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Improvement of growth, yield and quality of banana cv. Grand Naine by application of potassium humate

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ABSTRACT

Precise choice of potassium (K) source and application method does matter for its cost-effectiveness. The effect of soil potassium fertilization either as sulfate or humate form with or without K_2SO_4 foliar sprays was studied on vegetative growth, yield, and fruit quality of Grand Naine banana plants grown under clay loam soil conditions. The experiment included four treatments as follows: Control (800 g of K_2SO_4 as soil application), 250 g of K-humate as soil application, 800 g of K_2SO_4 as soil application + 2 % K_2SO_4 as foliar sprays, and 250 g of K-humate as soil application + 2 % K_2SO_4 as foliar sprays. Each treatment was replicated three times with three plants per each replicate and the randomized complete block design was arranged. Results indicated that potassium fertilization treatments showed a positive effect on vegetative growth parameters, N, P, K, chlorophyll a and b content in the leaves, and also improved yield and fruit properties. In this respect, the humate form was more pronounced than the sulfate form. In addition, treatments included K_2SO_4 as foliar sprays were more effective than those without it. Therefore, the usage of 250 g of K-humate as soil application + 2 % K_2SO_4 as foliar sprays could be recommended to improve the growth, yield, and quality of Grande Naine banana under these experimental conditions.

Keywords: Banana, potassium humate, soil application, foliar application, yield, quality

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1 Introduction

Banana (*Musa* sp.) belongs to the family Musaceae is one of the world's leading fruit crops that is widely cultivated in the tropical and subtropical regions for its valuable applications in food industry. Banana production occupies the forth order in fruit production of Egypt after citrus, dates and grapes, where the production area reached to 30.864 thousand ha with about 1.38 million tons of fruits annually (FAOSTAT, 2020).

Fertilization is an important and limiting factor for growth, production and quality of banana plants. Banana requires large quantity of chemical fertilizers for its growth and development (Nomura et al., 2016; Zhao et al., 2020). Moreover, such chemical fertilizers pose a health hazards and microbial population problem in soil besides being quite expensive and making the cost of production high (Meena et al., 2016; Toumi et al., 2015; Nkoa, 2013). So, it has drowned the attention to use another sources of fertilizers which are safe for human and environment. Thus, it is preferred to use these organic fertilizers to avoid pollution and to reduce the costs of chemical fertilizers (Ortas, 2012; Hazarika and Aheibam, 2019). Use of organic fertilizers for crop production is gaining momentum, as they are environmentally safe when compared to chemical fertilizers. Moreover, organic fertilizers on application remain in soils and keep benefiting the growing crops (Abou-Hussein et al., 2001).

Potassium humate (K-humate) can be used as a no expensive and natural source of potassium to improve the physio-biochemical characteristics of soils and improve growth, yield and nutritional state of plants (Abd-El-Aal et al., 2017; Hidayatullah et al., 2018; Idrees et al., 2018; Kumar et al., 2013; Abo-Gabien, 2021; Ennab and Khedr, 2021). K-humate can be used as an organic potassium fertilizer to supply the plants with high levels of soluble K in a readily available form. Combined with humic acid, potassium can be rapidly absorbed and incorporated into plants (Abd-El-Aal et al., 2017). Humic acid decreases soil compaction and increases cation exchange capacity which affects the retention and availability of nutrients. In addition, the humic acid promotes nutrient uptake as chelating agent (Eissa et al., 2007).

K-humate impacts plant performance and soil fertility by an increase in the activity of beneficial soil microorganisms, which stimulates the soil properties (Dawood et al., 2019). K-humate increases photosynthesis, leaf pigments, plant biomass, chlorophyll density, plant root respiration and accelerate cell division, which resulted in greater plant growth and yield (Carrubba, 2014; Ulukan, 2008; Hassanpanah, 2009; Yang et al., 2004). K-humate increases plant tolerance to abiotic stress such as salinity, heat, cold, drought stress, disease and pests (Ajalli et al., 2013). Many researchers indicated that K-humate improved productivity and quality of several fruit crops such as pomegranate, apple, olive and balady mandarin (Abd El-Rhman, 2017; Hidayatullah et al., 2018; Abo-Gabien, 2021; Ennab and Khedr, 2021). Keeping in view these facts, the objective of this study was to evaluate the effect of soil potassium fertilization either as sulfate or humate form with or without K_2SO_4 foliar sprays on vegetative growth, yield and fruit quality of Grand Naine banana plants grown under clay loam soil conditions.

