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Effect of humic substances on yield and nutrient contents of Eggplant Santana (*Solanum melongena*) plants in gray-brown soil

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Abstract

Humic substances promote the conversion of nutrients into forms available to plants. It also stimulates seed germination and viability, and its main effect usually being more prominent in the roots. This study was conducted in a randomized complete block design with three replications in Gobustan, Azerbaijan, in 2021 growing season, to determine the effects of different doses (0, 250, 500 and 1000 ppm) of humic substances such as humic acid (HA), fulvic acid (FA) and humic fulvic acid (HFA) on fresh yield and nutrient contents (N, P and K) of Eggplant Santana (*Solanum melongena* var. *esculentum Santana*) plants in a field experiment. According to the results of this study, humic substance treatments increased the fresh yields and leaf nutrient contents of Eggplant Santana, and this increase was found to be significant. The highest value for highest fresh yields and leaf NPK contents of Eggplant Santana plants were obtained from 1000 ppm HFA dose. These results suggest that 1000 ppm HA and FA combination to the standard humic substances application will be sufficient to obtain adequate fresh yield and nutrient contents in Eggplant Santana leafs.

Keywords: Humic acid, fulvic avid, soil, yield, Eggplant Santana, nutrients.

Introduction

Humic substances, namely humus, which is an important component of the soil organic matter as well as in geological organic deposits such as lake sediments, peats, brown coals and shales and these are very important components of soil that affect physical and chemical properties and improve soil fertility (IHSS, 2022). Because of the different contribution ways on plant growth, humic substances are used in different areas of agriculture (Chen and Aviad, 1990). Owing to chelating properties of humic substances with metallic cations, availability of many nutrients increase and thus plant growth is affected positively (Cansu and Erdal, 2018). Additionally, humic substances increase root and root hair growth leading to expanded root surface area and thus nutrient uptake capacity increases (Pinton et al., 1999; Cesco et al., 2002). Humic substances might show antistress effects under abiotic stress conditions such as, unfavorable temperature, pH, salinity, etc. Humic materials could improve growth of plant under soil condition with enhancing nutrients uptake and reducing toxic elements uptake (Kulikova et al., 2005). Sharif et al. (2002) found that the humus material has indirect effects on plant growth because it improves soil properties, i.e., water holding capacity, permeability, aggregation, hormonal activity, aeration, organic matter mineralization, and solubilization and nutrients availability (Nardi et al. 2002).

In many studies, humic substance such as humic acid and fulvic acid preparations were reported to increase the uptake of mineral elements, to promote the root length, and to increase the fresh and dry weights of plants (Tan and Nopamornbodi, 1979; Duplessis and Mackenzie, 1983; Adani et al., 1998; Mackowiak et al., 2001; Nardi et al., 2002; Dursun et al., 2002; Arancon et al., 2003; Cimrin and Yilmaz, 2005; Ulukan, 2008,

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Eyheraguibel et al., 2008; Saruhan et al., 2011; Merwad, 2017; Tursun et al., 2019). Although there are many studies showing the positive effect of humic substances on plant growth and plant nutrient uptake, negative or no effect of humic substances have been reported (Tahir et al., 2011; Leventoglu and Erdal, 2014). Due to the positive effect of humic substances on the visible growth of plants, these chemicals have been widely used by the growers instead of other substances such as pesticides etc. This, however, has led to growers using higher amounts of these substances (Khaled and Fawy, 2011). Furthermore, healthy and environmentally friendly food production is a priority for scientists and researchers. Organic agriculture presents itself as an efficient alternative, although there are concerns about yield (Awad et al., 2022).

The ultimate goal of the present study was to investigate the influence of different doses of humic substances on fresh yield and nutrient contents (N, P and K) of Eggplant Santana (*Solanum melongena* var. *esculentum Santana*) plants in a field experiment. In addition, the study compared humic substances (humic acid, fulvic acid and humic fulvic acid) applied as a soil application using drip irrigation to evaluate the optimal application doses and humic substances under gray-brown soils in Gobustan, Azerbaijan.

