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Original Research Article



The combined effect of potassium humate and bio-fertilizers on maize productivity and quality under water stress conditions

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Abstract

Water stress is one of the most devastating environmental stresses worldwide. Improving Maize to withstand drought stress is one of the most significant obstacles with the increasing global need for food, fiber, and fuel. Field experiments were carried out in National Research Centre, Nubaria, Egypt; during the two successive growing seasons of 2018 and 2019 to study the interaction effects of potassium humate and biofertilizers (*nitrobeine*) on growth, yield characters, and chemical composition of Maize plant under water stress. The results obtained can be summarized as follows: The highest values of all growth and yield characteristics of Maize were recorded in the first and second seasons when treating potassium humate (3 g L^{-1}) with biofertilizers as compared to all treatments under sufficient irrigation system. Also, it increased the nutrient content (N, P, and K) of grain of Maize as compared with control. Whereas, the water stress treatment reduced the macronutrient of maize grain as compared to the addition of sufficient irrigation treatment. Likewise, data showed that the application of potassium humate foliar spraying with biofertilizers under water stress enhanced the carbohydrate and protein content in the Maize plant. Results concluded that the application of potassium humate foliar spraying and biofertilizer is important to improve maize production and nutrient content under water stress conditions.

Keywords: Water stress, Maize, biofertilizers, potassium humate, yield,

Introduction

Maize is considered one of the three most important types of cereal crops after wheat and rice is grown in various places in a wide range of climates. A major move in global cereal demand is underway by 2020, demand for maize in improving countries is prospective to surpass request for both wheat and rice (Pingali and Pandey 2001). Maize is anticipated for its manifold purposes as animal feed, industrial manufacturing, and medicinal and human food. It is the staple food of the majority of people and is expended in many other republics, for pattern, corn flakes, corn syrup, and oil. For animal feed, it is highly desirable due to its high yield and forage value of grains, leaves, and stem, and is gaining importance in many countries (Suhana Puri *et al.*, 2019).

Water stress is the most abiotic environmental stress that has a detrimental effect on the productivity of large areas of agricultural land around the world. Increasing population and changing climate conditions are likely to increase water scarcity, which will lead to further decline in crop productivity

in the world. The crop, for example, maize crop is uncovered to a certain level of drought either during a particular period or during the whole growing season, without significant concession in yields (Sepaskhah and Ghahraman, 2004). Improving Maize for drought-stress tolerance is one of the most imperative obstacles as the global need for food, fiber, and fuel increases (Roth *et al.*, 2013). Several studies had been carried out to explore the effect of irrigation interval on maize growth, yield attributes, and its components. Mohsen *et al.*, (2012) detected that 100- kernel weight, grain weight/ear and grain yield decreased due to extreme drought. Maize (*Zea mays* L.) only consumes 22.5% of total nitrogen, phosphorus, and potassium fertilizers used in Egypt (Heffer, 2013), representing the largest fertilizer-consuming crop. It has been shown that adding substances to the soil such as humus increases enzyme activity and membrane permeability, in addition to increasing rates of hormonal activity, which increases the ability of plants to retain water and absorb nutrients, which is positively reflected in crop productivity (Jones *et al.*, 2007; Sharif *et al.*, 2002) the use of humic

materials led to significant increases in stem and root weight of the maize plant.

Potassium plays an important role in reducing abiotic stress on plants such as coldness, drought, and high light intensity (Waraich *et al.*, 2011). Potassium humate derived from brown charcoal lignite is naturally aromatic and contains many carboxylic and phenolic groups, provides favorable conditions for chemical reactions, biological activity, increases buffering of pH, improves the physical structure of the soil, and accelerates the transfer of nutrients to plants. Also, potassium humate can be peeled to obtain further improvement in the physical properties of the soil and biological activities and accelerate the transfer of nutrients to plant (Amjad *et al.*, 2014). Bio-fertilizers have been identified as an alternative to increasing soil fertility and crop production in sustainable agriculture.

Beneficial microbes are considered one of the most important biological fertilizers that play an important role in increasing crop yields due to their importance in food safety (Iteima *et al.*, 2018; Arshad *et al.*, 2008) reported that *Pseudomonas* spp. inoculation enhanced the growth, yield, and ripening of pea (*Pisum sativum* L.) under drought stress conditions. Hence the study was performed to investigate the combined effect of potassium humate a foliar sparing with biofertilizers on growth, yield, and nutrient uptake in maize grown under drought conditions.

Material and Methods

Experimental Procedures

The field experiment was carried out at the Research and Production Station of the National Research Centre, Nubaria region (30 30.054' N - 30 19.421' E), Behiera Governorate, Egypt during the summer season of 2018 and 2019. Seeds of Maize (*Zea mays* L.; cv. Giza 306) were sown on 20th August in both seasons. The experimental design was a split-plot with four replications. The Water treatments as sufficient and stressed irrigation applied depends on the water requirement of maize occupied the main plots and potassium humate treatments (0, 1, 2, 3, and 4 %) were allocated at random in sub-plots with or without biofertilizers (nitrobeine). Bio-fertilizer as nitrobeine by mixing Maize seeds in nitrobeine for 15 minutes before transplanting, which is a commercial product that contains active microorganisms that were responsible for fixation of nitrogen by atmosphere. The plot area was 10.5 m² (3.5 m × 3.0 m). Calcium super-phosphate (15.50% P₂O₅) was added pre-sowing at 358 kg ha⁻¹ to the soil; similarly, nitrogen in the form of ammonium nitrate (33.0%N) at the rate of 42 kg N ha⁻¹ as starter dose was added before first irrigation, Potassium sulfate (48% K₂O) was added at the rate of 119 k g ha⁻¹ to the soil in two equal doses at 21 and 35 days after sowing. Some physical and chemical properties of a representative soil sample used in the experimental soil were determined before cultivation according to (Rebecca, 2004) and presented in (Table 1).

Maize plants were irrigated during the whole growth season using sprinkler irrigation system. In both seasons, a foliar spray of potassium humate and nitrobeine was applied twice to Maize plants at 45 and 60 days from sowing. The interaction of different concentrations of both compounds was also assessed in addition to untreated plants (control).

