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Response of Grand Nain Banana Plants to Different Potassium Fertilizer Sources

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ABSTRACT

Finding a rich and natural source of potassium nutrient is a major challenge facing banana cultivation. In this study, four different sources of Potassium: potassium sulphate, slow release (feldspar), bio-fertilizer (yeast & potassin) and potassium thiosulphate were used to evaluate their effects on growth & fruit production of Grand Nain banana cultivar grown at Luxor Governorate condition, Egypt. The results indicated that using yeast or feldspar alone or in combination as a source of potassium and potassin significantly increased all growth aspects, yield and fruit quality compared to fertilize by potassium sulphate (check treatment); Moreover, there were insignificant differences in these studied traits due to fertilize with yeast, feldspar alone or in combination as well as spraying potassium thiosulphate or potassin. Using yeast or feldspar plus yeast were very effective in enhancing all growth aspects, yield, bunch traits and fruit characteristics compared to untreated ones; So, it is evident from the foregoing result that using feldspar or yeast alone or in combination improved the growth, nutritional status and fruiting of Grand Nain banana plants;. In addition, they are beneficial in organic farming production since they improve the soil structure and fertility; also, reduce the cost of production and environmental pollution.

Keywords: Bio-fertilization, Potassium, Feldspar, Fruit quality, Grand Nain Banana, Potassium, Pollution.

INTRODUCTION

Banana (*Musa* sp.) is the fourth largest fruit crop in the world, following grapes, citrus and apple. It is grown over 130 countries across the world in an area 5158582 hectare and producing 116781658 ton of bananas; it plays an important role in tropical economics as cash export and as complementary food in local sets (FAO, 2019).

Banana fruit is important fount of many nutrients having polysaccharides, carbohydrates, vitamins A , B6, C and minerals, as well as positive health properties; in addition to banana reduce the risk of some diseases because of its high levels of antioxidants and biologically active substances. The fruits considered one the most rich source of carbohydrate and energy; it have a great economic importance as one of the most popular fruits in Egypt for its nutritive value, cheap source of energy (El-Salhy *et al.*, 2019). The total acreage of banana increased to 79857 feddan with production 1314177 tons with average of 20.54 ton/feddan according to M.A.L.R. (2016). Potassium is the most essential nutrient in banana production; it's the most cations in banana plant cells.

Potassium fertilization is considered as an essential and limiting factor in the growth and productivity of various banana plants due to the rapid growth rate and large size of banana; it requires more potassium amount for increasing the yield and quality (Nijjar, 1985). Supply macronutrients including potassium by basic practices such as compost and manure application are not a valid option for the sufficient quantity because of its low nutrient content, emitting an unpleasant odor, greenhouse emissions, pathogen hazard (Sánchez *et al.*, 2015). There is a positive and clear link between the yield of bananas and the amount of potassium absorbed (Tan *et al.*, 2006). As plants absorb high nutrient amounts from soil, fertilization is a significant and decreasing factor in the growth and production of banana plants. Potassium, is one of these nutrients, which plays an important role in plants and positive effects on many human health related of fruit quality components (Usherwood, 1985). Potassium is a vital nutrient in banana nutrition, since it is consumed in greater amounts in comparison to other combined nutrients (Turner *et al.*, 1989). The growth and yield of cabbage, celery and lettuce, especially the yield quantity, were significantly affected by the increase in the potassium amount of the nutrient solution (Inthichack *et al.*, 2015). Deficiencies in potassium and nitrogen are the key factors limiting East African highland banana (Nyombi *et al.*, 2010). Potassium fertilization improve yield and quality of olive (Inglese *et al.* 2002; Ben Mimoun *et al.* 2004; Toplu *et al.*, 2009; Abbasi *et al.*, 2012; Malek and Mustapha, 2013 and Rosati *et al.*, 2015)

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The spatial heterogeneity in the deficit of nitrogen and potassium calls for successful agricultural management to increase the productivity of banana in the Ugandan highlands through models that predict the crop response to the supply of water and nutrients (Smithson *et al*., 2001and Wairegi Van Asten, 2010). Potassium alleviates the reduction in dry mass and yield resulting from drought at an early stage of development (Taulya, 2013) It is necessary for physiological and biochemical processes, vital for plant growth, fruiting and stress (Cakmak, 2005).