2 Materials and Methods

2.1 Experimental site, soil and climate

This investigation was carried out during 2017-18 and 2018-19 seasons on second and third ratoon Grand Naine banana plants grown on clay loam soil in a private plantation (latitude: 31.05° N, longitude: 31.38° E and 2.89 m above the Mediterranean Sea level) at Badaway, Al-Dakahlia governorate, Egypt. Soil physical and chemical analyses are shown in Table 1. According to climate data obtained from the Egyptian Meteorological Authority (https://nwp.gov.eg/), the two-year mean annual minimum and maximum air temperatures were 5.3 °C and 45.8 °C, respectively, with a mean annual precipitation of 47.46 mm.

2.2 Crop husbandry

Plants were spaced at 3.0 × 3.5 m and three suckers were selected per hole. Plants under investigation were treated with potassium fertilizers as soil application per plant either at sulfate (K_2SO_4: 48-52% K_2O) or humate (K-humate: 12% K_2O) form with or without foliar sprays of 2% K_2SO_4, Soil application of potassium fertilizers was added at four equal batches in April, May, June and July of each season (Mustaffa and Kumar, 2012), while the foliar sprays of K_2SO_4 were applied twice at mid June and mid August of each season.

2.3 Experimental treatment and design

This experiment included four treatments as follows: (i) Control (800 g of K_2SO_4 as soil application), (ii) 250 g of K-humate as soil application, (iii) 800 g of K_2SO_4 as soil application + 2% K_2SO_4 as foliar sprays, and (iv) 250 g of K-humate as soil application + 2% K_2SO_4 as foliar sprays. Each treatment was replicated three times with three plants per replicate and the randomized complete block design was arranged. The other fertilizing program was the same for all treatments, where each plant received 500 g N per year as ammonium sulfate (20.5% N), and 250 g calcium super phosphate per year (15.5% P_2O_5). The other cultural practices were the same for all plants.

2.4 Data collection and chemical analysis

After the bunch shooting (about end of August in both seasons), leaf samples were taken from the middle of the third leaf from the top of each plant (Hewitt, 1955; Abou-Aziz et al., 1987) leaf analysis as a guide to washed with tap water then with distilled water and dried in the oven at 70 °C until constant weight was obtained and then ground by using a manual mill 0.2 g. The ground material was digested using a mixture of 1:10 perchloric and sulphuric acid (v/v) for 15 minutes until the digestive solution became color-less and then transferred quantitatively to 50 mL volumetric flask. Total nitrogen was determined using the micro-Kjeldahl method (Pregl, 2013). Phosphorus was determined according to the colorimetric method (Truog and Meyer, 1929). Potassium was determined according to the photometric method (Brown and Lilleland, 1946). Chlorophyll a and b content was determined according to the method described by Bruuinsma (1963). Also, the following parameters were determined for each plant: height, circumference pseudostem, number of green leaves per plant and third leaf area (LA) were calculated according to the equation of Murray (1959):

$$LA = L \times W \times k \tag{1}$$

where L and W designate length and width, respective, and k is area co-efficient (0.86).

At harvest, number of days from shooting to harvest (days), bunch weight (kg) and yield (t ha^{-1}) were estimated; also number of hands, fingers per hand, and pulp peel ratio were calculated for each plant. After artificial ripening, finger samples were used to determine total soluble solids (%) using hand Refractometer. Acidity was measured as a malic acid/100g

Table 1. Physical and chemical characteristics of the experimental soil

Properties	Values	Properties	Values
Sand (%)	27.6	Ca^{2+} (mg kg^{-1}) soil	331.1
Silt (%)	31.5	K^+ (mg kg^{-1} soil)	427.2
Clay (%)	40.9	Na^+ (meq L^{-1})	13.71
Texture class	Clay- loam	Mg^{2+} (mg kg^{-1} soil)	1203.31
Organic matter (%)	1.02	P (mg kg^{-1} soil)	3.32
$CaCO_3$	17.2	Cl^- (meq L^{-1})	17.62
pH (1:2.5 extract)	7.6	SO_4^{-1}(meq L^{-1})	39.11
EC (dSm^{-1})	1.3	Zn (mg kg^{-1} soil)	0.95
Total N (mg kg^{-1} soil)	99.7	Fe (mg kg^{-1} soil)	24.47

pulp, also total sugars (%), sugar: acid ratio, non-reducing sugar (%), reducing sugar (%), and crude protein (%) were determined according to the methods described in AOAC (2005). Ascorbic acid (Vitamin C) content in the fruit was estimated and expressed as mg of ascorbic acid/100g pulp according to Said et al. (2016).