Table 1. Some physical and chemical properties of the experimental soil

| pH (1:2.5) | EC dSm ⁻¹ | OM % | CaCO ₃ % | Particle size distribution | | | Texture Class |
|--|----------------------|------------------|---------------------|-----------------------------------|-------------------------------|-----------------|------------------------------|
| | | | | Sand % | Silt % | Clay % | |
| 7.96 | 1.18 | 0.76 | 2.98 | 75.84 | 5.13 | 17.96 | Sandy loam |
| Cations (meq / L) | | | | Anions (meq / L) | | | |
| Na ⁺ | K ⁺ | Ca ⁺⁺ | Mg ⁺⁺ | CO ₃ ⁻ | HCO ₃ ⁻ | CL ⁻ | SO ₄ ⁻ |
| 3.82 | 1.77 | 3.78 | 1.88 | 0.38 | 3.62 | 1.91 | 5.34 |
| Available macronutrients (mg/100 g soil) | | | | Available micronutrients (mg /kg) | | | |
| N | P | K | | Fe | Zn | Mn | Cu |
| 14.63 | 3.84 | 16.92 | | 14.32 | 0.23 | 5.94 | 0.017 |

Analysis

Leaf pigment content

Leaf greenness present in barley plants was determined with the Minolta-SPAD® Chlorophyll Meter (Minolta Camera Co., Osaka, Japan). The SPAD-502 chlorophyll meter measures the chlorophyll absorbance in the red and near-infrared regions and calculates a numeric SPAD value which is proportional to the amount of chlorophyll in the leaf Minolta (1989).

Measurement of yield parameters

The growth parameters of Maize such as plant height, 100-seeds weight (g), Grain yield (ton/fed) were recorded according to FAO (1980).

Measurement of nutrient content

Macronutrients (N, P, and K) and micronutrients (Fe, Mn, Zn, and Cu) in Maize were determined according to Black *et al* (1982). Protein percentage was calculated by multiplying nitrogen content by 6.25.

Statically analysis

All data were statistically analyzed and the means were compared using the least significant difference test (LSD at 5% level) according to Gomez and Gomez (1984).

Results and discussion

Pigment content

Data in Fig.1 showed that the impact of potassium humate and biofertilizers (*nitrobeine*) on pigment content (chlorophyll) of maize under water stress. It was observed that all treatments increased chlorophyll compared with control. The results indicated that the addition of biofertilizers with potassium humate improved the chlorophyll of maize as compared to the addition of

potassium humate without biofertilizers. The results showed that the foliar addition of 3 g/L of potassium humate with or without biofertilizers increased the chlorophyll of maize as compared to the application of 1 g/L of potassium humate.

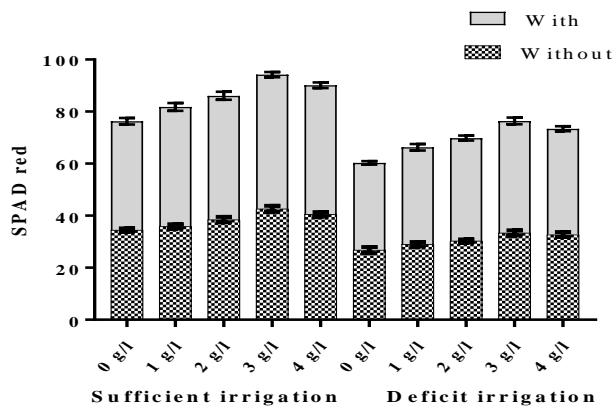


Fig. 1 Effect of potassium humate and biofertilizers on chlorophyll (SPAD) red of Maize under water stress

Whereas, the application of 4 g/L of potassium humate with biofertilizers gave the highest chlorophyll of maize as compared to all treatments. Development of plant roots occurs, which in turn increases the absorption rate of nutrients, due to the combined positive effect of potassium humate and bio-fertilizers. The use of bio-fertilizers enhances nutrient absorption, transfer, and synthesis resulting in increased plant growth characteristics and a profitable economic return (Singh *et al.*, 2006).

Yield parameters

Data in Table 2 showed that the effect of potassium humate and bio fertilizers (*nitrobeine*) on plant height, ear weight, and 100-grain weight of maize under water stress. Application of 4g/L of potassium humate with biofertilizers gave the highest plant height, ear weight, and 100 grain weight in maize as compared to all treatments. These microorganisms also produce plant growth-promoting vitamins and substances to improve plant growth. Application of 4 g/l potassium humate increased plant height and 100-grain weight by (15.1, 10.5%) and (25.8, 32.5%) whereas application of biofertilizer increased it by (15.2, 7.87%) and (7.51, 7.80%) compared to a control treatment under sufficient and deficit irrigation, respectively. Regardless of water application treatment, the addition of 4 g/l potassium humate increased plant height and 100-grain weight by 6.77 and 26.0% Compared to a control treatment. It was observed that the application biofertilizers gave the highest percentage of plant height (11.5%) and 100-grain weight (7.67%) as compared to no application of biofertilizer treatments. This result could be due to enhancement of the water retention of soil by biofertilizer and potassium humate

was a hydrophilic colloid with strong water absorption capacity. The weight of water absorbed from the saturated atmosphere can be more than doubled, which is much larger than that of an ordinary mineral colloid.

Potassium humate prevents crop transpiration, increases the soil water content, and slows down the rate of soil water consumption (Abou-Elseoud and Abdel-Megeed 2012).

Grain yield, biological yield

Data in Table 3 showed that the effect of the application of potassium humate foliar spraying biofertilizers on grain yield, biological yield, and harvest index. It was noticed that the application of potassium humate and biofertilizers increased the grain yield, biological yield, and harvest index as compared to 0 g/l potassium humate with or without biofertilizers. The foliar application of 3 and 4 g/l of potassium humate increased grain yield by (15.6, 13.3%) and (18.7, 22.3%) whereas application of biofertilizer increased grain yield by (8.78, 10.2%) compared with the control treatment under both two the irrigation levels, respectively.