Material and Methods

Location of the field experiment, climate conditions, timing and plant materials

A field trial was conducted at "Ugur" Farm in Gobustan, (40°32'3.59" N and 48°55'9.59" E), Azerbaijan, in the spring season of 2021 on Eggplant Santana with different levels of humic substances (HA, FA and HFA). The geographical location of the field trial is situated on the west part of Azerbaijan (Figure 1). In spite of the location parameters agro-climate condition is profitable to the gardening, horticulture and vegetable growing. For many years several vegetables (tomato, cucumber, all kinds of cabbages, onion and eatable green grasses) are being cultivated in the territory. There was large olive gardens around the vegetable cultivated field which territory has been decreased. In Gobustan mostly gray-brown soils exist. These soils are characterized by a gray-brown color. Before conducting the experiment, the soil sample was analyzed from Institute of Soil Science and Agrochemistry, Baku, Azerbaijan. Soil textural class named as clay loam (30% clay, 35% silt and 35% sand). The soil was characteristically alkaline reaction (pH 8), total soluble salt was 0.3%, soil organic matter was 1.43%, total nitrogen was 0.089%, available phosphorus ($NaHCO_3$ extractable) was 12.4 mg P kg^{-1} and available potassium was 123 mg K kg^{-1}. The variety of Eggplant Santana was produced by Research Institute of Crop Husbandry of Ministry of Agriculture of Azerbaijan Republic. The variety of *Solanum melongena* tested was var. *esculentum Santana*, which was sown on 12 April 2021 This Eggplant Santana requires a moderate amount of water and it thrives best in direct sunlight or full sun meaning that it loves at least 6-8 hours of bright direct light. For these reasons, the selected Eggplant Santana variety is the most prevalent in the study region as a result they are more adaptable to the climatic conditions in Gobustan, Azerbaijan. Weather conditions were presented in Figure 2.

Figure 1. Research area

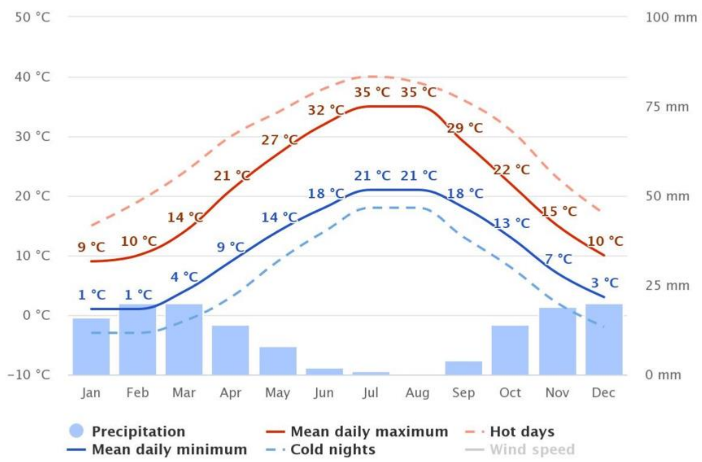

Figure 2. Monthly average temperature (A) and distribution of precipitation (B) of the experimental area

In study field, the summers are warm, dry, and mostly clear and the winters are freezing, snowy, and partly cloudy. The study area is classified as semi-arid climate with mild winters and long hot summers, with a daily average air temperature of 19-20°C and an annual precipitation of 200 mm at the experimental site. The average annual temperature is 16°C and the average relative air humidity is about 78.25 %. The average temperature can reach 21°C in August, while the lowest average temperature can reach 7°C in December. The earliest frost in the region is usually at the end of October, while the last frost is around the end of March. Most rainfalls occur in winter, and there is almost no rainfall from July to September. The highest humidity (70%) occurs in winter, while the lowest (30%) occurs in summer.

Treatments, Experimental Design and Humic substances application

As basal fertilization, 70 kg ha^{-1} N, 35 kg ha^{-1} P, 60 kg ha^{-1} K were applied using ammonium nitrate, mono ammonium phosphate and potassium nitrate. Eggplant Santana (*Solanum melongena var. esculentum Santana)* are planted as 50x50 cm were used as plant materials. As liquid humic substances, Fulvagra® liquid 25 and Humicraft® liquid made by Humintech GmbH was used. These humic substances contain humic acid, fulvic acid, water soluble N and K_2O ratios as given Table 1.