2.5 Statistical analysis

The data recorded were subjected to statistical analysis by Statistix 9.0 program (Analytical Software, Tallahassee, FL. USA). Mean values were compared by the LSD test at 5% level of probability.

3 Results and Discussion

3.1 Vegetative growth

Results in Fig. 1 showed that all treatments significantly ($P \leq 0.05$) increased length, girth of pseudostem, number of green leaves and third leaf area comparing with the control. On the other hand, it was observed that the humate form of K fertilization had positive effect on vegetative growth parameters compared with sulfate form. Moreover, treatments included foliar sprays of K_2SO_4 had a significant effect with respect to length, girth of pseudostem, number of green leaves and third leaf area compared with treatments without foliar sprays. The higher values of pseudostem length (292.39 cm), pseudostem girth (88.55 cm), number of green leaves (18.02) and third leaf area (2.71 m^2) were obtained when the plants fertilized with 250 g K-humate + 2 % K_2SO_4 foliar sprays, while the lower values of pseudostem length (191.21 cm), pseudostem girth (55.22 cm), number of green leaves (8.30) and third leaf area (1.10 m^2) were recorded with the control plants (Fig. 1).

The increment in growth parameters in response to soil application of potassium humate may be ascribed to its contents of proteins, amino acids, different nutrients, and a higher percentage of vitamin B that can play a crucial role in improving plant growth (Abbasi et al., 2014). It has been reported previously that the soil application of K-humate augmented plant growth parameters on fruit crops (Abd El-Rhman, 2017; Hidayatullah et al., 2018; Aml and Yousef, 2011; Mustafa and El-Shazly, 2015). Furthermore, the increase of banana plants by soil application of K- humate can be ascribed to its contents of auxins (indole-3-acetic acid and indole-3-butyric acid) and cytokinins (Zaki et al., 2014).

3.2 Mineral (NPK%) and chlorophyll content in the leaves

Fig. 2 showed mineral (NPK%) and chlorophyll content in the leaves as significantly ($P \leq 0.05$) affected by K fertilization forms with or without foliar sprays of K_2SO_4. As for nitrogen (N), phosphorus (P) and potassium (K), all treatments increased NPK % content in leaf than the control. However, it is clear that the humate form of K fertilization recorded higher NPK % content in leaf compared with the sulfate form either with or without foliar sprays. Also, it is observed that treatments included foliar sprays significantly raised NPK % content in leaf compared with the same treatments without it, especially with the humate form. Moreover, treatment included 250 g K-humate + 2 % K_2SO_4 as foliar sprays gave the highest value of N (3.38%), P (0.27%) and K (3.96%) in 2019 season (Fig. 2). As for chlorophyll a and b content in the leaves, there was a significant effect for treatments on these parameters, since a gradual increment was observed among the treatments in compared with the control. On the other hand, the humate form show a significant increase compared with the sulfate one. Moreover, treatments included K_2SO_4 as foliar sprays raised chlorophyll a and b especially with K-humate treatment. The highest values of chlorophyll a (1.23 mg g^{-1}) and chlorophyll b (0.40 mg g^{-1}) were obtained when the plants fertilized with 250 g K-humate + 2 % K_2SO_4 foliar sprays, while the lowest values of chlorophyll a (0.54 mg g^{-1}) and chlorophyll b (0.14 mg g^{-1}) were recorded with the control (Fig. 2).