Regardless of water application treatment, the addition of 3 and 4 g/l potassium humate increased grain yield by 14.7 and 16.9% compared to a control treatment. It was observed that the application biofertilizers gave the highest percentage of grain yield by (9.41%) compared with no application of biofertilizer treatments. Improving the nutrient utilization efficiency in the presence of bio-fertilizers and potassium humate may lead to an increase in the grain yield of maize. Several research studies have shown that potassium humate slowly releases nutrients and may reduce leaching losses, especially N (Nevens and Reheul, 2003 and Naveed *et al.*, 2008).

Macronutrient of maize grain

The effect of potassium humate foliar spraying and biofertilizers (*nitrobeine*) on macronutrient of Maize grain under water stress were show in Table 4. Foliar application of 3 g/L potassium humate with biofertilizers gave the highest N, P, and K of grain yield of maize.

The deficit irrigation reduced the macronutrient content of grain yield of maize as compared to the addition of sufficient irrigation. Data showed that the addition of 3 and 4 g/l potassium humate increased nitrogen and potassium of maize grains by (13.3, 15.5%), (12.0, 13.5%) and (11.2, 20.0%), (21.1, 29.4%) whereas application of biofertilizer increased it by (13.3, 11.7%) and (29.8, 15.7%) compared to a control treatment under sufficient and deficit irrigation, respectively. Muhammadn *et al.* (2013) showed that nutrients (N, P and K) contents were significantly increased by the application of humic acid and PSB inoculation.

Table 2. Effect of potassium humate and biofertilizers on vegetative growth of maize under water stress

| K Humate | Bio-fertilizers | Plant height (cm) | | Ear weight (g) | | 100 Seed wt. | |
|-------------|-----------------------|-------------------|---------|----------------|---------|--------------|---------|
| | | Irrigation levels | | | | | |
| | | Sufficient | Deficit | Sufficient | Deficit | Sufficient | Deficit |
| 0.0 g/L | without | 145.0 | 132.5 | 188.8 | 170.4 | 15.3 | 13.7 |
| | with | 152.8 | 147.3 | 193.4 | 190.2 | 15.7 | 14.6 |
| 1.0 g/L | without | 149.1 | 146.2 | 269.0 | 203.5 | 18.2 | 17.6 |
| | with | 155.6 | 154.6 | 306.6 | 303.7 | 19.5 | 18.3 |
| 2.0 g/L | without | 153.6 | 152.9 | 289.3 | 236.5 | 18.5 | 18.4 |
| | with | 189.1 | 156.4 | 133.8 | 130.3 | 20.5 | 19.1 |
| 3.0 g/L | without | 164.7 | 182.8 | 190.0 | 173.2 | 22.2 | 21.4 |
| | with | 201.3 | 195.1 | 196.2 | 190.4 | 24.4 | 23.6 |
| 4.0 g/L | without | 160.5 | 168.6 | 290.8 | 240.9 | 20.4 | 18.7 |
| | with | 191.8 | 191.2 | 278.9 | 215.8 | 21.6 | 21.2 |
| LSD 0.05 | Potassium (K) | 0.514 | 0.765 | 0.77 | 4.26 | 0.416 | 0.388 |
| | Bio-fertilizers (Bio) | 1.524 | 1.247 | 1.25 | 2.24 | 0.142 | 0.117 |
| | (K*Bio) | 1.882 | 1.858 | 1.86 | 5.74 | 0.516 | 0.466 |

Table 3. Effect of potassium humate and biofertilizers on grain yield of maize under water stress

| K Humate | Bio-fertilizers | Grain yield (ton/fed) | | Biological yield (ton/fed) | | Harvest index | |
|-------------|-----------------------|-----------------------|---------|----------------------------|---------|---------------|---------|
| | | Irrigation levels | | | | | |
| | | Sufficient | Deficit | Sufficient | Deficit | Sufficient | Deficit |
| 0.0 g/L | without | 2.31 | 1.69 | 5.82 | 4.56 | 39.7 | 37.0 |
| | with | 2.87 | 2.22 | 7.11 | 5.12 | 40.3 | 43.4 |
| 1.0 g/L | without | 2.74 | 2.23 | 6.66 | 5.95 | 41.0 | 37.5 |
| | with | 3.15 | 2.31 | 7.43 | 6.65 | 42.3 | 34.6 |
| 2.0 g/L | without | 2.84 | 2.33 | 7.28 | 6.38 | 38.9 | 36.5 |
| | with | 3.03 | 2.45 | 7.65 | 7.14 | 39.6 | 34.3 |
| 3.0 g/L | without | 3.33 | 2.51 | 9.11 | 7.72 | 36.5 | 32.5 |
| | with | 3.31 | 2.67 | 9.82 | 8.74 | 33.7 | 30.6 |
| 4.0 g/L | without | 3.58 | 2.68 | 8.49 | 7.01 | 42.1 | 38.2 |
| | with | 3.74 | 2.96 | 9.44 | 8.18 | 39.7 | 36.1 |
| LSD 0.05 | Potassium (K) | 0.036 | 0.070 | 0.251 | 0.151 | | |
| | Bio-fertilizers (Bio) | 0.038 | 0.048 | 0.129 | 0.087 | | |
| | (K*Bio) | 0.069 | 0.109 | 0.351 | 0.219 | | |

Regardless of water application treatment, the addition of 4 g/l potassium humate increased macronutrient content of maize grains by 12.6, 10.2, and 15.8% comparison with control treatment. It was observed that the application of biofertilizers gave the highest increased percentage of nitrogen and potassium of maize grains (12.5%) and (22.9%) compared with no application of biofertilizer treatments. This may be attributed to the ability of biofertilizers to conveyance major nutrients similar to N and P besides concealing plant growth-promoting substances for example IAA, gibberellins, and abscisic acid. An organic acid obtained from potassium humate has led to an increment in soil acidity, therefore change unsolvable forms of phosphorus into solvable ones (Wani *et al.*, 2007 and Abou-Elseoud and Abdel-Meggeed, 2012).