Banana has a high nutrient demand because it removes a large amount of nutrients from the soil for growth and fruiting; additionally, the high cost of fertilizers is a major challenge for banana growers. On the other hand, the overuse of chemical fertilizers produces polluting agents for the air, soil, and water (Kuttimani *et al*., 2013 and Abdel-Hafiz *et al*., 2016).

Scientists from all over the world have begun to focus their efforts on assuring agrarian sustainability through the use of beneficial soil microbes rather than chemical fertilizers and pesticides (Yadav, and Sarkar, 2019) .

To raise productivity, bio fertilizers provide a scope for an alternative remedy by using the natural and renewable biological resources to meet the nutrient requirement of the plants (El-Salhy, 2004 and Calvo *et al*., 2014). Feldspar rock application caused the release of the macro-elements and converted them to the soluble form of phosphorus, potassium, calcium and magnesium (Fayed, 2005; Baiea *et al*., 2015 and El-Salhy *et al*., 2017). Feldspar is a slow release fertilizers, that microbes can increase the dissolution rate by generating organic (Aisha and Taalab, 2008); in addition, the direct contact between minerals and bacteria may be important in mineral alteration and can enhance K mineral dissolution rate by producing and excreting metabolic (Paris *et al*., 1996 and Sheng & Huang, 2002). Slow release and bio fertilizers have recently been considered an effective instrument for improving the growth and productivity of fruit trees and are a positive substitute for chemical fertilisers. They're healthy for the environment and humans. The use of them was followed by the reduction of the major pollution in our environment, as well as the production of organic food for export (Abdelaal *et al*., 2010; Baiea *et al*., 2015 and El-Salhy *et al*., 2017). Therefore, this study was conducted to investigate the effectiveness of natural and biological fount of potassium nutrient on the development and productivity Grande-Nain Banana cultivar grown at Luxor governorate conditions, Egypt

MATERIALS AND METHODS

Plant material and growing condition

This study was conducted during two successive growing seasons of 2018/2019 fourth ratoon and 2019/2020 fifth ratoon Grande Nain Banana plants grown in clay soil and irrigated by flood system in a private banana orchard located at Armant district, Luxor Governorate at Upper Egypt. Soil analysis was performed to Wilde *et al*. (1985) and the obtained data are presented in table (1). Plant spacing was 3.0x3.5 meters a part and selecting three suckers/hole.

Table 1. Analysis of the tested orchard soil.

Characters	Values	Characters	Values
Particle size distribution:		Total N %	1.064
Sand %	0.0	Available P (mg kg-1)	2.11
Silt %	35	Available K (mg kg-1)	1.94
Clay %	65	Available S (mg kg-1)	1.68
Texture	Clay loam	Available EDTA extractable micronutrients (mg kg-1)	
pH (1:2.5 extract)	6.40	Zn	3.94
EC (1:2.5 extract) dSm-1	0.52	Fe	33.6
O.M %	1.38	Mn	13.8
CaCO3 %	1.50	Cu	31.1

Fertilizer treatments

The experimental plants obtained all the farming practices traditionally used in banana planting. The plants were received compost at the rate of 40 m^3/fed/year with the soil root zone during the first week of December and the recommended fertilizer NPK (600, 100, 600 N, P_2O_5, K_2O actual g/plant). Other horticulture practices such as irrigation, holing and pest control were carried out as usual.

The experiment contained six treatments, as it follows:

1. Application the recommended dose of potassium (RDK) as 1250 g potassium sulphate (600 g K_2O plant/year) (K_1)
2. Spraying potassium thiosulphate 36% (830 ml/plant) (K_2).
3. Spraying potassin 30% (980 ml/plant) (K_3).
4. Application of active dry yeast at 150 g/plant (K_4).
5. Application of feldspar (12% K_2O) at 5 kg/plant (K_5).
6. Application of active dry yeast of 75 g plus feldspars at 2.5 kg/plant (K_6).