Table 1. Humic substances component used

Components	Fulvagra® liquid 25 (FuL) Volume (%w/w)	Humicraft® liquid (HuL) Volume (%w/w)
Total organic substances	8	27
Dry matter	20	30
Fulvic acids	18	1
Humic acids	1	8
Free amino acids	-	10
Potassium humates	-	10
Total N	-	1
Water Soluble K_2O	-	2
pH	3-3.5	8.5-9.5
Bulk density, kg/L	1.10	1.12

The experiment was planned according to randomized blocks with 3 replications and each replicate consisted of ten (10 seeds in a parcel) plant and parcel dimensions were designed to have dimensions 1.6×2= 3.2 m^2. Once the Eggplant Santana seedlings that were to be grown commercially were obtained, they were planted into row spacing and row tops so that they were in parcels of dimensions 40×40 cm. The experiment was carried out between 10.04.2021 and 21.10.2021. In the experiment, for soil application 4 levels of humic substances (humic acids-HA, fulvic-acids-FA and humic-fulvic-acids-HFA) corresponding to 0, 250, 5000 and 1000 ppm were given to before planting seedlings and water irrigation using with drip irrigation system lasted to this term. The amounts of humic substances applied to the land with water are given in the Table 2.

Table 2. Humic substances application doses with water

Aplication doses, ppm	HA	FA	HFA
0	0	0	0
250	30 L ha^{-1} HA from HuL	35 L ha^{-1} FA from FuL	25 L ha^{-1} HFA from HuL (100 ppm) + FuL (150 ppm)
500	20 L ha^{-1} HA from HuL	25 L ha^{-1} FA from FuL	20 L ha^{-1} HFA from HuL (200 ppm) + FuL (300 ppm)
1000	15 L ha^{-1} HA from HuL	15 L ha^{-1} FA from FuL	10 L ha^{-1} HFA from HuL (400 ppm) + FuL (600 ppm)

Evaluation of Leaf Nutrients

At the end of the experiment, in order to determine leaf nutrient concentrations, samples were collected from the four sides of plants from the shoots. Then, samples were brought to laboratory and washed with water, dilute acid (0.2 N HCl) and distilled water. Later, samples were dried at 65±5 ^{0}C for 2 days. Afterwards, samples were dried, grounded and wet digested by using HNO_3+$HClO_4$ (4:1) mixture. Total N was determined according to Kjeldahl method. Leaf P concentration was measured vanadomolybdphosphoric method, K concentrations were determined using atomic absorption spectrophotometer (Jones, 2001).

Results and Discussion

Fresh Eggplant Santana yield, t ha^{-1}

The application of various humic substances such as HA, FA and HFA gave an increase in the Fresh Eggplant Santana yields compared with untreated (control) soil (Figure 3). This is explained by the fact that the addition of humic materials improves physical and chemical characteristics of gray-brown soil. This finding stands in agreement with those of Mackowiak et al. (2001), Nardi et al. (2002), Cimrin and Yilmaz (2005) and Merwad, (2017). It was determined that the main effect of humic substances is as follows: HFA>FA>HA>untreated soil. In the 2021 growing seasons, the highest Fresh Eggplant Santana yields were obtained from the treatment of 1000 ppm HFA (50.2 t ha^{-1}) and 1000 ppm FA (45.4 t ha^{-1}) while the lowest Fresh Eggplant Santana yields were obtained from the control (15 t ha^{-1}). When the average of doses of treatment was calculated, the treatment of HFA gave a significantly higher Fresh Eggplant Santana yield (40.4 t ha^{-1}) than the other treatments. Improvement of soil conditions and establishing equilibrium among plant nutrients are also important for soil productivity and plant production. Humic substances and organical improvement of soil increased the yields of some field crops in several studies (Ulukan, 2008). Studies on the effects of humic substances on plant growth, showed improved effects on growth, independent of nutrition (Dursun et al., 2002; Saruhan et al., 2011). Duplessis and Mackenzie (1983) found that the grain yield of legumes, such as mung bean, soybean and pea increased by the use of these humic substances. Some researchers found that humic acid increased the yields in some plants. Studies indicate that humic substances causes increased weights of above-ground parts of plants such as common wheat (Malik and Azam, 1985), parsley (Tursun et al., 2019), strawberry, tomato, marigold, pepper (Adani et al., 1998; Arancon et al., 2003), corn (Tan and Nopamornbodi, 1979; Eyheraguibel et al., 2008).

