky *et al*. [23] who mentioned that treated soil with humic acid through the irrigation water caused marked increases in available N, P and K in soil. Soil application of humic acid was associated with significant increases in available N, P and K. Mahmoud *et al*. [6] reported that the combined application of humic acid and mineral fertilizers recorded higher values in respect to N, P and K as compared to the treatments received solely application of mineral fertilizers, and the highest values of available N, P and K (92.0, 16.3 and 350 mg/kg soil, respectively) were obtained under the treatment of 30 kg humic acid per feddan along with 100% of recommended dose of fertilizers.

CONCLUSION

With the use of humic acid added to the sandy soil at a rate of 50 kg fed^{-1}, and with the reduction of the added mineral fertilizers, it is possible to obtain a production comparable to the yield resulting from the addition of full mineral fertilizer (100%). Thus, mineral fertilization rates can be safely reduced without any decrease in yield or lack of elemental content in potato tubers, thus reducing the economic cost and increasing profitability, as well as reducing pollution resulting from the non-optimal use of mineral fertilizers. Humic acid had an effective role in the availability of nitrogen, phosphorus and potassium in the sandy soil, where with the addition of humic acid greatly helped to facilitate these nutrients in the root zone of potato plants, which led to improving the nutritional status of potato tubers and increasing the fertility of sandy soil.

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