Macronutrient of Maize straw

Table 5 indicated that the potassium humate a foliar application and biofertilizers increased the macronutrient content of maize straw. Application of 4 g/L of potassium humate with biofertilizers under sufficient irrigation gave the highest straw yield of maize as compared to other treatments. This might be due to more availability of nutrients from potassium humate and beneficial effects accrued due to biofertilizer application which provide nitrogen and phosphorous to plant growth. Data showed that the addition of 4 g/l potassium humate increased nitrogen and potassium of maize grains by (89.1, 114.3%) and (74.2, 115.0%) whereas application of biofertilizer increased it by (17.2, 20.1%) and (25.6, 17.7%) compared with control treatment under sufficient and deficit irrigation, respectively. Patel and Singh (1998) observed that water stress reduced the uptake of nutrients in plants, and most of N and P were accumulated in

grains, while most of K was in stem and leaves. Regardless of water application treatment, the addition of 4 g/l potassium humate increased nitrogen and potassium of maize grains by 65.4 and 64.0% compared with the control treatment.

It was observed that the application biofertilizers gave the highest increased percentage of nitrogen and potassium of maize grains 18.6 and 21.9% comparison with no application of biofertilizer treatments. Beneficial microorganisms secrete some growth-promoting compounds such as indole acetic acid and gibberellic acid, in addition to the production of amino acids and vitamins that increase the absorption, transport, and composition of nutrients, which is positively reflected on plant growth and crop yield, which increases economic return (Singh *et al.*, 2006 and Suke *et al.*, 2001).

Micronutrient of maize grain

The impact of potassium humate foliar spraying and biofertilizers on Fe, Mn, and Zn of Maize grain under water stress were shown in Table 6. Data indicated that the application of biofertilizers increased the Fe, Mn, and Zn of grain yield of maize compared to without biofertilizers. It was noticed that the addition of 3 g/L potassium humate with biofertilizers gave the highest Fe, Mn, and Zn of grain yield of maize. The deficit irrigation reduced the Fe, Mn, and Zn of grain yield of maize as compared to the addition of sufficient irrigation.

Data also presented that the addition of 3 and 4 g/l potassium humate increased iron and zinc of maize grains by (5.93, 11.5%), (2.80, 4.09%) and (2.98, 3.94%), (4.55, 4.89%) whereas application of biofertilizer increased it by (16.6, 22.5%) and (27.7, 26.3%) compared with control treatment under sufficient and deficit irrigation, respectively.

Regardless of water application treatment, the addition of 4 g/l potassium humate increased iron and zinc of maize grains by 4.55 and 3.70% compared with the control treatment. It was observed that the application biofertilizers gave the highest increased percentage of iron, manganese, and zinc of maize grains by 19.1%, 3.21, and (27.1%) compared with no application of biofertilizer treatments. Similar results have been reported by Said-Al Ahl *et al.* (2009,b) on *Origanum vulgare* and Zaghoul *et al.* (2009) on *Thuja orientalis* who indicated that spraying the plants with potassium humate increment growth compared with control plants due to the direct effect of humic acid on solubilization and transport of nutrients. These results are consistent with those obtained by Norman *et al.* (2004) on marigolds and peppers and the number of fruits of strawberries, Bohme and Thi Lua (1997) described that humic acid had beneficial effects on nutrient uptake by plants, and was particularly important for the transport and availability of micronutrients due to the better-developed root systems.

Micronutrient of Maize straw

Table 7 indicated that the potassium humate a foliar application and biofertilizers increased the Fe, Mn, and Zn of straw of maize. The addition of 4 g/l of potassium humate with biofertilizers foliar application with sufficient irrigation increased the Fe and Zn of straw of maize by 11.3 and 3.45% as compared to 0 g/L of potassium humate. Whereas under deficit irrigation treatment were 1.94 and 4.04% It was observed that the addition of biofertilizers with sufficient irrigation increased Fe and Zn of straw of maize by 36.6 and 19.7% as compared to without biofertilizers. Whereas the amount of increase in Fe and Zn of straw under deficit irrigation was 12.9, and 27.8%.

Regardless of water application treatment, the application biofertilizers gave the highest increased percentage of iron and zinc of maize grains by 26.3% and 22.9% compared with no application of biofertilizer treatments. This might be due to more availability of nutrients from potassium humate and beneficial effects accrued due to biofertilizers which provide nitrogen and phosphorous to plant growth. The application of moisture improved the growth of various groups of beneficial microorganisms, increased the permeability of plant membranes, increased rates of root growth, rapid cell division and all plant organs for several herbaceous herbs and horticultural crops as well as the growth of some trees Russo and Berlyn (1990), Sanders *et al.* (1990) and Pioncelot (1993).

Carbohydrate and protein of Maize

Data in Fig. 2 and 3 indicated the effect of potassium humate and biofertilizers on the carbohydrate and protein of Maize under water stress. It was observed that potassium humate a foliar application with biofertilizers increased the carbohydrate and protein content in Maize as compared to the addition of potassium humate without biofertilizers. The increasing potassium humate application up to 3g/L gradually increased carbohydrate and protein in Maize. Whereas the application of water stress treatment reduced the carbohydrate and protein content in Maize. Results showed that the application of 3 g/L of potassium humate with biofertilizers under sufficient irrigation treatment gave the highest carbohydrate and protein content in the maize plant. This could be attributed to the combined application of biofertilizers and potassium humate which enhance the carbohydrate and protein content these results are in agreement with the work of (Shaharoonar *et al.*, 2006). Potassium humate contains carboxyl, phenolic hydroxyl, and other functional groups, has a strong complexation and surface adsorption capacity, can reduce the loss of ammonium nitrogen, enhance the synthesis of sugar, starch, protein, fat, and various vitamins (Amruthesh *et al.*, 2003).

