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# Response of Potato Growth, Yield and Quality to Fulvic Acid and Biochar Applications under Different Levels of Chemical Fertilization

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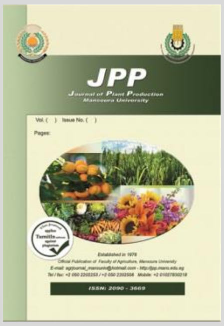


## ABSTRACT

Two field trials were conducted on potato cv. Spunta, in private farm at Kafr Meet Faris, Dakahlia Governorate, during 2018 and 2019 seasons to study the effect of NPK levels (100%, 75% and 50% NPK of the recommended rate) either single or in combination with some applications of fulvic acid and biochar treatments (untreated, fulvic acid at 10 kg/fed, biochar at 5 $m^3$/fed and fulvic acid at 10 kg/fed + biochar at 5 $m^3$/fed)) on plant growth, yield and its quality as well as chemical constituents of plant foliage and tubers. Results showed that the most studied characteristics of potato plants were significantly increased with increasing NPK-level up to 100%. Besides, the most interesting observation was the increasing of the yield and its components by 100% NPK level. Moreover, this treatment significantly increased concentration of all chemical constituents in foliage and tubers comparing with those of the other treatments. Application of fulvic acid and biochar treatments caused significant increases in the most studied parameters as comparing with the control treatment. The highest record data was obtained from application of fulvic acid + biochar. The combined treatments of NPK levels and fulvic acid and biochar treatments were generally more effective on the most studied parameters than with single ones. The best results were obtained by 75 % NPK level with fulvic acid + biochar treatment. Therefore, this treatment could be recommended for raising potato yield and improving tuber quality under similar conditions to this work.

***Keywords:*** Potato, NPK mineral fertilizers, fulvic acid and biochar, yield and tuber quality.

## INTRODUCTION

Potato (*Solanum tuberosum,* L.) is one of the most important vegetables in Egypt for both local consumption and exportation. It has a considerable importance as an export crop to the European and Arab markets and one of the national income resources. Therefore, increasing potato yield and improving tuber quality are essential aims for both growers and consumers, but that advances usually depends on many factors especially that influence the plant growth throughout the growth period.

Nitrogen, phosphorus and potassium nutrition are three of major factors affecting growth, yield and quality of potato. Nitrogen is a main constituent of many organic compounds in plants, such as proteins, enzymes, pigments, hormones and vitamins, (Gardener *et al*., 1985). Likewise, phosphorus plays an important role in certain essential steps, such as accumulation and release of energy during cellular metabolism. In addition, it is a constituent of many organic compounds in plants (Marschner, 1995). On the other hand, potassium is involved in many processes with the plant as a catalyst. It plays a role in carbohydrate synthesis and translocation, enhances N uptake, and promotes protein synthesis (Marschner, 1995). It also has stimulates early haulm growth and vigor as well as increases tuber size and yield (EI-Sawy*et al.* 2000).

There was a close relationship between the applied NPK-levels and potato productivity. In this regard, (Singh and Raghar, 2000 and Bărăscu*et al.* 2015) found thatplant growth, plant chemical constituents were significantly enhanced by increasing the applied NPK. Similar findings reported by Elsharkawy (2013), Kumar *et al*. (2001), Nizamuddin *et al*. (2003), Eleiwa (2012) and Shubha *et al.* (2018), they showed that total yield and its components as well as tuber quality were significantly increased with increasing the applied NPK. Also, Cucci and Lacolla, (2007), Adhikari, (2009) and Bošković *et al*., (2018) potato quality were enhanced with NPK applied.

However, the continuous increase in the costs of chemical fertilizers and environmental pollution problems prevents to application of sufficient amount for plants by many farmers. Thus, it has become essential to use of untraditional fertilizers as substitutes or supplements for chemical fertilizers. In this respect, Youseef *et al.* (2017) and El- Metwaly (2019) indicated that using biochar and fulvic acid as a organic source are considered a promising alternative or supplements for chemical fertilizers under Egyptian soil conditions. There are many beneficial effects for using biochar and fulvic acid in agriculture such as, quick supplying of plant nutrients and increasing crop productivity, as well as reducing costs and the pollution of environment.

Many studies pointed out that plant growth, chemical constituents, yield and yield quality were increased with the plants treated with fulvic acid (Suh *et al*., 2014 a and b on tomato and potato; Abou El Hassan and Husein, 2016 on tomato; El-Hassanin *et al*., 2016 on sugar beat and Mansour and El- Metwaly, 2019 on potato).

Morever, treated plants with biochar increased plant growth, yield and quality (Graber *et al*., 2010 on tomato, Dou *et al*., 2012 on sweet potato, Carter *et al*., 2013 on lettuce and cabbag, Nair 2015 on potato, Vaccari *et al*., 2015 on tomato, Silva *et al*., 2017 on common bean and Youseef *et al.*, 2017 on potato).

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Therefore, the main objectives of present investigation to study the influence of fulvic acid and biochar applications under some mineral NPK-levels to reach the best one to have the perfect beneficial towards better growth, yield, as well as quality of potato tubers under the local conditions.