From the previous results, it is clear that K fertil-

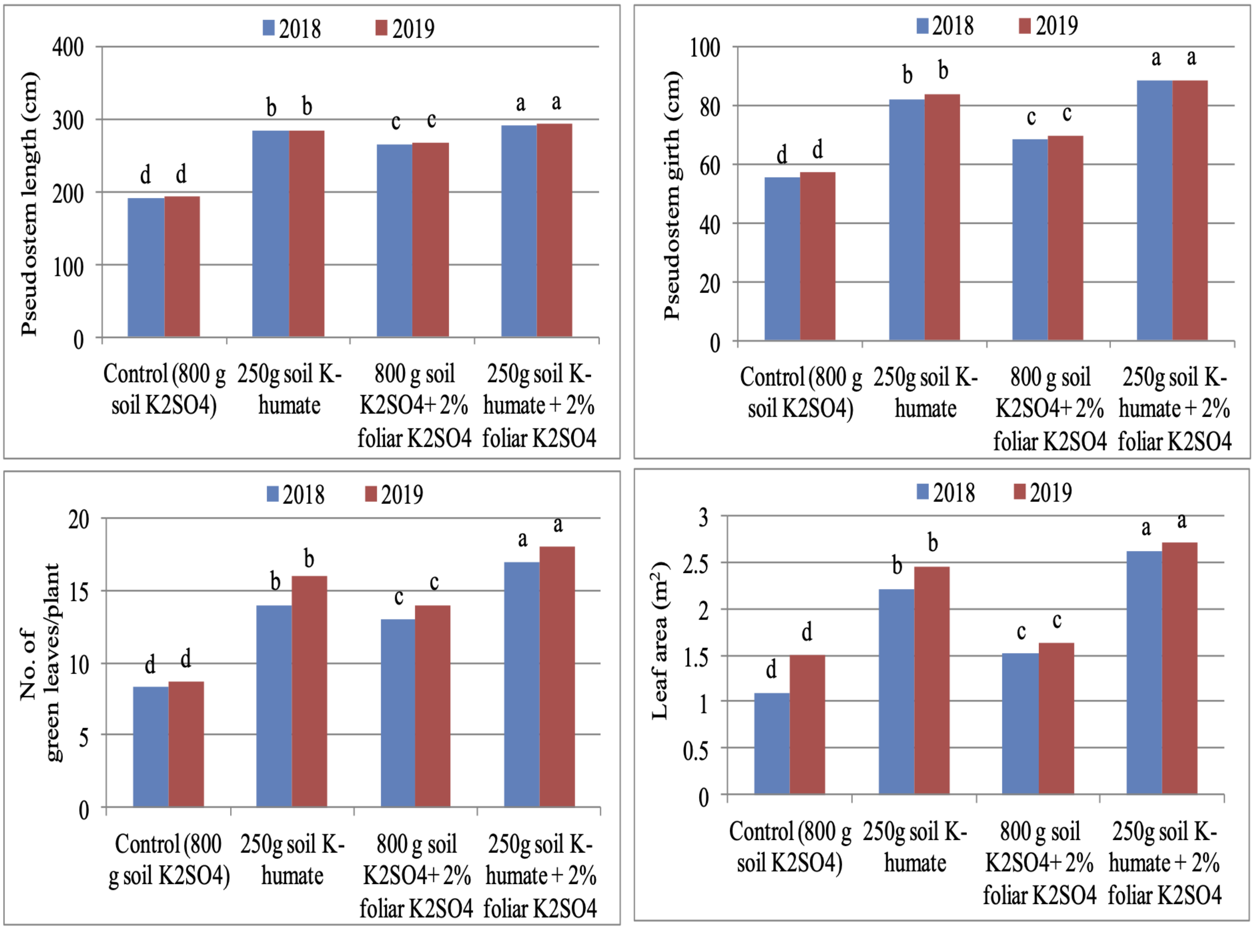

Figure 1. Effect of soil and foliar sprays of potassium on vegetative growth of Grande Naine banana plants. Values in the bars followed by the same letter(s) are not significantly different at 5% level of probability

ization treatments showed a positive effect on NPK % and chlorophyll a and b content in Grande Naine banana leaves. In this respect, the humate form was more pronounced than the sulfate form; also treatments included K_2SO_4 sprays were more effective than those without it. The positive correlation between K-humate treatments and leaf NPK concentration evidenced the beneficial and stimulatory effect of K-humate on NPK availability. The favorable effect of K- humate form on NPK % and chlorophyll a and b content in the leaves may be attributed to the same factors that activated vegetative growth as mentioned previously. These findings are in harmony with those of Abd El-Rhman (2017) on pomegranate, Hidayatullah et al. (2018) on apple and Abo-Gabien (2021) on olive.