Potassium sulphate, potassium thiosulphate and potassin were added at four equal dosages as soil drench or foliar spray at early of March, April, May and June. In addition, feldspar rock contains potassium 12% K_2O at rate of 2.5 or 5 kg/plant as slow release-K in early March of both seasons one trench (40x40x40 cm) was excavated on one side of the plant, The provided quantity of feldspar with surface soil then was blended together and added the check hole and accompanied by the irrigation. As well as, yeast as a bio fertilizer (each 19 contains 12000 yeast cells) was activated before the application by using sugar solution at 5%. The media was left at 30°C for six hours and subjected to freezing and thawing for disruption of yeast tissues and releasing their bio constituents directly before using, according to Barnett *et al*. (1990). Soil application of yeast was carried out once at the first week of March.

Vegetative characteristics:

After the emergence of the inflorescence at the 3rd week of July for both the fourth and fifth rations, the following parameters were studied, vegetative characteristics included pseudostem length (cm), green leaves number of each plant at bunch shooting as well as leaf area (m2) were calculated by the third full leaf sized leaves according to Murray (1959) and calculated as follows: Leaf area (m^2) = length x width x 0.8, then, the assimilation area/plant (m^2) was calculated as follows: Leaf No. x Leaf area

Number of days taken from shooting to harvest (maturity days) was also recorded.

Leaf mineral contents:

The third upper leaf from plant top was used for leaf samples after bunch shooting in September of each season. A sample of 10x10 cm from the middle part of the leaf blade was used as recommended by Hewitt (1955). The samples were dried in the oven at 70 ° C and digested. The clear digestion was quantitatively transferred to 100 ml volumetric flask. In this solution, the following nutrients were determined according to Wilde *et al.* (1985). Micro-Kjeldahl was used to determine the total nitrogen and potassium was determined in the clear digest solution by using a flame photometer.

Yield and fruit quality:

Bunches of banana were picked during the common harvest data during the period from November to January in both seasons which the bunch (or fruits) were suitable (when fingers full mature stage) for harvesting, the artificial ripening for bunches was carried out, then the fruit quality was evaluated.

Bunch weight and two hands were taken from the base, middle and distal end of each bunch as sample for each replicate.

Finger weight (g) and pulp % were recorded. Total sugars, acidity (as malic acid per 100 gram pulp) and total soluble solids percentage was determined pursuant to A.O.A.C. (1995).

Statistical analysis

The experiment included six treatments each treatment replicated three time one hole per each. The experiment was set as completely randomized block design. The obtained data were subjected to the analysis of variance (ANOVA) were according to Gomez and Gomez (1984) and Mead *et al.* (1993). Duncan Multiple range test at 5% of probability level was used to compare the differences between treatment means.

RESULTS AND DISCUSSIONS

Results

Vegetative growth and percentage of N and K in leaves:

Data presented in Figures (1, 2) show the effect of different potassium fertilization sources on the height of pseudostem; number of green leaves/plant and total leaves area/plant and percentage of N and K in leaves of Grande Nain banana plants during 2018/2019 and 2019/2020 seasons. It was clear from obtained data in the two studied seasons, the results had an identical trend; data indicated that all studied pseudostem growth and leaf traits as well as leaf contents of N and K were significantly increased due to spray potassin as well as application yeast or feldspar singly or incombination compared to unsprayed ones. Insignificant differences in these growth characters due to fertilizer with potassin, yeast or feldspar were recorded.

The highest values of pseudostem height (322.60 cm), total leaves area/plant (20.29 m²) and leaf N (2.45%) av. the both studied seasons were documented in plants that applied with yeast (K_4). For all examined growth characteristics, the least values were recorded due to use 100% mineral-K potassium sulphate, (K_1). In ascending order, the recorded leaf area/plant and leaf N and K percent were as follows: $K_1<K_2<K_3<K_5<K_6<K_4$; Hence, the increment percentage of leaves area/plant was attained 8.1, 18.2, 19.4, 12.6 & 13.6% due to use K_2, K_3, K_4, K_5 and K_6 compared to K_1, respectively. Also, using active dry yeast as soil dressing (K_4), induced an increase by 7.07, 7.97, 9.86 & 7.05% in the height of pseudostem, leaf area, leaf-N % and leaf-K %, respectively compared with the use of 100% mineral (K_1), respectively. On the other hand, such fertilization treatment induced a decrease by 8.11% in maturity days compared to K_1 (check treatment).