Nutrient contents of Fresh Eggplant Santana leaf, %

The concentration of different nutrients, namely, nitrogen, phosphorus and potassium, were determined in Eggplant Santana leaf grown under application of various humic substances such as HA, FA and HFA. The results obtained at the harvesting stage of growth were evaluated as percentage in dry weight. The nutrient concentrations of Eggplant Santana leaf among the HA, FA and HFA treatments are shown in Figure 4, 5 and 6. In general, it was determined that soil applications of humic substances had a significant effect on the NPK concentration of Eggplant Santana leaf. When compared with the control treatment, NPK concentration of Eggplant Santana plant leaf were higher both application doses of humic substances. Chen and Aviad (1990), Fagbenro and Agboda (1993) and David et al. (1994) have reported promoted growth and nutrient uptake of plant due to the addition of humic substances. The plants take more mineral elements due to the better developed root systems. In addition, the stimulation of ion uptake in applications with humic substances led many researchers to propose that these materials affect membrane permeability (Zientra, 1983). It is related to the surface activity of humic substances resulting from the presence of both hydrophilic and hydrophobic sites (Chen and Schnitzer, 1978). Therefore, the humic substances may interact with phospholipids structure of cell membranes and react as carriers of nutrients through them (Aşık et al., 2009).

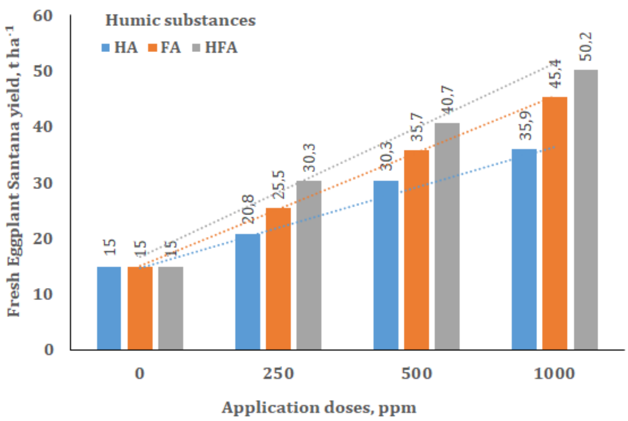

Figure 3. The effects of humic substances on Fresh Eggplant Santana yield, t ha^{-1}

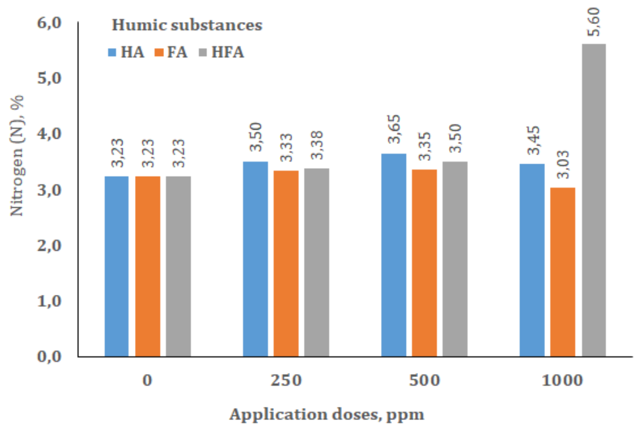

Figure 4. The effects of humic substances on Nitrogen contents of Fresh Eggplant Santana leaf, %