3.3 Yield contributing characters and yield

The results presented in Fig. 3, revealed that yield parameters such as period from shooting to harvest, bunch weight, estimated yield per ha, number of hands per bunch, number of fingers per hand, finger weight and pulp peel ratio had significant ($P \leq 0.05$) influence due to K fertilization treatments. The period from bunch shooting (time to flowering) to harvesting date was significantly affected by the different treatments. Treatments included the K-humate form significantly reduced the days taken from bunch shooting to harvest than those fertilized with K sulfate form either with foliar sprays or not. Moreover, treatment included 250 g K-humate + 2 % K_2SO_4 as foliar sprays took the shortest time from bunch shooting to harvest (91.45 days), while control took the longest time (126.01 days).

Also, treatments significantly increased bunch weight and yield in compared with the control. In this respect, the highest significant bunch weight (38.08 kg) and yield (108.41 ton/ha) were recorded when the plants fertilized with 250 g K-humate + 2 % K_2SO_4 foliar sprays (Fig. 3). Moreover, treatments included the K-humate form significantly increased bunch weight and yield than those fertilized with K sulfate form either with foliar sprays or not. On the other hand,

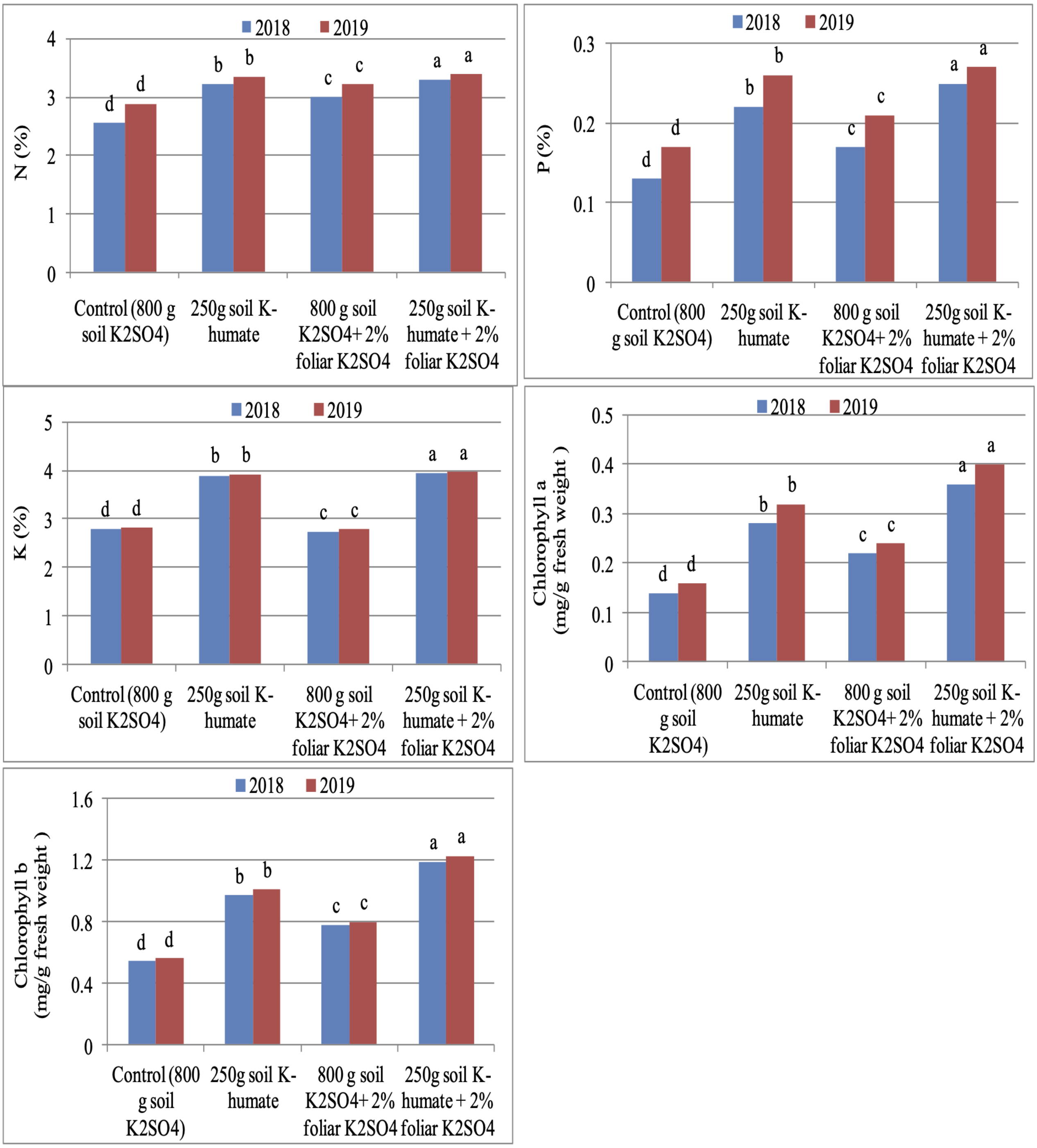

Figure 2. Effect of soil and foliar sprays of potassium on minerals (NPK %) and chlorophyll (a, b) content in Grande Naine banana leaves. Values in the bars followed by the same letter(s) are not significantly different at 5% level of probability