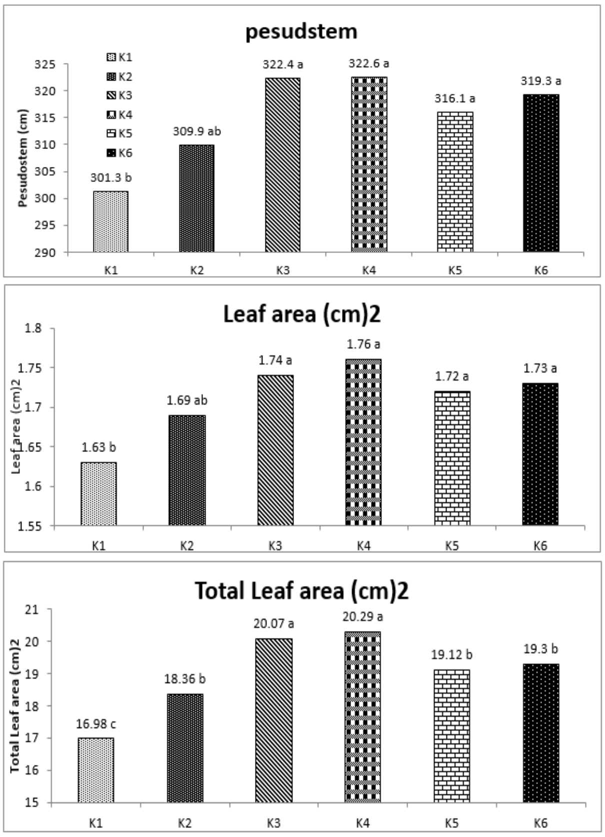

Fig. 1. Vegetative growth of Grande Nain Banana plants affected by different potassium fertilizer sources as a mean of 2018 and 2019 seasons.

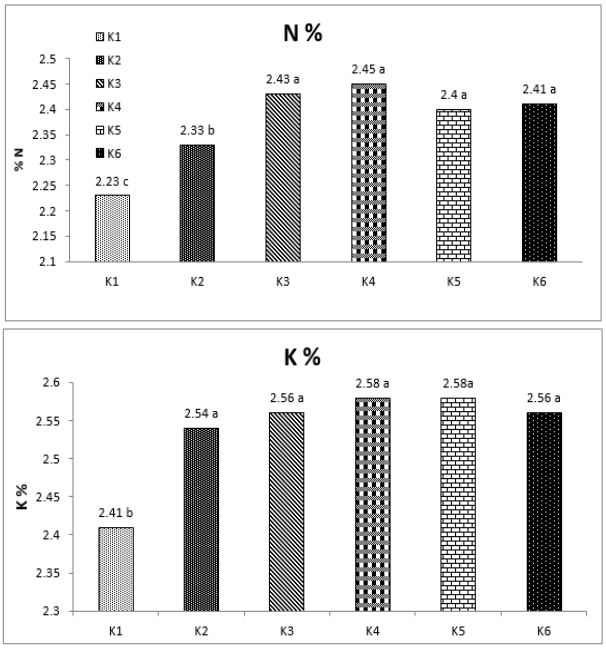

Fig. 2. Concentration of N and K in Grande Nain Banana plants affected by different potassium fertilizer sources as a mean of 2018 and 2019 seasons.

bunch weight:

As presented in Table (2) declared that application of Grande Nain banana plants with different potassium fertilizer sources significantly increased the bunch weight compared to use mineral form only (check treatment, K_1). It is obvious from the data in the previous table that the single or in combination fertilization of Grande Nain banana plants with either yeast or feldspar significantly increased bunch weight compared to the use of the RDK only through mineral-K source (check treatment, K1). There were insignificantly difference in the bunch weight due to use of yeast, feldspar either singly or incombination. The heaviest weight of bunch (27.14 & 27.05 kg as av. the two studied seasons) was recorded on the plants that fertilized by yeast singly or yeast plus feldspar, respectively. The bunch weight values were found in the following ascending order as $K_1<K_3<K_2<K_5<K_6<K_4$, respectively. Then the corresponding increment percentage of bunch weight was attained 5.67, 7.35, 13.23, 13.65 and 14.03 as av. the two studied seasons compared to check treatment, K_1, respectively; therefore, it is clear that fertilization using yeast or feldspar either singly or incombination have beneficial effects on the bunch weigh of Grande Nain banana plants.