Simple correlation in Table 8 was estimated among the yield parameters and nutrient as affected by K humate and bio fertilizer application under sufficient irrigation and data

Table 4. Effect of potassium humate and biofertilizers on macronutrient of Maize grain under water stress

| K Humate | Bio-fertilizers | Nitrogen (%) | | Phosphorus (%) | | Potassium (%) | |
|-------------|-----------------------|-------------------|---------|----------------|---------|---------------|---------|
| | | Irrigation levels | | | | | |
| | | Sufficient | Deficit | Sufficient | Deficit | Sufficient | Deficit |
| 0.0 g/L | without | 1.33 | 1.26 | 0.104 | 0.075 | 0.53 | 0.52 |
| | with | 1.38 | 1.33 | 0.116 | 0.083 | 0.72 | 0.57 |
| 1.0 g/L | without | 1.42 | 1.36 | 0.138 | 0.114 | 0.60 | 0.59 |
| | with | 1.50 | 1.47 | 0.156 | 0.138 | 0.74 | 0.71 |
| 2.0 g/L | without | 1.57 | 1.43 | 0.204 | 0.151 | 0.65 | 0.61 |
| | with | 1.56 | 1.51 | 0.227 | 0.185 | 0.85 | 0.80 |
| 3.0 g/L | without | 1.72 | 1.62 | 0.306 | 0.305 | 1.04 | 0.94 |
| | with | 2.21 | 1.99 | 0.335 | 0.303 | 1.35 | 1.05 |
| 4.0 g/L | without | 1.62 | 1.62 | 0.255 | 0.246 | 0.77 | 0.78 |
| | with | 2.03 | 1.84 | 0.264 | 0.228 | 1.00 | 0.85 |
| LSD 0.05 | Potassium (K) | 0.032 | 0.044 | 0.012 | 0.008 | 0.051 | 0.036 |
| | Bio-fertilizers (Bio) | 0.017 | 0.019 | 0.004 | 0.005 | 0.031 | 0.016 |
| | (K*Bio) | 0.046 | 0.057 | 0.015 | 0.012 | 0.076 | 0.048 |

Table 5. Effect of potassium humate and biofertilizers on macronutrient of Maize straw under water stress

| K Humate | Bio-fertilizers | Nitrogen (%) | | Phosphorus (%) | | Potassium (%) | |
|-------------|-----------------------|-------------------|---------|----------------|---------|---------------|---------|
| | | Irrigation levels | | | | | |
| | | Sufficient | Deficit | Sufficient | Deficit | Sufficient | Deficit |
| 0.0 g/L | Without | 0.22 | 0.15 | 0.022 | 0.011 | 0.53 | 0.46 |
| | With | 0.24 | 0.20 | 0.025 | 0.014 | 0.75 | 0.54 |
| 1.0 g/L | Without | 0.26 | 0.21 | 0.051 | 0.049 | 0.85 | 0.78 |
| | With | 0.31 | 0.27 | 0.047 | 0.048 | 1.00 | 0.77 |
| 2.0 g/L | Without | 0.41 | 0.35 | 0.069 | 0.069 | 1.00 | 0.97 |
| | With | 0.46 | 0.40 | 0.100 | 0.072 | 1.23 | 1.18 |
| 3.0 g/L | Without | 0.50 | 0.46 | 0.195 | 0.156 | 1.27 | 1.16 |
| | With | 0.61 | 0.53 | 0.220 | 0.192 | 1.63 | 1.36 |
| 4.0 g/L | Without | 0.47 | 0.52 | 0.126 | 0.109 | 1.19 | 1.03 |
| | With | 0.56 | 0.63 | 0.155 | 0.128 | 1.47 | 1.33 |
| LSD 0.05 | Potassium (K) | 0.018 | 0.017 | 0.010 | 0.010 | 0.055 | 0.085 |
| | Bio-fertilizers (Bio) | 0.009 | 0.013 | 0.005 | 0.004 | 0.050 | 0.031 |
| | (K*Bio) | 0.024 | 0.028 | 0.014 | 0.012 | 0.096 | 0.107 |

Table 6. Effect of potassium humate and biofertilizers on micronutrient of Maize grain under water stress

| K Humate | Bio-fertilizers | Iron (ppm) | | Manganese (ppm) | | Zinc (ppm) | |
|-------------|-----------------------|-------------------|---------|-----------------|---------|------------|---------|
| | | Irrigation levels | | | | | |
| | | Sufficient | Deficit | Sufficient | Deficit | Sufficient | Deficit |
| 0.0 g/L | without | 55.54 | 41.39 | 11.52 | 9.79 | 24.35 | 20.36 |
| | with | 63.00 | 51.91 | 17.57 | 11.42 | 31.43 | 26.63 |
| 1.0 g/L | without | 58.46 | 42.27 | 12.32 | 10.10 | 25.03 | 21.37 |
| | with | 64.23 | 52.28 | 18.28 | 11.67 | 31.86 | 27.24 |
| 2.0 g/L | without | 61.34 | 43.63 | 12.50 | 10.37 | 25.58 | 21.89 |
| | with | 70.85 | 53.49 | 18.68 | 12.01 | 32.40 | 27.40 |
| 3.0 g/L | without | 61.88 | 44.49 | 13.06 | 10.54 | 26.23 | 22.51 |
| | with | 75.25 | 53.71 | 19.26 | 12.29 | 33.64 | 28.10 |
| 4.0 g/L | without | 62.36 | 45.24 | 13.38 | 10.80 | 26.82 | 22.89 |
| | with | 76.17 | 54.44 | 19.32 | 12.38 | 34.18 | 28.29 |
| LSD 0.05 | Potassium (K) | 0.219 | 0.599 | 0.541 | 0.428 | 0.272 | 0.331 |
| | Bio-fertilizers (Bio) | 0.129 | 0.298 | 0.127 | 0.211 | 0.206 | 0.159 |
| | (K*Bio) | 0.321 | 0.828 | 0.617 | 0.590 | 0.441 | 0.453 |