## MATERIALS AND METHODS

Two field experiments were carried out at the privet Farm at Kafr meet Fares village, near El-Mansoura, Dakahlia Governorate, during two summer growing seasons of 2018 and 2019, to study the effects of NPK levels either single or in combination with some applications of of fulvic acid and biochar levels on potato (Spunta cv) growth, yield and its components, as well as chemical constituents in potato shoots. The soil of the experimental field was clay loam in texture, the physical and chemical analyses of the experimental soil and the use of biochar are presented in Tables(a and b).

**Table a. The physical and chemical properties of the experimental soil**

| Soil properties | 2018 season | 2019 season |
|---|---|---|
| Physical properties | | |
| Sand (%) | 24.26 | 23.53 |
| Silt (%) | 27.80 | 26.78 |
| Clay (%) | 47.81 | 49.86 |
| O.M (%) | 1.89 | 1.76 |
| Chemical properties | | |
| pH | 7.82 | 7.75 |
| Total N (%) | 0.18 | 0.19 |
| Available $P_2O_5$ (%) | 0.042 | 0.039 |
| Available $K_2O$ (%) | 0.61 | 0.59 |

**Table b.The chemical properties of the used biochar**

| Chemical properties | | 2018 season | 2019 season |
|---|---|---|---|
| Total (DW %) | C | 33.81 | 32.58 |
| | N | 0.92 | 0.95 |
| | S | 0.11 | 0.13 |
| Mg/kg | P | 18.66 | 18.32 |
| | K | 322 | 319 |
| | Mg | 181 | 185 |
| | Ca | 665 | 715 |
| | Fe | 82.13 | 83.24 |
| | Mn | 172 | 179 |
| | Zn | 13.65 | 13.63 |
| | pH | 9.21 | 9.27 |

The experimental design was split plots with three replicates. Tuber seeds were planted on the $10^{th}$ and $12^{th}$ of January at 20 cm apart in the first and the second seasons, respectively. NPK levels occupied the main plots which were subdivided to 4 sub plots each contained one of the fulvic acid and biochar applications. The sub-plot area was 21 $m^2$ (1/200 feddan) which contained 5 rows, each 6 m long and 0.7m width. Each experiment included 12 treatments which were 3 levels of NPK fertilizers, 4 applications of fulvic acid and biochar treatments including control treatment as follows:

**a- NPK-levels:**

1- 100% from recommended dose (120 kg N + 80 kg P/fed + 96 kg K).

2- 75% from recommended dose.

3- 50% from recommended dose.

**b- Fulvic acid and biochar applications:**

1- Control treatment. (untreated).

2- Fulvic acid (10 kg/fed).

3- Biochar (5 $m^3$/fed).

4- Fulvic acid (10 kg/fed) + Biochar (5 m3/fed).

The treatments of N, P and K were received in the form of ammonium sulfate (20.6 % N), triple superphosphate (37 % P2O5) and potassium sulphate (48-52 % K2O), respectively. 30% of mentioned doses (nitrogen and potassium and all P2O5) were applied during preparing the soil before planting and 70% of NK were applied in three equal doses after 30, 45 and 60 days from planting.

Fulvic acid and biochar were added as soil application in the center of rows and covered by soil pre-planting. The other cultural practices for potato commercial production were used according to the instruction laid down by the Ministry of Agriculture, Egypt. The harvesting was done 110 days after planting in both seasons.

**Data recorded**

**1.Growth parameters:**

At 70 days after planting, in both seasons of study, a random sample of five plants was taken from every plot for measuring the growth characters of potato plants expressed as follows: Plant length (cm), number of leaves/plant, leaf area/plant , fresh and dry weight shoots/plant (gm).

**2. Chemical constituents and its uptake:**

At 70 days after planting in both seasons, the dry matter of foliage were finely ground and wet digested for N, P and K determination. Total Nitrogen, phosphorus and potassium were determined according to the methods described by Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970), respectively. N,P and K uptake were calculated .

**Yield and its components**:

At harvest (110 days after planting) tubers from each plot were calculated, weighed, counted and the following data were recorded: average tuber weight (gm), tuber yield per plant (gm), total yield (ton/fed.) and relative yield (%).

**Tuber Quality:**

Percentage of total soluble solids (TSS%) was determined by a hand refractometer, Starch% of tuber were determined according to A.O.A.C. (2000), dry matter % determined as one hundred grams of the grated mixture were dried at 105 $^0$C till constant weight and DM% was recorded, ascorbic acid (mg/100g f.w.) was determined in juice using 2, 6 dicholorophenol indophenol dye according to A.O.A.C (2000) and nitrate content determined according to the methods described by Cafado *et al.* (1975).

**Statistical Analysis:**

Recorded data were subjected to the statistical analysis of variance according to Snedecor and Cochran (1980), and means were compared using LSD at 5 % level.