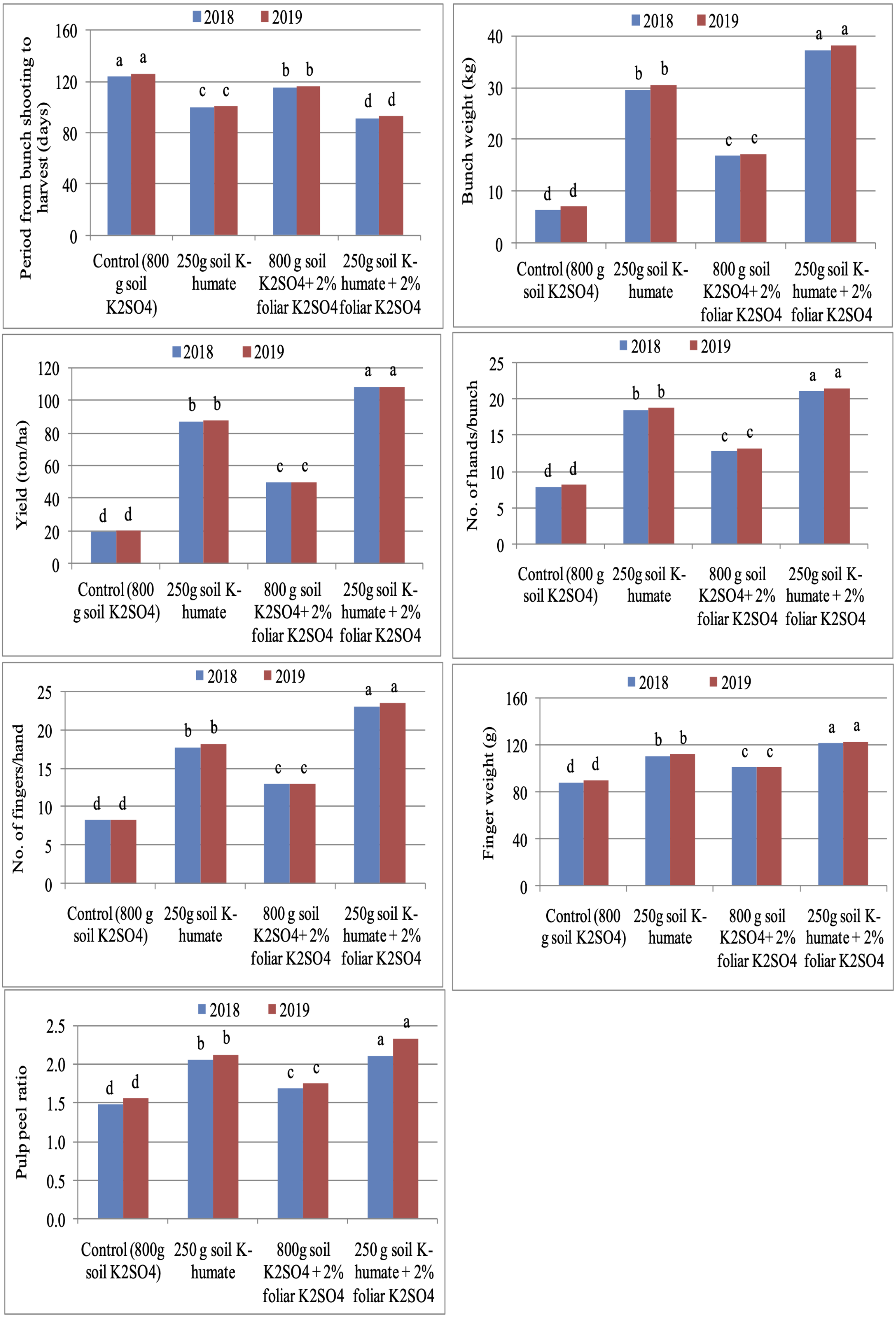

Figure 3. Effect of soil and foliar sprays of potassium on yield and yield contributing characters of Grande Naine banana. Values within each column, followed by the same letter/s are not significantly different at 5% level of probability