Table 7. Effect of potassium humate and biofertilizers on micronutrient of Maize straw under water stress

| K Humate | Bio-fertilizers | Iron (ppm) | | Manganese (ppm) | | Zinc (ppm) | |
|-------------|-----------------------|-------------------|---------|-----------------|---------|------------|---------|
| | | Irrigation levels | | | | | |
| | | Sufficient | Deficit | Sufficient | Deficit | Sufficient | Deficit |
| 0.0 g/L | without | 86.53 | 66.31 | 16.39 | 13.41 | 35.32 | 24.57 |
| | with | 102.85 | 75.05 | 24.64 | 16.18 | 42.47 | 31.13 |
| 1.0 g/L | without | 87.33 | 66.74 | 16.96 | 14.01 | 35.66 | 24.79 |
| | with | 116.07 | 76.26 | 25.20 | 16.49 | 43.45 | 31.42 |
| 2.0 g/L | without | 88.21 | 67.37 | 17.43 | 14.37 | 36.49 | 25.36 |
| | with | 123.87 | 76.73 | 25.55 | 16.86 | 43.98 | 32.59 |
| 3.0 g/L | without | 88.88 | 67.80 | 18.15 | 14.85 | 37.53 | 25.53 |
| | with | 127.52 | 77.33 | 26.11 | 17.16 | 44.40 | 33.07 |
| 4.0 g/L | without | 90.16 | 71.18 | 18.44 | 15.21 | 38.48 | 26.24 |
| | with | 132.23 | 77.83 | 26.34 | 17.31 | 45.28 | 33.40 |
| LSD 0.05 | Potassium (K) | 0.407 | 3.401 | 0.245 | 0.603 | 0.322 | 0.265 |
| | Bio-fertilizers (Bio) | 0.177 | 0.838 | 0.174 | 0.193 | 0.233 | 0.232 |
| | (K*Bio) | 0.540 | 3.915 | 0.387 | 0.735 | 0.512 | 0.458 |

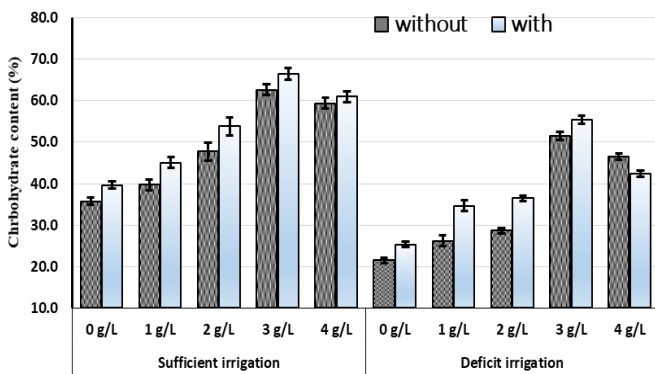


Fig (2) Carbohydrate content as affected by interaction between of biofertilizers with potassium humate

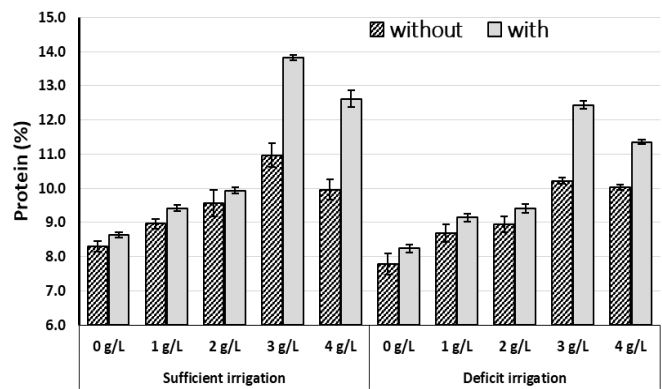


Fig (3) Protein content of maize grain as affected by interaction between of biofertilizers with potassium humate

Table (8). Correlation between of grain yield and nutrient content under sufficient irrigation.

| | P. h (cm) | 100 G. wt. | G Y | N % | P % | K % | Fe | Mn |
|----------------------|-----------|------------|-------|-------|-------|-------|-------|-------|
| 100 Grain wt. | 0.854 | | | | | | | |
| G Y (ton/fed) | 0.532 | 0.782 | | | | | | |
| N % | 0.852 | 0.915 | 0.814 | | | | | |
| P % | 0.918 | 0.921 | 0.736 | 0.976 | | | | |
| K % | 0.846 | 0.895 | 0.636 | 0.907 | 0.949 | | | |
| Fe (ppm) | 0.095 | 0.383 | 0.795 | 0.449 | 0.344 | 0.261 | | |
| Mn (ppm) | 0.221 | 0.517 | 0.898 | 0.576 | 0.476 | 0.388 | 0.978 | |
| Zn (ppm) | 0.285 | 0.536 | 0.899 | 0.600 | 0.504 | 0.400 | 0.974 | 0.990 |

Table (9). Correlation between of grain yield and nutrient content under deficit irrigation

| | P. h (cm) | 100 G .wt. | G Y | N % | P % | K % | Fe | Mn |
|----------------------|-----------|------------|-------|-------|-------|-------|-------|-------|
| 100 Grain wt. | 0.897 | | | | | | | |
| G Y (ton/fed) | 0.628 | 0.561 | | | | | | |
| N % | 0.906 | 0.912 | 0.642 | | | | | |
| P % | 0.940 | 0.973 | 0.591 | 0.949 | | | | |
| K % | 0.843 | 0.897 | 0.598 | 0.934 | 0.946 | | | |
| Fe (ppm) | 0.520 | 0.431 | 0.886 | 0.499 | 0.501 | 0.587 | | |
| Mn(ppm) | 0.355 | 0.295 | 0.850 | 0.322 | 0.341 | 0.440 | 0.955 | |
| Zn (ppm) | 0.476 | 0.408 | 0.916 | 0.464 | 0.461 | 0.546 | 0.980 | 0.985 |

revealed that 100 grain yield positively correlated with nitrogen (0.915), phosphorus (0.921); potassium (0.895) while it was not significant correlation with micronutrient. Whereas, grain yield positively collated with macronutrient (nitrogen (0.814), phosphorus (0.736); potassium (0.636) and micronutrient iron (0.795), Manganese (0.898); Zinc (0.899).

Simple correlation in Table 9 was estimated among the yield parameters and nutrients as affected by K humate and biofertilizer application under deficit irrigation and data revealed that 100-grain yield positively correlated with nitrogen (0.912), phosphorus (0.973); potassium (0.897) but it was not significantly correlated with micronutrient. Whereas, grain yield significantly collated with macronutrient (nitrogen (0.642), phosphorus (0.591); potassium (0.598) and highly correlated with micronutrient (iron (0.886), Manganese (0.850); Zinc (0.916).