## RESULTS AND DISCUSSION

**1- Plant growth parameters:**

**1-Effect of NPK-levels:**

The data presented in Table (1) show that NPK-levels had a significant effect on vegetative growth in the two summer seasons, except number of leaves/plant in the first season. Stem length, number of leaves/plant and leaf area/plant significantly increased with increasing NPK levels up to 100% of the recommended rate (RR) with no significant differences with 75 % NPK level concerning stem length in the first season, number of leaves/plant in the second season and foliage dry weight/plant in both seasons.

**Table 1. Effect of NPK levels, biochar and fulvic acid applications and their interactions on plant growth at 90 days after planting of potato plants during 2018 and 2019 summer planting seasons.**

| Characters Treatments | | Stem length(cm) | | Number of leaves/plant | | Leaf area ($m^2$) | | Foliage dry weight (gm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| NPK levels | | | | | | | | | |
| 100% NPK | | 66.41 | 72.33 | 23.91 | 27.16 | 0.328 | 0.346 | 31.08 | 30.67 |
| 75% NPK | | 65.50 | 70.33 | 24.58 | 25.83 | 0.323 | 0.344 | 30.41 | 30.17 |
| 50% NPK | | 63.16 | 67.83 | 23.33 | 22.91 | 0.306 | 0.309 | 21.83 | 25.08 |
| LSD at 5% | | 2.34 | 1.42 | NS | 1.54 | 0.006 | 0.016 | 1.29 | 1.68 |
| Fulvic & biochar app. | | | | | | | | | |
| Control | | 61.77 | 64.00 | 20.22 | 20.44 | 0.254 | 0.270 | 22.50 | 22.67 |
| Biochar | | 66.88 | 71.44 | 26.00 | 26.11 | 0.341 | 0.368 | 33.50 | 32.17 |
| Fulvic acid | | 62.44 | 68.11 | 22.00 | 25.33 | 0.300 | 0.343 | 31.67 | 30.50 |
| Fulvic +Biochar | | 69.00 | 77.11 | 27.55 | 29.33 | 0.382 | 0.398 | 35.33 | 36.33 |
| LSD at 5% | | 2.17 | 2.07 | 1.06 | 1.18 | 0.014 | 0.012 | 1.33 | 1.18 |
| Interactions: | | | | | | | | | |
| NPK | Fulvic & biochar | | | | | | | | |
| 100% NPK | Control | 63.33 | 66.66 | 20.33 | 22.33 | 0.253 | 0.296 | 26.33 | 26.00 |
| | Biochar | 70.00 | 72.00 | 26.33 | 28.66 | 0.360 | 0.360 | 33.33 | 30.33 |
| | Fulvic acid | 63.00 | 69.33 | 21.33 | 28.00 | 0.313 | 0.336 | 30.33 | 30.0 |
| | Fulvic + Biochar | 69.33 | 81.33 | 27.66 | 29.66 | 0.386 | 0.390 | 34.33 | 36.33 |
| 75% NPK | Control | 60.66 | 63.66 | 20.00 | 20.00 | 0.246 | 0.243 | 18.66 | 19.33 |
| | Biochar | 68.33 | 71.66 | 26.66 | 26.66 | 0.346 | 0.376 | 33.66 | 34.00 |
| | Fulvic acid | 62.66 | 70.00 | 22.66 | 25.33 | 0.306 | 0.35 | 33.00 | 31.00 |
| | Fulvic + Biochar | 70.33 | 76.00 | 29.00 | 31.33 | 0.393 | 0.406 | 36.33 | 36.33 |
| 50% NPK | Control | 61.33 | 61.66 | 20.33 | 19.00 | 0.263 | 0.23 | 15.00 | 16.33 |
| | Biochar | 62.33 | 70.66 | 25.00 | 23.00 | 0.316 | 0.316 | 21.33 | 25.66 |
| | Fulvic acid | 61.66 | 65.00 | 22.00 | 22.66 | 0.280 | 0.313 | 21.66 | 27.66 |
| | Fulvic + Biochar | 67.33 | 74.00 | 26.00 | 27.00 | 0.366 | 0.376 | 29.33 | 30.66 |
| L.S.D. at 5% | | 3.76 | 3.59 | 1.83 | 2.04 | 0.024 | 0.022 | 2.31 | 2.05 |

The increase in plant growth might be attributed to the favorable effects of nitrogen on stimulating the meristematic activity for producing more tissues and organ, since nitrogen plays an important role in protein and nucleic acids synthesis as well as protoplasm formation (Marschner, 1995), Also, the great role of phosphorus element which is extremely important as a structural part of many organic compounds in plants, in addition, it has an important role in energy metabolism as the high energy released from hydrolysis of pyrophosphate and various organic phosphate bonds is used to induce chemical reactions of plant growth (Gardener *et al*., 1985). Moreover, Potassium component is very essential in plant enzyme activity general metabolism, it has been discovered to serve a crucial function in photosynthesis by directly growing growth and leaf region. Potassium also has a positive impact on water use (Gardener *et al*., 1995). These results are harmony with those reported with Singh and Raghar (2000) and Bărăscu *et al*. (2015).