Table 2. Effect of different potassium fertilizer sources on the bunch weight, finger weight and maturity days index of Grand Nain fruits during 2019 and 2020 season.

	Bunch weight			Finger weight (g)			Maturity days index		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
K1	23.0C	24.6C	23.80	87.8C	92.6C	90.2	114A	108A	111
K2	24.6B	26.5B	25.55	94.7B	98.8B	96.75	107B	102B	104.5
K3	24.3B	26.0B	25.15	93.4B	98.1B	95.75	108B	103B	105.5
K4	26.4A	28.4A	27.14	100.8A	105.5A	103.15	105B	99B	102.0
K5	26.4A	27.5A	26.95	97.6A	102.7A	100.15	106B	100B	103.0
K6	26.3A	27.8A	27.05	99.0A	104.5A	101.75	106B	100B	103.0

Means followed by the same letter(s) in the same column are not significantly different using Duncan's Multiple Range Test at 5% of Probability

K_1- Application the recommended dose of potassium (RDK) as 1250 g potassium sulphate (600 g K_2O plant/year).

K_2- Spraying potassium thiosulphate 36% (830 ml/plant).

K_3- Spraying potassin 30% (980 ml/plant).

K_4- Application of active dry yeast at 150 g/plant.

K_5- Application of feldspar (12% K_2O) at 5 kg/plant.

K_6- Application of active dry yeast of 75 g plus feldspars at 2.5 kg/plant.

Fruit quality:

Data in Tables (2 & 3) indicate that various sources of potassium fertilizers were significantly improved fruit quality in terms of increasing finger weight, pulp %, total soluble solid % and sugar contents and reducing the total acidity compared to use potassium sulphate (check treatment). It is evident from the data in Tables (2 & 3) that using potassin spraying or yeast, feldspar singly or incombinatioin significantly enhances the quality of fruit in terms of rising finger weight, pulp %, TSS % and sugar contents and decreasing the total acidity compared to use the recommended dose of potassium (RDK) via mineral-N source only. Moreover, there were insignificant differences in these studied traits due to fertilize with yeast, feldspar or yeast plus feldspar. Treating the plants with active dry yeast gave the highest values of fruit traits.

Table 3. Effect of different potassium fertilizer sources on some traits of Grand Nain fruits during 2019 and 2020 season.

	Pulp %			TSS %			Total sugar %			Acidity		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
K1	62.54B	63.17B	62.86	17.33B	17.86B	17.60	15.64B	15.89B	15.77	0.163A	0.171A	0.167
K2	65.0AB	65.51AB	65.31	18.21A	18.73A	18.47	16.66A	16.88A	16.77	0.148B	0.150B	0.147
K3	65.68A	65.68AB	65.68	18.27A	18.56A	18.42	16.60A	16.78A	16.69	0.138B	0.145B	0.142
K4	67.10A	67.13A	67.12	18.69A	19.06A	18.88	17.10A	17.25A	17.18	0.159B	0.143B	0.141
K5	66.63A	67.05A	66.84	18.47A	18.80A	18.64	16.90A	17.05A	16.98	0.138B	0.144B	0.141
K6	66.52A	66.92A	66.72	18.41A	18.71A	18.56	16.83A	16.85A	16.84	0.139B	0.144B	0.142

Means followed by the same letter(s) in the same column are not significantly different using Duncan's Multiple Range Test at 5% of Probability