Conclusion

Foliar application of potassium humate combined with biofertilizer gradually increased the grain yield, biological yield, and nutrient content under water stress conditions. This due to potassium humate contains carboxyl, phenolic hydroxyl, and other functional groups, has a strong complexation and surface adsorption capacity, can reduce the loss of ammonium nitrogen, enhance the synthesis of sugar, starch, and protein.

Biofertilizers are also able to produce growth-promoting substances like indole acetic acid and gibberellic acid enhanced nutrient uptake, translocation and synthesis of photosynthetic assimilates which resulted increased plant growth characters and in obtaining economically profitable yield.

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Conflict of Interest

The author hereby declares no conflict of interest.

Consent for publication

The author declares that the work has consent for publication.

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References

A.O.A.C. (1990). Official Methods of Analysis. 20th edition. Association of Official Analytical Chemists, Arlington, Virginia, U.S.A.

- Abou-El-Seoud, I. I. and Abdel-Megeed, A. (2012). Impact of rock materials and biofertilization on P and K availability for maize (*Zea mays*) under calcareous soil conditions. Saudi J. of Biolo. Sci., 19: 55-63
- Albayrak, S. and Camas, N. (2005). Effects of different levels and application times of humic acid on root and leaf yield and yield components of forage turnip (*Brassica rapa* L.). J. Agron., 4 (2): 130-133.
- Amjad Muhammad, Akhtar Javaid and Muhammad Anwar-ul-Haq. (2014). Soil and foliar application of potassium enhances fruit yield and quality of tomato under salinity. Turkish Journal of Biology 38(2):208-218.
- Amruthesh, K. N., Raj, S. N., Kiran, B., Shetty, H. S. and Reddy, M. S. (2003). Growth promotion by plant growth promoting Rhizobacteria in some economically important crop plants. In: Sixth international PGPR Workshop, 5-10 October, Calicut, India. 97-103.
- Anup Das, Gour, C. M., Dharmendra, P. P., Probir, K. G., Shishomvnao, N. and Pankaj, B. (2010). Productivity, nutrient uptake and postharvest soil fertility in lowland rice as influenced by composts made from locally available plant biomass. Arch. Of Agron. Soil Sci., 56 (6): 671-680.
- Arshad, M., Khalid, A., Mahmood, M. H. and Zahir, Z. A. (2004). Potentiality of nitrogen and L-tryptophan enriched compost for improving growth and yield of hybrid maize. Pak.J.Agric. Sci., 41: 16-24
- Bates, L. S., Waldan, R. P. and Teare, L. D. (1973). Rapid determination of free proline under water stress studies. Plant and Soil, 39: 205-207.
- Böhme, M. and Thi Lua, H. (1997). Influence of mineral and organic treatments in the rhizosphere on the growth of tomato plants. Acta Hort. 450:161-168.
- Brown, J. D., Lilliland O. (1946). Rapid determination of K and Na in plant material and soil extracts by flame photometer. J. Amer. Soc. Hort. Sci.:48:341-346.
- Carpena, R., Ramon, A. H., Garate, A. (1990). The effects of short term deficiency of B, K, Ca, and Mg ions distribution in leaves and roots of tomato (*Lycopersicon esculentum* L.) plants. In: Van Benschichem ML. (ed.), Plant Nutrition Physiology and Application. 287-290.
- Chapman, H. D., Pratt, P. F. (1978). Methods of analysis for soil, plant and water. Agric. Sci. Dept. Univ. of California USA 309. Chem. 36:345-347.
- Chen, J. X. and Wang, X.F. (2006). Plant physiology experimental guide. Higher Education Press, Beijing, pp 24-25: 55-56.
- Danil, A. D. and George, C. M. (1972). Peach seed dormancy in relation to endogenous inhibitors and applied growth substances. J. of Amer. Society for Hort. Sci., 17: 621-624.
- Dubois M, Gilles KA, Hamilton JR, Robers PA, Smith F. (1958). Colorimetric method for determination of sugar and related substances. Annal. Chem.28:350-356.
- Faithfull, N. T. (2002). Methods in agricultural chemical analysis. A practical handbook. CABI Publishing. 84-95.
- Fedak, G. and De La Roche, I. (1977). Lipid and fatty acid composition of barley kernels. J. Plant Sci., 57: 257.
- Hameeda, b., Harini, G., Rupela, O. P., Wani, S. P. and Gopala, R. (2008). Growth promotion of maize by phosphate solubilizing bacteria isolated from composts and macrofauna. Microbiological Res., 163 : 234-242.
- Heffer, P. (2013). Assessment of fertilizer use by crops at the global level 2010-2010/11. International Fertilizer Industry Association. Paris, France. p. 9.
- Homme, P. M., Gonzalez, B. and Billard, J. (1992). Carbohydrate content, fructose and sucrose enzyme activities in roots, stubble and leaves of rye grass (*Lolium perenne* L.) as affected by sources / link modification after cutting. J. Plant Physiol. 140: 282-291.
- Itelima JU, Bang WJ, Onyimba IA (2018). A review: biofertilizer; a key player in enhancing soil fertility and crop productivity. J MicrobiolBiotechnol Rep 2:22-28.
- Jones, C. A., Jeffrey, S. J. and Mugaas, A. (2007). Effect of low-rate commercial humic acid on phosphorus availability, micronutrient uptake, and spring wheat yield. Commun. Soil Sci. Plant Anal. 38: 921-933.
- Kumar, K. B. and Khan, P. A. (1982). Peroxidase and polyphenol oxidase in excised ragi (*Eleusine coracana* cv. PR 202) leaves during senescence. Indian J. Exp. Bot. 20: 412-416.
- Larsen, P., Harbo, A., Klungron, S. and Ashein, T. A. (1962). On the biosynthesis of some indole compounds in *Acetobacter Xylinum*. Physiologia Plantarum, 15: 552-565.