**2- Effect of fulvic acid and biochar applications:**

Application of fulvic acid, biochar singly or in combination had a significant effect on all plant growth parameters compared with untreated plants in both seasons (Table 1). The highest values of stem length, number of leaves/plant, leaf area/plant and foliage dry weight were recorded at application of fulvic acid + biochar, followed by treated with biochar alone in both seasons. The increases in total dry weight were about (57.0 and 60.3%) for the fulvic acid + biochar treatment and (48.9 and 41.9) for biochar treatment over untreated plants in the 1st and 2nd seasons, respectively.

These results may be related to the positive effect of fulvic acid on plant length and leaf area, explained its least molecular weight and it has necessary and capacity to readily bond minerals and elements into its molecular structure causing them resolve and be mobilized fulvic complexes. Fulvic acid usually loads carries 70 or more mineral and effect elements as bit of its molecular complexes (Aiken and McKnight 1985). However, biochar induced stimulation of plant growth and this can be ascribed to a change in microbial communities to positive plant growth supporting rhizobacteria or fungi as a consequence of either the biochar's chemical or physical characteristics (Elad*et al*., 2011). Also, biochar enhanced the dry weight of plants and this can be ascribed to the immediate impacts of the nutrients provided by biochar (Silber *et al*., 2010).

These results are agree with Graber *et al*., (2010) on tomato, Carter *et al*., (2013) on lettuce and cabbage and Nair (2015) on potato. They found that treated plants with biochar increased plant growth than untreated ones. Also, similar results reported by Abou El Hassan and Husein (2016) on tomato and El-Hassanin *et al*. (2016) on sugar beat for fulvic acid.

**3- Effect of interaction between NPK-levels and applications of fulvic acid and biochar:**

The data in Table (1) show the effect of the interaction between NPK-levels and applications of fulvic acid and biochar on growth of potato plants. It is clear from data, the combined treatments are more superior effect than single ones, this is true for both seasons. Plants received 75% from NPK recommended rate with Fulvic acid +

biochar gave the maximum number of leaves/plant, leaf area and foliage dry weight for both seasons and the highest stem length in the first season only compared with the other treatments.

**2- Chemical constituents and its uptake:**

**1- Effect of NPK-levels:**

The current data in Table (2) show that fertilizing potato plants with different NPK levels had a significant effect on N,P and K contents in foliage and its uptake in both seasons. The maximum values of N, P and K contents and N,P and K uptake were obtained with the plants received 100% NPK level followed by 75% NPK level with no significant differences between these treatments on N and K contents and uptake in both seasons. While, the P content and uptake were increased significantly with increasing NPK level.These results coincided with those found by Elsharkawy (2013).

**2- Effect of fulvic acid and biochar applications:**

It is clear from the data in Table (2) that application offulvic acid or biochar exerted a marked significant effect on N, P and K contents and its uptake than untreated plants in both seasons. However,application the mixture of fulvic acid + biochar recorded the maximum N, P and K contents and its uptake, followed by biochar treatment in both seasons. These results may be related to the fulvic acid is key ingredients of high quality foliar spray fertilizers. As its can help the penetration to the plant parts, stimulate the uptake of elements from plant surfaces into plant tissues (Chen *et al*., 2004). Also may be related to the beneficial impacts of biochar on plant chemical constituents that biochar can lead to modifications in soil's physical and chemical properties resulting in an rise in soil nutrient accessibility and enhanced plant root colonization and then enhanced nutrient content and plant uptake (Yamato *et al*., 2006).

The present findings are in agreement with those of Yildirim and Unay (2011) who indicated that foliar application of fulvic acid enhances the nutritional status of tomato plants. Also, Ameri and Tehranifar (2012) investigated that spraying of humic acid on strawberry plants enhanced N, P and K uptake. Besides, these results are in accordance with those reported by Youseef *et al.,* (2017) at treated with biochar.

**Table 2. Effect of NPK levels,biochar and fulvic acid applications and their interactions on N,P and K contents in plant voliage and its uptake at 90 days after planting during 2018 and 2019 summer planting seasons**

