Optimizing Nitrogen and Potassium Dose to Enhance Growth and Productivity of Three Banana Cultivars Grown in Sandy Soils

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ABSTRACT

This study was conducted during the 2022-2023 / 2023-2024 seasons on a private farm on the Alexandria Desert Road, to determine banana plant needs for nitrogen and potassium fertilization for three banana cultivars (Rahan, Jaffa, and Grand Naine), and to evaluate their effect on growth and yield. The analysis of the results shows a large variation in the studied measurements. The obtained results showed that the low concentrations of potassium (K_2O-400 and K_2O-800) had the advantage in the measurements of the length and weight of bunch and the number of hands/bunch. While the medium nitrogen treatment (N-600) was the highest in weight, length and pulp weight. We also find that most of the measurements of the control treatment recorded the lowest significant growth or yield characteristics. Also, the use of the highest concentration of nitrogen (N-900) had the lowest measures. Regarding the response of the cultivars, we find that in the measures of growth, the Rahan cultivar was the most responsive, unlike the Grand Naine cultivar, which were less significant in most measurements. On the contrary, in the yield measurements, we find that the Rahan cultivar was the lowest significant and the Jaffa cultivar was the most responsive. While the Grand Naine cultivar had the advantage in some characteristics, such as length, weight and pulp weight. Rahan cultivar was the lowest in the weight and length of the bunch. It can be confirmed that the use of different levels of nitrogen and potassium fertilizers had a significant and positive effect in the development stages.

Keywords: **Enhance growth- *Musa sp*. Productivity- Optimizing- Nitrogen and Potassium dose.**

INTRODUCTION

Banana (*Musa sp*.), Musaceae family is valuable fruit crops worldwide, and one of the most popular fruits in Egypt and has a significant economic impact. Banana is highly appreciated by consumers due to its delicious taste and excellent nutritional value and low cost of energy. According to M.A.L.E (2016), the total area of bananas expanded to 79857 faddan, producing 1.35 million tons. Plants can easily obtain nutrients from soilless mineral sources; nevertheless, this might lead to a surplus of nutrients in the soil, causing losses and hindering root development Rosolem and Steiner (2017) and Yang et al. (2017). To minimize nutrient losses and maximize fertilization effectiveness, banana orchards are fertilized five times a year Livramento and Negreiros (2017). Banana growth, yield and fruits quality are highly depending on cultivar genotype, climate conditions, and cultural practices Arvanitoyannis and Mavromatis (2009) and Nofal and Rezk (2021). Nutrition management is one of the most important factors affecting banana yield, and fruit quality Thangaselvabai and Suresh (2009). Nitrogen, phosphorus and potassium are the primary nutrients in commercial fertilizers; each of these nutrients plays a key role in plant nutrition Osman (2013). Engels and Marschner (1995), mentioned that N has a favorable impact on protein synthesis, respiration, and photosynthesis in plants and is essential for enhancing growth. Nitrogen (N) is the nutrient that is most easily absorbed during both the vegetative and reproductive phases, Ibrahim, (2003) and Al-Harthi and Al-Yahyia, (2009). According to Obreza, (2003) and Abbas and Fares, (2008) potassium is also essential for fruit formation and can improve fruit size, flavor, and colour. Meanwhile, Alva et al. (2006) mentioned that potassium is essential for many physiological processes, including the synthesis of proteins, the formation of sugars and starches. In this context, the plant's growth parameter was increased by increasing N and K fertilization levels, and it responded well to higher K treatment after flowering Chandrakumar et al., (2001). Also, the responses of banana plants to fertilization with potassium and nitrogen were examined Fratoni et al. (2017), found that the foliar K, magnesium (Mg), and copper (Cu) content of plants growing in the humid

tropical Amazon were significantly impacted by the K_2O application, the foliar N and S content was significantly influenced by the N rates. According to Jambingum et al. (2011), greater rates of K_2O application also considerably enhanced the pseudo stem height, girth, leaf area, sucker generation, early flowering, and maturity with well-graded bunches. Also, the plant's growth parameter was enhanced by the increased N and K fertilization levels, and it responded favorably to increased K application following flowering Chandrakumar et al. (2001). Banana growth parameters are impacted by fertilizers with high nitrogen and potassium content, using these two fertilizers separately or in combination was also the best way to produce the best growth and yield performance in bananas Islam et al. (2020). Meanwhile, it was better to use three different sources of nitrogen instead of just mineral-N Gouda et al. (2021). According to Hossain and Haque (2013), increasing the amount of N in combination with uniform doses of P_2O_5 and K_2O per plant led to enhanced vegetative development, and increase plant height, pseudo-stem girth and produces greater yield Jagirdar and Ansari (2016). A different dose of N and K_2O per 'Nanico IAC 2001' and 'Grand Naine' bananas, achieved the maximum yield, while 'FHIA 17' bananas showed a low response to nitrogen and potassium fertilization Nomura et al. (2017). El-Mehrat et al. (2017) found that banana growth, yield, and fruit quality were increased by applying potassium silicate and/or organic fertilizers (compost) with less mineral fertilizer. For commercial banana plantations, dosages of 200 kg N, 80 kg P_2O_5, and 400 K_2O are typically advised Bley et al. (2017) and Umesha et al. (2017). This study was conducted to determine the extent of the banana plant's nitrogen and potassium fertilization requirements for three banana cultivars grown in Egyptian soil, assess their effect on growth, yield and fruit quality.