- Minolta (1989). Chlorophyll meter SPAD-502. Instruction manual. Minolta Co., Ltd., Radiometric Instruments Operations, Osaka, Japan.
- Mohsen, A.A.M., (2012). Response of garlic plant to nitrogen, phosphorus, potassium and some biofertilizer levels under sandy soil conditions. Ph.D. Thesis, Fac. Agric., Zagazig Univ., Egypt.
- Muhammadn, S., Syed, H. I. and Muhammad, E. A. (2013). Conjunctive use of humic acid, bio fertilizer and phosphorus augmented nutrients contents in chickpea under greenhouse conditions. *Advanced Journal of Agricultural Research*, Vol. 1(1):1-5.
- Naveed, M., Khalid, M., Jones, D. L., Ahmad, R. and Zahir, Z. A. (2008). Relative efficacy of *Pseudomonas* spp., containing ACC-deaminase for improving growth and yield of maize (*Zea mays* L.) in the presence of organic fertilizer. *Pak. J. Bot*, 40(3):1243-1251.
- Nevens, F. and Reheul, D. (2003). The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: nitrogen availability and use. *Europ.J.Agron*, 19: 189-203.
- Norman, Q. Stephenlesa, A. Edwardsa, C. A. and Atiyeha, R. (2004). Effect of humic acid derived from cattle, food and paper –waste vermiconiposts on growth of greenhouse plants. The Soil Ecology Laboratory. The Ohio State Univ., 1735 Neil Avenue, Columbus, OH 43210, USA.
- Patel, A. L. and Singh, J. (1998). Nutrient uptake and distribution in aerial parts of wheat under water stress at different growth stages. *Ann. Agric. Bio, Res*.3:5-8.
- Pingali, P.L. and S. Pandey. 2001. Meeting world maize needs: Technological opportunities and priorities for the public sector. In P.L. Pingali (ed.). CIMMYT 1999-2000 World Maize Facts and Trends. Mexico, D.F.: CIMMYT.
- Pioncelot, R. P. (1993). The use of a commercial organic biostimulant for bedding plant production *J. Sustainable Agriculture*. 3: 99-110.
- Rebecca, B. (2004): "Soil Survey Methods Manual". Soil Survey Investigations Report No. 42, *Natural Resources Conservation Services*, USA.
- Roth JA, Ciampitti IA, Vyn TJ (2013). Physiological Evaluations of Recent Drought-Tolerant Maize Hybrids at Varying Stress Levels. *Agronomy Journal* 105:1129-1141.
- Russo, R. O. and Berlyn, G. P. (1990). The use of organic biostimulants to help low input sustainable agriculture. *J. Sustainable Agriculture*.1: 19-42.
- Said-Al Ahl, H. A., Hasnaa, H., Ayad, S. and Hendawy, S. F. (2009b). Effect of potassium humate and nitrogen fertilizer on herb and essential oil of oregano under different irrigation intervals. *Ocean Journal of Applied Science*, 2 (3): 319-329.
- Sanders, D.C. Ricotta, J.A. and Hodges, L. (1990). Improvement of carrot stands with plant biostimulants and fluid drilling. *Hortscience*, 25: 181-183.
- Sepaskhah, A. R. and Ghahraman, B. (2004). The Effects of Irrigation Efficiency and Uniformity Coefficient on Relative Yield and Profit for Deficit Irrigation. *Biosystems Engineering*. 87(4):495-507.
- Shaharoon, B., Arshad, M., Zahir, Z. A., and Khalid, A. (2006). Performance of *Pseudomonas* sp containing ACC-deaminase for improving growth and yield of maize (*Zea mays* L.) in the presence of nitrogenous fertilizer. *Soil Biol. Biochem.*, 38: 2971- 2975.
- Sharif, M., Khattak, R. A., Sarir, M. S. (2002). Effect of different levels of lignitic coal derived humic acid on growth of maize plants. *Communication Soil Science Plant Analysis* 33: 3567– 3580.
- Singh, y., Singh, C. S., Singh, T. K. and Singh, J. P. (2006). Effect of fortified and unfortified rice-straw compost with NPK fertilizers on productivity, nutrient uptake and economics of rice (*Oryza sativa*). *Indian J. Agron*, 51 (4):297-300.
- Snedecor, G. W., Cochran, W. G. (1990). "Statistical Methods". 8th Ed. Iowa State Univ. Press Ames, Iowa, U.S.A. 609.
- Suhana Puri Goswami, Akhila N and Dubey, AditiChourasia, Sri Laxmi and Dinesh Kumar Singh (2019). Water stress and its management strategies on rainfed maize: A review. *Journal of Pharmacognosy and Phytochemistry* 2019; 8(1): 2433-2438.
- Suke, S. N., Deotale, R. D., Hiradeve, P., Degirkar, M. and Sorte, S. N. (2011). Effect of nutrients and biofertilizers of chemical and biochemical parameters of maize (*Zea mays* L.). *J. soil and crops*, 21(1):107-112.
- Vartainan, N., Hervochon, P., Marcotte, L. and Larher, F. (1992). Proline accumulation during drought rhizogenesis in *Brassica napus* var. Oleifera. *Plant Physiol*. 140: 623-628.
- Wani, P. A., Khan, M. S. and Zaidi, A. (2007). Synergistic effects of the inoculation with nitrogen-fixing and phosphate –solubilizing rhizobacteria on the performance of field-growth chickpea. *J. Plant Nut. Soil Sci*.170: 283-287.
- Waraich, E.A., Ahmad, R., Saifullah, Ashraf, M.Y., Ehsanullah, (2011). Role of mineral nutrition in alleviation of drought stress in plants. *Australian J. Crop Sci.*, 5(6): 764-777.
- Yemm, E. W. and Cocking, E. C. (1955). The determination of amino acids with Ninhydrin. *Analyst*. 80: 209-213.
- Yemm, E.W. and Willis, A.J. (1954). The respiration of barley plants. IX. The metabolism of roots during assimilation of nitrogen. *New Phytol*. 55: 229-234.
- Zaghloul, S. M., El-Quesni, F. E. M. and Mazhar, A. A. M. (2009). Influence of Potassium Humate on Growth and Chemical constituents of Thuja Orientalis L seedlings. *Ocean Journal of Applied Sciences*.2 (1): 73-78.

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