| Characters Treatments | | Mineral contents% | | | | | | Mineral uptake (mg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | | P | | K | | N | | P | | K | |
| | | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| NPK levels | | | | | | | | | | | | | |
| 100% NPK | | 3.58 | 3.50 | 0.369 | 0.358 | 3.44 | 3.54 | 1114.81 | 1076.31 | 115.02 | 110.14 | 1075.36 | 1096.36 |
| 75% NPK | | 3.47 | 3.43 | 0.317 | 0.345 | 3.42 | 3.42 | 1070.10 | 1056.84 | 98.83 | 106.71 | 1068.49 | 1057.23 |
| 50% NPK | | 2.83 | 2.73 | 0.257 | 0.306 | 3.27 | 3.27 | 623.43 | 690.24 | 57.37 | 78.74 | 736.04 | 846.26 |
| LSD at 5% | | 0.24 | 0.16 | 0.013 | 0.009 | 0.08 | 0.13 | 52.7 | 38.9 | 2.29 | 3.27 | 65.44 | 47.11 |
| Fulvic&biochar app. | | | | | | | | | | | | | |
| Control | | 3.29 | 3.09 | 0.307 | 0.310 | 2.95 | 2.94 | 746.61 | 708.69 | 70.62 | 71.27 | 672.42 | 0670.39 |
| Biochar | | 3.64 | 3.65 | 0.346 | 0.351 | 3.69 | 3.69 | 1217.50 | 1173.06 | 115.84 | 112.81 | 1234.38 | 1186.34 |
| Fulvic acid | | 3.42 | 3.41 | 0.338 | 0.365 | 3.19 | 3.36 | 1080.23 | 1040.35 | 106.69 | 111.22 | 1009.40 | 1024.50 |
| Fulvic +Biochar | | 3.75 | 3.70 | 0.381 | 0.381 | 3.88 | 3.93 | 1325.48 | 1344.21 | 134.56 | 138.42 | 1371.50 | 1425.95 |
| LSD at 5% | | 0.21 | 0.14 | 0.11 | 0.008 | 0.07 | 0.12 | 28.5 | 34.02 | 2.00 | 2.85 | 57.18 | 41.17 |
| Interactions: | | | | | | | | | | | | | |
| NPK | Fulvic&biochar | | | | | | | | | | | | |
| 100% NPK | Control | 3.46 | 3.34 | 0.35 | 0.343 | 3.18 | 3.09 | 911.02 | 868.40 | 92.16 | 089.18 | 837.29 | 0803.40 |
| | Biochar | 3.66 | 3.61 | 0.376 | 0.356 | 3.63 | 3.72 | 1219.88 | 1094.91 | 125.32 | 107.97 | 1209.88 | 1128.28 |
| | Fulvic acid | 3.5 | 3.35 | 0.363 | 0.356 | 3.12 | 3.42 | 1061.55 | 1005.00 | 110.10 | 106.80 | 946.30 | 1026.00 |
| | Fulvic +Biochar | 3.69 | 3.68 | 0.386 | 0.376 | 3.81 | 3.93 | 1266.78 | 1336.94 | 132.51 | 136.60 | 1307.97 | 1427.77 |
| 75% NPK | Control | 3.12 | 2.84 | 0.263 | 0.276 | 2.72 | 2.78 | 582.19 | 548.97 | 49.08 | 053.35 | 507.55 | 0537.37 |
| | Biochar | 3.61 | 3.68 | 0.316 | 0.346 | 3.74 | 3.66 | 1215.13 | 1251.20 | 106.37 | 117.64 | 1258.88 | 1244.40 |
| | Fulvic acid | 3.33 | 3.47 | 0.313 | 0.373 | 3.25 | 3.3 | 1098.90 | 1075.70 | 103.29 | 115.63 | 1072.50 | 1023.00 |
| | Fulvic +Biochar | 3.81 | 3.72 | 0.376 | 0.386 | 3.95 | 3.92 | 1384.17 | 1351.48 | 136.60 | 140.23 | 1435.04 | 1424.14 |
| 50% NPK | Control | 2.68 | 2.51 | 0.243 | 0.256 | 2.54 | 2.41 | 402.00 | 409.88 | 36.45 | 041.80 | 381.00 | 0393.55 |
| | Biochar | 2.82 | 2.86 | 0.21 | 0.283 | 3.65 | 3.65 | 601.51 | 733.88 | 44.79 | 072.62 | 778.55 | 0936.59 |
| | Fulvic acid | 2.75 | 2.61 | 0.27 | 0.326 | 3.08 | 3.35 | 595.65 | 721.93 | 58.48 | 090.17 | 667.13 | 0926.61 |
| | Fulvic +Biochar | 3.05 | 2.92 | 0.306 | 0.36 | 3.81 | 3.68 | 894.57 | 895.27 | 89.75 | 110.38 | 1117.47 | 1128.29 |
| L.S.D. at 5% | | 0.37 | 0.25 | 0.019 | 0.014 | 0.12 | 0.20 | 49.50 | 58.92 | 3.46 | 4.95 | 99.03 | 0071.30 |

**3-Effect of interaction between NPK-levels and fulvic acid and biochar applications:**

It is evident from data presented in Table (2) that the interaction between NPK-levels and fulvic acid and biochar applications had a significant effect on N, P and K contents and its uptake in both seasons. The interaction between fertilizing potato plants with NPK at 75 % RR and treated with fulvic acid + biochar gave the highest values of N,P and K contents in foliage and its uptake in both seasons, without significant differences with 100 % NPK with the same treatment (fulvic acid + biochar) concerning N and P contents in both seasons, K content and N, P and K uptake in the second season.

**3- Yield and its Components:**

**1- Effect of NPK-levels:**

Data presented in Table (3) show that, average tuber weight, yield/plant and total yield/fed significantly affected by NPK-levels in both seasons. Average tuber weight, yield/plant and total yield/fed were increased with increasing NPK level up to 100% RR in both seasons.These increases in total yield and its components may be due to the increases in plant growth characteristics, i.e, plant stem length, number of leaves, leaf area and foliage dry weight (Table 1) which increase photosynthesis rate and this in turn increased the total yield and its components. The obtained results are in harmony with those reported by (Kumar *et al*., 2001; Nizamuddin, *et al.* 2003;Eleiwa, 2012 and Shubha *et al*., 2018).