MATERIAL AND METHODS

- Experimental location and soil properties.

The current experiment was carried out on three banana cultivars (Rahan, Jaffa, and Grand Naine) planted on a private orchard (52 km along Cairo, Alex's desert route) over two seasons of 2022-2023 and 2023-2024 to study the effects of varying nitrogen and potassium fertilizer levels on the growth and yield of bananas. The water salinity in the experimental field was less than 600 ppm, and the soil texture is sandy had pH 8.7 with 1.09% organic matter, N (0.78 µg/kg soil), P (20.9 ppm) and K (43.83 ppm).

- Materials and treatments.

Control treatment beside three levels of nitrogen are used as mineral materials (N1= 300g, N2= 600g, and N3= 900g) NH_4NO_3/plant and three levels of potassium were (K1=400g, K2=800g 0, and K3=1200g) K_2O/plant/year.

- Experimental layout and design.

The banana was planted on 15th of March 2022 following which the plants were spaced at 4.5m apart and the spacing between plants was 2m, the total number of plants was 933 plants/ fed.

Banana plants were planted in 60 cm by 60 cm by 60 cm pits on March 15, 2022 All the horticultural practice including weeding, watering, and pest control were done when they were needed to improve the growth and development of banana plants. All recommended fertilizers were added to each pit before ten days of planting, except for nitrogen and potassium.

The method of fertilization is carried out throughout the irrigation period amounts are distributed according to the irrigation days followed in the farm's irrigation program, whenever possible. The fertilization is mixed in a 1000-liter tank, nitrogen (NH_4NO_3 33%) and potassium (K_2O 50%) were added in the period from the beginning of planting on 15/March until 15/December the treatment plan is as in **Table (1).**

Table (1). Application system of treatments Nitrogen and Potassium fertilization.

	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
% N/Plant/year	25	25	20	10	10	5	5	-	-	-	100%
% K_2O/Plant/year	-	-	-	5	5	10	10	20	25	25	100%

- Data Collection

When the fingers were fully grown and developed, bunches were picked. The harvest began in January and continued through February.

Data were collected from three plants selected at random. Data were recorded on morph-physiological parameters namely: pseudo-stem height (cm), pseudo-stem girth (cm), total number of leaves at bunch shooting per plant, leaf area at bunch shooting (cm^2) of the third full-sized leaf (from the top) were calculated using the equation = leaf length (cm) × leaf width (cm) × 0.8 Murry, (1960) and assimilation area at bunch shooting per plant (cm^2) was determined using the equation= leaf area × number of green leaves Ibrahim, (1993). Fruit physical characteristics such as: bunch weight (kg/plant), bunch length (cm), number of hands per bunch, finger weight (g), finger length (cm) by measuring the length of the finger with the pedicel, and pulp weight (g), was done by weighing all fingers of each hand than the average weight of each finger/fruit in (g) was calculated.

- Analytical statistics

The field was designed using the randomized complete block design (RCBD) with three replications for each treatment, significance of the differences between the various treatments were determine using new LSD test at 5% Steel, *et al*., (1997), carried out using the statistical program (Statistix 8.0). Using XLSTAT (Addinsoft, version 23.5.1227), PCA and cluster analysis were carried out to find parameters with larger contributions to total variability Jolliffe, (2002). Hierarchical cluster analysis Saraçli, *et al*., (2013) was also carried out and presented in a heatmap.

RESULTS AND DISCUSSION

1. Morph-physiological parameters.

1.1. Pseudo-stem height (cm):

Results in **Table (2),** indicated that the highest significance pseudo-stem height was recorded with (N-300) treatment, reaching (249.2 and 252.2 cm) in both seasons, respectively. While, the control treatment recorded the lowest significant (197.7 and 191.1 cm) through both seasons, respectively.