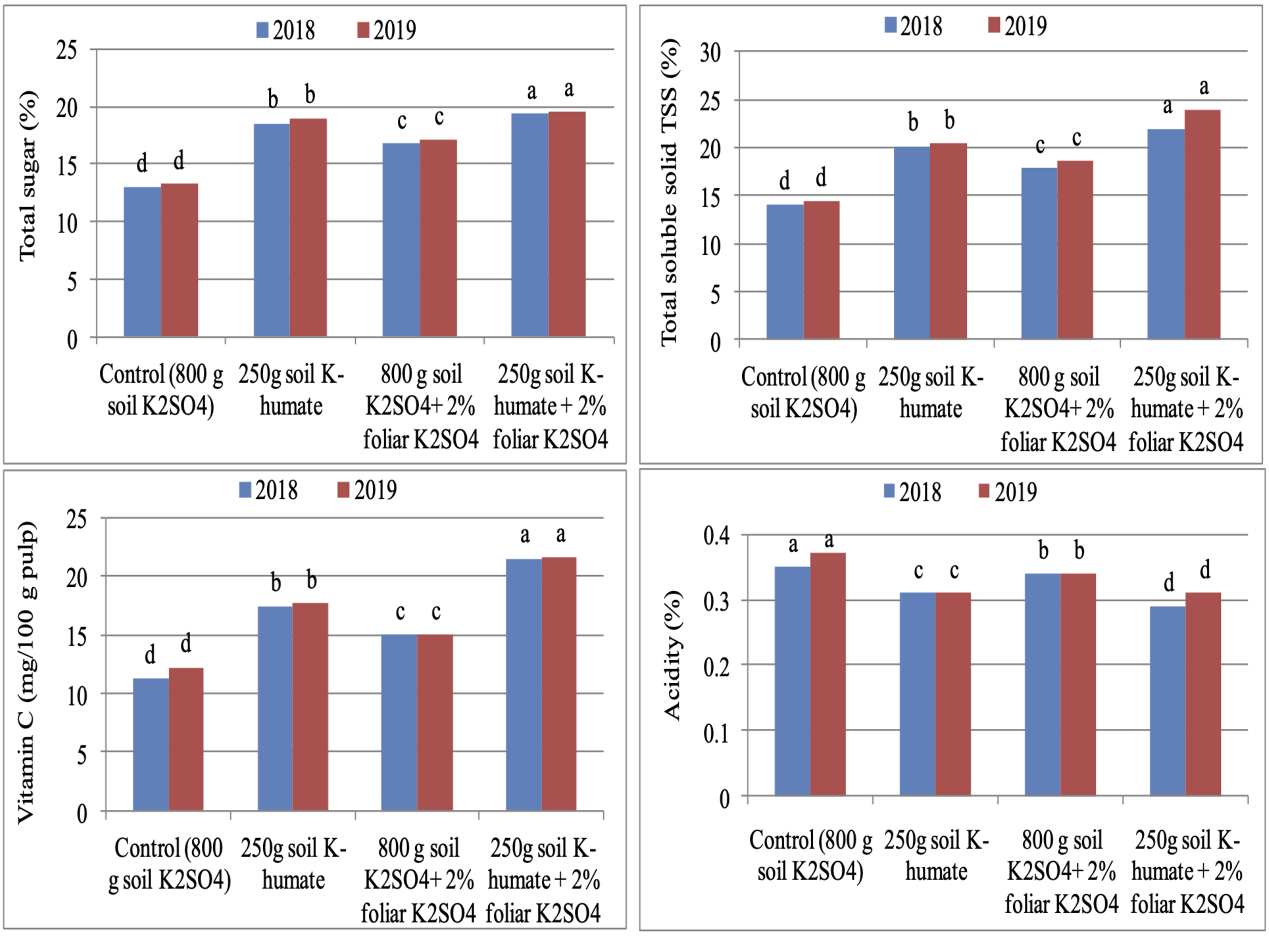

Figure 4. Effect of soil and foliar sprays of potassium on chemical properties of Grande Naine banana fruits. Values within each column, followed by the same letter/s are not significantly different at 5% level of probability

treatments included K_2SO_4 as foliar sprays raised bunch weight and yield especially with K-humate treatment. Similar results were obtained with respect to number of hands and fingers/hand (Fig. 3).

Finger weight was affected by treatments, since all K fertilization treatments significantly increased finger weight (Fig. 3). Significant differences were detected between K fertilization treatments. In this respect, the highest significant finger weight (123.17 g) was recorded when the plants fertilized with 250 g K-humate + 2 % K_2SO_4 foliar sprays. Regarding pulp peel ratio, results indicated that parameter toke the same trend. Since, all treatments significantly increased pulp peel ratio than the control. Also treatment included K-humate form and foliar sprays improved this parameter than those included sulfate form with or without foliar sprays.

3.4 Fruit chemical attributes

Results in Fig. 4 showed that all treatments were significantly ($P \leq 0.05$) improved fruit quality attributes in terms of increasing total sugar percentage, total soluble solid TSS and vitamin C and reducing the acidity as compared to control. On the other hand, K-humate treatments increased total sugar and TSS in comparing with the sulfate treatments, also foliar sprays treatments increased the same parameters than without foliar sprays. Moreover, it is clear that treatments included K-humate + K_2SO_4 foliar sprays gave the highest value for total sugar, TSS and vitamin C content in the fruits. As for acidity %, treatments had no effect on this parameter although there is a decreasing trend through the treatments in comparing with the control. Vitamin C content in the fruits was significantly increased by all treatments than the control and the highest significant value was obtained when the plants fertilized with K-humate and K_2SO_4 foliar sprays (Fig. 4). The highest