**2- Effect of fulvic acid and biochar applications:**

It was evident from the data in Table (3) that treated potato plants with fulvic acid and biochar singly or in the mixture had a significant effects on total yield and its components compared with untreated plants in both seasons. Application of fulvic acid + biochar treatment recorded the maximum increment of average tuber weight, yield/plant and total yield, followed biochar treatment in both seasons.

**Table 3. Effect of NPK levels, biochar and fulvic acid applications and their interactions on yield and its components of potato plants during summer plantation of 2018 and 2019 summer planting seasons.**

| Characters Treatments | | Average tuber weight (g) S1 | Average tuber weight (g) S2 | Yield / plant ( g) S1 | Yield / plant ( g) S2 | Total yield ( ton/fed.) S1 | Total yield ( ton/fed.) S2 |
|---|---|---|---|---|---|---|---|
| NPK levels | | | | | | | |
| 100% NPK | | 116.19 | 110.92 | 470.99 | 447.81 | 13.003 | 13.617 |
| 75% NPK | | 113.58 | 110.97 | 463.05 | 445.36 | 12.758 | 13.352 |
| 50% NPK | | 87.03 | 90.77 | 349.90 | 362.08 | 10.281 | 9.894 |
| LSD at 5% | | 2.94 | 1.96 | 9.81 | 6.54 | 0.289 | 0.327 |
| Fulvic&biochar app. | | | | | | | |
| Control | | 89.02 | 88.37 | 371.19 | 354.82 | 11.030 | 11.821 |
| Biochar | | 109.75 | 106.37 | 435.99 | 424.82 | 13.107 | 13.770 |
| Fulvic acid | | 102.78 | 104.82 | 418.79 | 423.93 | 12.976 | 13.520 |
| Fulvic +Biochar | | 120.84 | 117.31 | 485.94 | 470.08 | 14.410 | 14.827 |
| LSD at 5% | | 2.57 | 1.71 | 8.57 | 5.71 | 0.200 | 0.171 |
| Interactions: | | | | | | | |
| NPK | Fulvic&biochar | | | | | | |
| 100% NPK | Control | 107.76 | 97.97 | 435.02 | 395.89 | 11.252 | 12.365 |
| | Biochar | 116.21 | 111.15 | 468.84 | 440.61 | 12.971 | 13.342 |
| | Fulvic acid | 111.03 | 109.56 | 459.11 | 456.25 | 13.398 | 13.817 |
| | Fulvic+Biochar | 129.75 | 125 | 520.98 | 498.49 | 14.389 | 14.942 |
| 75% NPK | Control | 82.19 | 86.69 | 376.74 | 362.74 | 10.808 | 11.277 |
| | Biochar | 123.44 | 115.87 | 472.75 | 457.47 | 13.242 | 14.198 |
| | Fulvic acid | 114.23 | 113.75 | 464.91 | 450.98 | 12.553 | 13.222 |
| | Fulvic+Biochar | 134.45 | 127.56 | 537.79 | 510.25 | 14.43 | 14.712 |
| 50% NPK | Control | 77.1 | 80.46 | 301.82 | 305.84 | 9.086 | 8.687 |
| | Biochar | 89.6 | 92.1 | 366.39 | 376.39 | 10.327 | 10.142 |
| | Fulvic acid | 83.09 | 91.14 | 332.35 | 364.56 | 10.39 | 9.472 |
| | Fulvic+Biochar | 98.32 | 99.38 | 399.05 | 401.51 | 11.32 | 11.273 |
| L.S.D. at 5% | | 4.45 | 2.97 | 14.85 | 9.90 | 0.346 | 0.297 |

The relative increases in total yield due to treated potato plants with the fulvic acid + biochar treatment were about (30.6 and 25.4%) followed by (18.8 and 16.5%) at plants treated by biochar and (17.6 and 14.4 %) at treated by fulvic acid over untreated plants in the first and second seasons, respectively.

The increase in total yield might be due to the favorable effect of fulvic acid+ biochar on vegetative growth (Table 1). In this respect, Fulvic acid is particularly preferred in that it allows surrounding stress to decrease, helps absorb other minerals and positively contributes to yield and its components (Bethke *et al*., 1987). Furthermore,Lehmann *et al.* (2006) found that Biochar addition may enhance the productivity of plants directly due to their nutrient content and release features or indirectly due to enhanced nutrient retention. Beside, Nair *et al.* (2014) stated that increases in potato crop yields cv. Atlantic was ascribed to improved water holding capacity, enhanced cation exchange capacity, enhanced nutrient retention, and biochar's ability to decrease bulk density.

These results are in harmony with those reported by Suh *et al.* (2014 b), Nair (2015) on potato, Vaccari*et al.* (2015) on tomato, Abou El Hassan and Husein (2016) on tomato and El-Hassanin *et al.* (2016) on sugar beet, Silva *et al.* (2017) on common bean and Youseef *et al.* (2017) on potato.