In the same measurement, significantly the highest pseudo-stem height was recorded for the variety Rahan (244.5 and 245.5 cm) in the two seasons, respectively. The lowest significant was for the Jaffa cultivar in the two seasons (228.9 and 225.1 cm) respectively.

Regarding the interaction coefficients between nutrient dose and cultivar treatment (N-300) gave the highest significant pseudo-stem height (276.3 and 287.6 cm) in the two seasons respectively in Rahan cv., while the lowest height in two seasons, was recorded for control treatment (172 and 160.6 cm) respectively with the same cultivar.

This finding is consistent with that of Islam et al. (2020), who found that significant variation between different fertilization treatments; the individual and combined application of N and K fertilizers had a direct impact on the pseudo-stem heights of bananas. At 210 days after planting, the maximum pseudo-stem height was recorded with N=500g urea/plant, which was statistically distinct from other N treatments. On the other hand, the smallest pseudo-stem height was measured with N (300g urea/plant). Additionally, the growth parameters of plants were improved by N and K fertilization levels (Chandrakumar et al., 200, Naresh et al., 2004 and Jambulingum et al., 2011).

1.2. Pseudo-stem diameter (cm):

The results showed that the highest significant value of pseudo-stem diameter was

recorded for the (K_2O-800) treatment, which scored (82.2 cm) in the first season and (77.2 cm) in the second season, and the lowest results was for the control treatment (58.2 and 62.2 cm) in both seasons, respectively.

Table (2). Effect of fertilization treatments of different nitrogen and potassium on the pseudo-stem height and diameter (cm), total number of leave at bunch shooting per plant, leaf area at bunch shooting (cm^2) and Assimilation area at bunch shooting per plant (cm^2) of Rahan, Jaffa and Grand Naine banana cultivars in the two seasons (2022-2023 and 2023-2024).

Treatments	First season (Mother plant)				Second season (Second ratoon)			
	Cultivars			Mean A	Cultivars			Mean A
	Rahan	Jaffa	Grand		Rahan	Jaffa	Grand	
1- Pseudo-stem height (cm)								
Control	172.6	219.0	201.6	197.7^{C}	160.6	211.3	201.3	191.1^{C}
N-300	276.3	232.3	239.0	249.2^{A}	287.6	231.6	240.3	252.2^{A}
N-600	260.0	223.0	261.3	248.1^{A}	258.0	218.3	275.6	250.6^{A}
N-900	269.0	248.0	207.6	241.5^{A}	265.6	238.3	194.3	232.7^{B}
K_2O-400	232.6	228.3	237.6	232.8^{B}	245.0	229.3	222.6	232.3^{B}
K_2O-800	253.0	220.0	252.3	241.7^{A}	254.0	220.0	238.0	237.3^{B}
K_2O-1200	248.0	231.6	240.0	239.8^{AB}	247.6	226.6	241.0	238.4^{B}
Mean B	264.5^{A}	228.8^{C}	234.2^{B}	A*B=21.67	245.5^{A}	225.1^{C}	230.4^{BC}	A*B=16.12
2- Pseudo-stem diameter (cm)								
Control	62.6	56.6	55.3	58.2^{D}	55.3	63.6	67.6	62.2^{D}
N-300	86.0	72.3	75.6	78.0^{AB}	85.0	71.0	70.6	75.5^{AB}
N-600	72.6	71.6	68.6	71.0^{C}	75.6	71.6	74.6	74.0^{AB}
N-900	76.3	78.6	73.3	76.1^{ABC}	75.3	78.0	74.0	75.7^{AB}
K_2O-400	67.6	76.0	73.6	72.4^{BC}	65.0	75.3	61.6	67.3^{C}
K_2O-800	88.3	81.3	77.0	82.2^{A}	86.6	81.0	64.0	77.2^{A}
K_2O-1200	78.3	71.3	66.0	71.8^{C}	78.3	73.3	65.3	72.3^{B}
Mean B	76.0^{A}	72.5^{A}	69.9^{B}	A*B=10.87	74.4^{A}	73.4^{A}	68.2^{B}	A*B= 7.93
3- Number of leave at bunch shooting per plant								
Control	11.0	13.0	11.6	11.8^{A}	12.6	12.0	11.0	11.8^{C}
N-300	13.6	13.0	11.3	12.6^{A}	13.6	13.3	15.0	14.0^{AB}
N-600	15.0	13.0	12.3	13.4^{A}	15.3	15.0	13.0	14.4^{A}
N-900	14.0	13.3	12.0	13.1^{A}	13.3	15.6	11.3	13.4^{B}
K_2O-400	15.0	14.0	11.0	13.3^{A}	16.0	11.6	11.0	12.8^{BC}
K_2O-800	15.3	14.3	10.6	13.4^{A}	15.6	17.0	12.0	14.8^{A}
K_2O-1200	16.0	12.3	10.0	12.3^{A}	15.3	12.0	12.0	13.1^{B}
Mean B	14.2^{A}	13.2^{A}	11.2^{B}	A*B= 3.67	14.5^{A}	13.8^{B}	12.2^{C}	A*B= 1.80
4- Leaf area at bunch shooting (cm^2)								
Control	6.2	6.7	6.4	6.4^{C}	7.5	6.6	7.6	7.2^{F}
N-300	12.0	10.5	11.0	11.1^{A}	12.0	10.5	11.6	11.3^{AB}
N-600	13.3	12.1	10.8	12.1^{A}	13.2	11.7	10.5	11.8^{A}
N-900	13.1	10.1	10.5	11.2^{A}	11.5	10.6	10.3	10.8^{BC}
K_2O-400	9.6	7.1	10.8	9.2^{B}	9.3	7.4	9.3	8.7^{E}
K_2O-800	9.7	7.7	11.5	9.6^{B}	10.5	8.1	12.0	10.2^{CD}
K_2O-1200	10.4	7.7	10.5	9.5^{B}	10.6	8.0	10.4	9.6^{DE}
Mean B	10.6^{A}	8.8^{B}	10.2^{A}	A*B= 2.20	10.6^{A}	9.0^{B}	10.2^{A}	A*B= 1.57
5- Assimilation area at bunch shooting per plant (cm^2)								
Control	68.2	87.1	74.2	76.5^{C}	94.5	79.2	83.6	85.8^{E}
N-300	163.2	136.5	124.3	141.3^{AB}	163.2	139.6	174.0	158.9^{A}
N-600	199.5	157.3	132.8	163.2^{A}	201.9	175.5	136.5	171.3^{A}
N-900	183.4	134.3	126.0	147.9^{AB}	152.9	165.3	116.4	144.9^{B}
K_2O-400	144.0	99.4	118.8	120.7^{B}	148.8	85.8	102.3	112.3^{D}
K_2O-800	148.4	110.1	121.9	126.8^{B}	163.8	137.7	144.0	148.5^{B}
K_2O-1200	166.4	94.7	105.0	122.0^{B}	162.1	96.0	124.8	127.6^{C}
Mean B	153.3^{A}	115.7^{B}	114.7^{B}	A*B=43.88	155.0^{A}	125.6^{B}	125.9^{B}	A*B=16.12