Moreover, there were insignificant differences in these fruit traits due to using yeast, feldspar either singly application or incombination. The recorded finger weight was 90.2, 96.75, 95.75, 103.15, 100.15 & 101.75 g av. two studied seasons due to K_1, K_2, K_3, K_4, K_5 and K_6, respectively. Whereas, the increment percentage of finger weight attained 7.26, 6.15, 14.36, 11.03 & 12.8 av. the two studied seasons due to K_2, K_3, K_4, K_5 and K_6 over K_1 (check treatment), respectively. The correlating TSS% 17.60, 18.47, 18.42, 18.88, 18.64 & 18.56% av. the two studied seasons, respectively; Hence, the increment percentage of TSS% was attained 4.94, 4.66, 7.27, 5.91 & 5.45% due to K_2 to K_6 compared to K_1 (check treatment), respectively. Subsequently, the cost wise evaluation of the application of these potassium sources is in favor of natural source (feldspar) or bio-form (yeast or potassin). Such fertilization program is important for the production of banana fruits, since the improve of the fruit quality induces and increase the packable yield; in addition, such fertilization treatments reduce the cost of production and environmental pollution.

The effects of different potassium sources applications on the influence of correlation of various indicators were observed under different treatments in Fig. 3, it revealed that K%, total soluble solid, and pulp% were positively correlated with each other, pseudo-stem high and total leaves area are close together, reflecting their relatively large positive correlation. The K5 and K6 treatments, that are slightly above the positive horizontal axis, those are close to the direction defined by K%, total soluble solid are not far from the directions of pulp%, which implies that they should have higher than average scores on these three variables. Whereas, the K1 and K2 treatments have a limited effect on all traits.

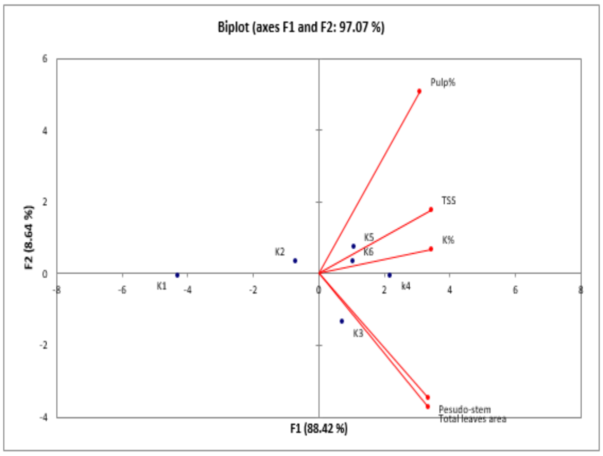

Fig. 3. Principal component analysis of different indicators in growth and fruit quality of Grand-Nine Banana Plants treated with K1- Application the recommended dose of potassium (RDK) as 1250 g potassium sulphate (600 g K2O plant/year); K2- Spraying potassium thiosulphate 36% (830 ml/plant); K3- Spraying potassin 30% (980 ml/plant); K4- Application of active dry yeast at 150 g/plant; K5- Application of feldspar (12% K2O) at 5 kg/plant; K6- Application of active dry yeast of 75 g plus feldspars at 2.5 kg/plant.

Discussion

Chemical fertilizers cause environmental problems that farmers are concerned about, bolstering the case for adopting of environmentally friendly agricultural practices.

The study's findings revealed that all potassium sources improved banana plant growth and yield. Given the drawbacks of mineral fertilizers, the use of biofertilizers, whether potassin or yeast, as well as feldspar as a natural potassium source, is required to overcome these drawbacks in conservative agriculture.

Vegetative growth parameters of banana plants were improved by application of all potassium fertilizers. The positive effects of potassium fertilizer on plant growth were demonstrated on several crops (Delfine *et al*., 2005, El-Shall *et al*. 2010, Canellas *et al*., 2013; Puglisi *et al*., 2013, Caporale *et al*. 2018; Olivares *et al*., 2015 and Ekin, 2019)

The increase of plants growth, under application of potassium fertilizer may be due to In the photosynthesis feature, K plays an important role and the availability of supplemental K results in increasing the net photosynthetic rate and plant yield Marschner (1995). Basker *et al*., 1992 found that improved K uptake could be due to higher soil K availability. Potassium is essential in the structure and function of carbohydrates, proteins, fats, chlorophyll and in safe the plant cell under salt stress (Marschner, 1995)

Potassium activates many different enzymes involved in plant growth and vigor improves qualitative aspects of production such as color, taste, consistency and preservation of many fruits (Dhillon *et al*., 1999).