**3- Effect of interaction between NPK-levels and fulvic acid and biochar applications:**

It is clear from the data in Table (3) that the interaction between NPK-levels withfulvic acid and biochar applications had a significant effect on total yield and its components. It is notable that plants fertilized with 75% from NPK recommended rate in the presence of fulvic acid + biochar achieved abundant yield which was superior that produced by using 100% NPK recommended rate alone. These results may be due to beneficial effect of both NPK and this application of fulvic acid + biochar on plant growth. This interaction increased total yield/fed were about 28.2 and 19.0 % in the first and the second season, respectively.

**4-Tuber quality:**

**1- Effect of NPK-levels:**

Data in Table (4) show that all tuber quality parameters were significantly affected by different NPK-levels, except TSS in both seasons and ascorbic acid in the first season. Tuber quality parameters were increased with increasing NPK level up to 100% from recommended rate,there were no significant differences showed at used 100% or 75% NPK level on the studies parameters in both seasons. These results agreed with Cucci and Lacolla (2007), Bošković*et al.* (2018) and Adhikari (2009).

**2- Effect of fulvic acid and biocharapplications:**

Application of fulvic acid, biochar as a single or in the mixture had a significant effect on all traits of tuber quality compared with untreated ones (Table 4).

Application of fulvic acid + biochar as a mixture treatment increased DM%, TSS%, ascorbic acid and starch contents, in the same time this treatment was decreased nitrate contents in tuber in both seasons. On the other hand, biochar treatment came in the second rank in this concerning in both seasons also. The decrease in nitrate content in tuber were about 35.29 and 32.39 % for application of fulvic acid + biochar, also, it decreased by 19.79 and 28.40 % with application of biochar in the first and the second seasons, respectively.

These results are in harmony with those of Yildirim and Unay (2011) and Abou El- Hassan and Husein (2016) they found that foliar application of fulvic acid enhance fruit quality of tomato on tomato.

**3- Effect of interaction between NPK-levels and fulvic acid and biochar applications:**

Data in Table (4) show that the interaction between NPK-levels and fulvic acid and biochar applications had a significant effect on all tuber quality, except TSS in both seasons. DM %, ascorbic acid content and Starch content % in tuber significantly increased with the interaction between 75 % NPK level with fulvic acid + biochar treatment. On the other hand, this interaction treatment wasrecord the lowest nitrate content compared with 100% NPK alone in both seasons.

The decrease in nitrate content in tuber was about 44.02 and 44.85 % for the interaction between 75 % NPK level with application of fulvic acid + biochar treatment less than fertilized by 100% NPK level alone in the first and the second seasons, respectively.

**Table 4. Effect of NPK levels, biochar and fulvic acid applications and their interactions on tuber quality after harvesting time of potato plants during 2018 and 2019 summer planting seasons.**

| Characters Treatments | | DM (%) | | TSS% (brix) | | Ascorbic acid mg/100 g FW | | Starch contents (%) | | Nitrate contents (mg/kgF.W.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| NPK levels | | | | | | | | | | | |
| 100% NPK | | 13.64 | 13.67 | 5.20 | 5.16 | 21.08 | 21.42 | 21.08 | 21.16 | 343.58 | 317.92 |
| 75% NPK | | 13.45 | 13.53 | 5.25 | 5.41 | 21.00 | 21.25 | 20.92 | 20.76 | 259.17 | 281.17 |
| 50% NPK | | 13.16 | 13.37 | 5.12 | 5.25 | 20.25 | 20.91 | 19.50 | 20.08 | 249.33 | 252.83 |
| LSD at 5% | | 0.17 | 0.12 | NS | NS | 0.45 | 0.32 | NS | 0.49 | 3.52 | 1.71 |
| Fulvic&biochar app. | | | | | | | | | | | |
| Control | | 12.15 | 12.35 | 4.88 | 5.00 | 18.66 | 18.83 | 18.50 | 18.67 | 340.78 | 354.33 |
| Biochar | | 13.88 | 13.80 | 5.33 | 5.33 | 21.83 | 22.33 | 21.67 | 21.67 | 273.33 | 253.67 |
| Fulvic acid | | 13.01 | 13.54 | 5.11 | 5.11 | 21.00 | 21.00 | 21.17 | 20.66 | 301.33 | 288.33 |
| Fulvic +Biochar | | 15.14 | 14.71 | 5.44 | 5.66 | 22.67 | 23.17 | 22.67 | 22.86 | 220.67 | 239.56 |
| LSD at 5% | | 0.40 | 0.44 | 0.42 | 0.38 | 0.50 | 0.72 | 0.80 | 0.49 | 4.02 | 3.90 |
| Interactions: | | | | | | | | | | | |
| NPK | Fulvic&biochar | | | | | | | | | | |
| | Control | 12.35 | 12.86 | 4.83 | 5.00 | 18.66 | 19.66 | 19.00 | 19.00 | 377.33 | 360.67 |
| 100% | Biochar | 13.95 | 13.78 | 5.33 | 5.33 | 22.33 | 22.00 | 21.33 | 21.33 | 341.67 | 289.33 |
| NPK | Fulvic acid | 13.33 | 13.54 | 5.33 | 5.00 | 21.00 | 21.00 | 21.00 | 20.66 | 355.33 | 320.00 |
| | Fulvic + Biochar | 14.93 | 14.50 | 5.33 | 5.33 | 22.33 | 23.00 | 23.00 | 23.66 | 300.00 | 301.67 |
| | Control | 11.94 | 11.83 | 5.00 | 5.00 | 18.66 | 18.00 | 18.0 | 18.33 | 324.33 | 329.33 |
| 75% | Biochar | 13.81 | 13.82 | 5.33 | 5.33 | 21.33 | 22.66 | 22.00 | 22.00 | 244.00 | 232.00 |
| NPK | Fulvic acid | 12.69 | 13.54 | 5.00 | 5.33 | 21.00 | 21.00 | 21.33 | 20.66 | 276.00 | 274.67 |
| | Fulvic + Biochar | 15.34 | 14.91 | 5.66 | 6.00 | 23.00 | 23.33 | 22.33 | 22.06 | 192.33 | 175.33 |
| | Control | 11.56 | 11.70 | 4.83 | 5.00 | 19.00 | 19.66 | 17.33 | 18.66 | 320.67 | 373.00 |
| 50% | Biochar | 13.68 | 13.62 | 5.33 | 5.33 | 20.66 | 21.00 | 20.33 | 21.00 | 234.33 | 239.67 |
| NPK | Fulvic acid | 12.86 | 13.45 | 5.00 | 5.00 | 19.66 | 20.66 | 18.66 | 19.33 | 272.67 | 270.33 |
| | Fulvic + Biochar | 14.55 | 14.69 | 5.33 | 5.66 | 21.66 | 22.33 | 21.66 | 21.33 | 169.67 | 241.67 |
| L.S.D. at 5% | | 0.64 | 0.77 | NS | NS | 0.87 | 1.25 | 1.40 | 0.85 | 6.96 | 6.75 |