values of total sugar (19.57%), total soluble solid TSS (23.93%) and vitamin C (21.63 mg/100 g pulp) were obtained when the plants fertilized with 250 g K-humate + 2 % K_2SO_4 foliar sprays, while the lowest values of total sugar (13.05%), total soluble solid TSS (14.13%) and vitamin C (11.35 mg/100 g pulp) were recorded with the control (Fig. 4).

The reason for the significant improvement in yield and fruit quality may be due to the improvement of the vegetative growth of plants. Thus, the processed food items in the leaves were increased and collected in the fruits, and this was reflected positively in the yield, weight of the bunch and finger and pulp thickness (Kumar et al., 2006; Santos et al., 2015; Mohammed and Salman, 2017). These findings are agreed with those of Alva and Obreza (1998) and Abo-Gabien (2021) who reported that humic materials significantly increased orange, grape and olive fruit production. Moreover, there was positive correlation between Grande Naine banana fruit yield and leaf NPK concentration which evidenced the beneficial and stimulatory effect of K-humate on nutrient availability and yield. According to the results, increasing K concentration in leaves increased TSS, sugars, and Vitamin C content in Grande Naine banana fruit. These results agree with those reported by Kumar et al. (2006) on papaya (*Carica papaya* L).

4 Conclusion

From the above mentioned results, it could be concluded that soil potassium fertilization had a positive effect on Grande Naine banana plants with or without potassium spray. However, fertilizing K at humate form was more evident than the sulfate one. Moreover, using K_2SO_4 as foliar sprays was more effective than without it especially when applied with K-humate form. Therefore, the usage of 250 g of K-humate as soil application + 2 % K_2SO_4 as foliar sprays could be recommended to improve the growth, yield and quality of Grande Naine banana under these experimental conditions.

Conflict of Interest

The author declares that there is no conflict of interests regarding the publication of this paper.

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