The feldspar as a slow release-K gave a significant advantage if the release continues over a number of years. The residual material after the release of potassium and other nutrients easily gets soil fertility. Nutrients from feldspar release at a rate that allows them to remain in the soil top to be utilized by plants. The feldspar effects due to its role as a potassium source, which it activates a lot physiological process as occur in plant such as maintaining cell organization, cell hydration and permeability. It activates many enzymes system such that occur in protein synthesis and formation of carbohydrate (Nijjar, 1985; Tamim *et al*., 2000 and El-Salhy *et al*., 2017). There are many studies that showed the positive effect of yeast on growth and yield characteristics in different crops (Nakayan *et al*., 2009; Wali Asal 2010; Agamy *et al*. 2013 and Dima, *et al*. 2020). Ferweez and Abd El-Monem 2018 reported that, combining application of potassium fertilizer and yeast increased yield, quality and profitability of sugar beet. The beneficial effect of yeast is due to its role in increasing nutrient availability for plants, as well as its content of macro and micronutrients, growth regulators, and vitamins (Mirabal Alonso, *et al*., 2008 and Hesham & Mohamed, 2011). In addition, yeast increasing nutrient use efficiency and nutrient uptake (Du Jardin, 2015).

Also, active dry yeast contains different nutrients, higher percentage of proteins, vitamin B and natural plant growth hormones that activated photosynthesis (Moor, 1979; Abou-Zaid, 1984; Barnett *et al*., 1990 and El-Salhy *et al*., 2019). The abovementioned findings are in accordance with those obtained by Mahalakshmis and Sathiyamoorthy 1999; Kumar *et al*. 2008; Al-Harthi and Al-Yahyai 2009; Badgujar *et al*. 2010; Ganeshamurthy *et al*. 2011; Roshdy 2016; Fratoni *et al*. 2017 and El-Salhy *et al*. 2019.

CONCLUSION

From this study, it could be concluded that using feldspar as, slow release K and active dry yeast or potassin as bio-form of potassium improve the fruit quality leading to increase in the packable yield. In addition, it minimizes the production costs and environmental pollution, which could be occurred by excess of chemical fertilizers. These advantages will eventually enable growers to obtain high yield with good fruit quality. Furthermore, using organic and bio-fertilization sources improve the soil fertility and reduce the added fertilizer requirements. Thus, the growers are able to produce organic farming products.

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استجابة نباتات الموز جراندنان لمصادر مختلفة من التسميد البوتاسي

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يعتبر ايجاد مصدر طبيعي غني بالبوتاسيوم تحدي كبير يواجه زراعة الموز، لذلك تم فى هذه الدراسة استخدام اربعة مصادر مختلفة من التسميد البوتاسي (سلفات البوتاسيوم، اسمدة بطيئة التحلل(فلدسبار)، اسمدة حيوية (الخميرة و البوتاسين)، ثيوسلفات البوتاسيوم) لدراسة تاثيرها علي النمو وانتاجية الثمار لصنف الموز جراندنان خلال موسمي 2018-2019 و 2019 -2020 تحت ظروف محافظة الاقصر ، مصر. اوضحت النتائج ان استخدام الخميرة او الفلدسبار منفردة او خلطا او البوتاسين كمصدر للتسميد البوتاسي ادي الي زيادة معنوية في جميع صفات النمو، المحصول وجودة الثمار مقارنة بالتسميد بسلفات البوتاسيوم (كنترول) . لذلك، يتضح من نتائج هذه الدراسة ان استخدام الفلدسبار او الخميرة منفردة او خلطا يحسن النمو والحالة الغذائية والمحصول لنباتات الموز جراندنان، اضافة الي اهميتها في الزراعة العضوية لانها تحد من تلوث البيئة كما انها تقلل تكاليف الانتاج.