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## استجابه النمو، المحصول وجودة نبات البطاطس للمعامله بحمض الفولفيك والبيوشار تحت مستويات مختلفه من التسميد الكيماوى

**حمادة ماهر بدير المتولى**

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أجريت تجربتان حقليتان خلال موسمى صيف ٢٠١٨ و ٢٠١٩ بمزرعة خضر خاصة - بقرية كفر ميت فارس - محافظة الدقهلية ، وذلك لدراسة تأثير مستويات مختلفة من التسميد الكيماوى (١٠٠%، ٧٥% و ٥٠% من الموصى به من النتيروجين والفوسفور والبوتاسيوم) وبعض محسنات التربه ( بدون ، حمض الفولفيك بمعدل ١٠ كجم/فدان، البيوشار بمعدل ٥ م٣/فدان و حمض الفولفيك بمعدل ١٠ كجم/فدان + البيوشار بمعدل ٥ م٣/فدان) على النمو، المحصول وجوده الدرنات للبطاطس. بصفة عامة أوضحت النتائج أن تسميد نباتات البطاطس عند مستوى ١٠٠% من الموصى به من النتيروجين والفوسفو ر والبوتاسيوم أدى إلى زياده معنويه فى طول النبات، عدد الأوراق/النبات، المساحه الورقيه /النبات، الوزن الجاف لعرش النبات، محتوى العرش من النيتروجين والفوسفور والبوتاسيوم والممتص، أعلى متوسط لوزن الدرنه ، محصول النبات ومحصول الفدان. بينما كانت الزيادة فى نسبة المواد الصلبة الكلية و محتوى الدرنه من حمض الأسكوربيك ومن النشا، وأقل محتوى من النترات كانت بالتسميد بمستوى ٧٥% من الموصى به من النتيروجين والفوسفور والبوتاسيوم فى كلا الموسمين.أما بالنسبة لإضافة بعض المواد العضوية كمحسنات للتربة (حمض الفولفيك و البيوشار) فقد أدت لزيادة فى معظم الصفات الخضرية المدروسة مقارنة مع معاملة الكنترول، وكانت أفضل النتائج بإضافة حمض الفولفيك والبيوشار مجتمعين.وبخصوص التفاعل بين مستويات التسميد الكيماوى مع إضافة محسنات التربة، فكانت أكثر تأثيراً على معظم الصفات المدروسة مقارنة مع التسميد الكيماوى منفرداً، وكانت أفضل النتائج باستخدام التسميد الكيماوى عند معدل ٧٥% من الموصى به مع إضافة حمض الفولفيك والبيوشار مجتمعين، حيث سجل هذا التفاعل زيادة فى فى صفات النمو الخضرى المدروسة ومحتوى العرش من النتروجين والفوسفور والبوتاسيوم وكذا معدل إمتصاص هذه العناصر، كما أدت لزيادة المحصول ومكوناته وتحسين صفات جودته. هذا التفاعل أدى إلى زيادة فى المحصول تصل إلى ٢٨,٢% و ٢٣,٨% فى الموسم الأول والثانى على التوالى.ولذلك يمكن التوصية باستخدام هذه المعاملة لزيادة محصول البطاطس وتحسين صفات جودته تحت الظروف المشابهة لظروف هذه الدراسة.