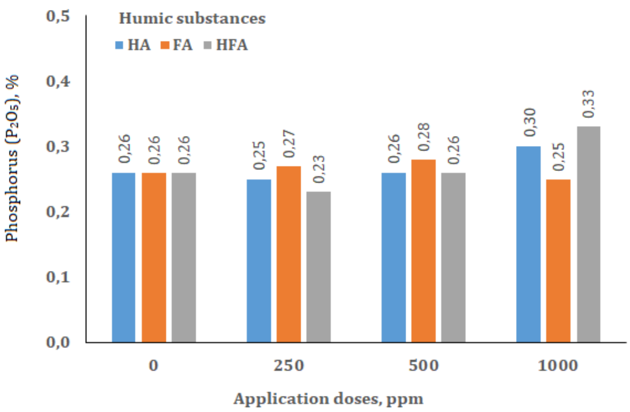

Figure 5. The effects of humic substances on Phosphorus contents of Fresh Eggplant Santana leaf, %

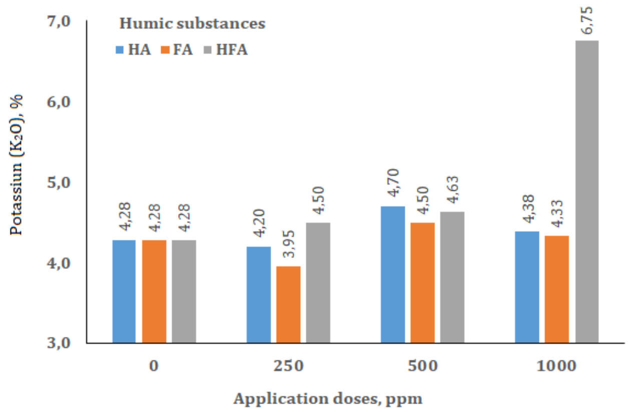

Figure 6. The effects of humic substances on Potassium contents of Fresh Eggplant Santana leaf, %

The highest NPK concentrations of Eggplant Santana leaf were obtained from 1000 ppm HFA dose. Nitrogen content of Eggplant Santana plant leaf was significantly affected with the applications of different humic substances sources and their doses when compared with the control. Nitrogen content of Eggplant Santana plant leaf varied from 3.23% in the control to 5.65 % in 1000 ppm HFA dose (Figure 4). Phosphorus content of plant leaf was not affected by the treatments and ranged from 0.23% in 250 ppm HFA dose to 0.33% in 1000 ppm HFA dose. The highest phosphorus content of plant leaf was determined in 1000 ppm HFA dose which was higher than the other treatments but it was not significantly different (Figure 5). Potassium content of plant leaf was affected by the treatments and followed a similar trend with nitrogen content of plant leaf. The lowest potassium content of plant leaf was found in the 250 ppm FA dose, and the highest potassium content of leaf was measured in 1000 ppm HFA dose (Figure 6). In general, it was determined that 1000 ppm humic substances increased the nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) contents of Eggplant Santana plant leaf over the control. It is in agreement with Fagbenro and Agboola (1993), Bohme and Thi Lua (1997), Atiyeh et al. (2002), Sanchez–Sanchez et al. (2002) and Nikbakht et al. (2008).

Conclusion

Technically, humic substances such as humic acid (HA), fulvic acid (FA) and humicfulvic acid (HFA) are not fertilizers, although most farmers do consider them so, and their applications are environmentally friendly; furthermore it is considered one of the most important production factors in sustainable agriculture practice. It can be concluded from this study that different doses of humic substance treatments increased the fresh yields and leaf nutrient contents of Eggplant Santana compared to the control groups, and this increase was found to be significant. The highest value for highest fresh yields and leaf NPK contents of Eggplant Santana plants grown in gray-brown soils were obtained from 1000 ppm HFA dose. These results suggest that 1000 ppm HA and FA combination to the standard humic substances application will be sufficient to obtain adequate fresh yield and nutrient contents in Eggplant Santana leafs. More research is needed to optimize the combined effect of different HFA application rates and mineral fertilizers on the crop performance and soil quality parameters under defined field conditions; more importantly, long-term studies involving different soil types, crops and climate patterns in warranted to truly exploit the benefits of humic substances.

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