While, the highest value was recorded for both Rahan and Jaffa cultivars in both seasons with non-significant differences between them, and the lowest significant was for the cultivar Grand Naine in both seasons (69.9 and 68.2 cm) respectively.

The highest pseudo-stem diameter recorded in (K_2O-800) treatment with the Rahan cultivar, (88.3 and 86.6 cm) respectively in the two seasons. The lowest significant value recorded for the control treatment (55.3 cm) with the Grand Naine cultivar in the first season and the Rahan cultivar in the second season was (55.3 cm).

These findings show that nitrogen and potassium improve the banana pseudo-stem diameter. According to Chandrakumar et al. (2001), the growth of pseudo-stem girth was enhanced by higher N and K fertilization levels. Saleh (2001) and Shailendra et al. (2015) reported similar outcomes in their field trials when they applied 200g N/plant. Also, Islam et al. (2020) discovered that applying 500g urea/plant produced the largest pseudo-stem width while applying 300g urea/plant produced the lowest pseudo-stem height. However, there were notable differences in pseudo-stem girth with varying potassium treatment doses.

1.3. Total number of leaves at bunch shooting per plant:

Table (2), showed that, there is non-significant differences in number of leaves at bunch shooting per plant in the first season between all treatments, the highest measurement of the number of leaves at bunch shooting per plant was recorded with (N-600 and K_2O-800) treatments which was also, non significant in the second season.

The highest measurements were recorded for the (K_2O-1200) treatment with the Rahan cultivar in the first season, and the (K_2O-800) treatment for the Jaffa cultivar in the second season. The lowest value was recorded for the Grand Naine cultivar with the (K_2O-1200) treatment in the first season and with the control treatment in the second season.

Here, it becomes clear that the cultivar's response to the elements used in the study plays an effective role in number of leaves. This conclusion conforms to Srinivas et al. (2001) who found that the number of functional leaves per plant increased with the increase in N and K fertilization. Also, Islam et al. (2020) reported that different levels of nitrogen and potassium fertilizer significantly influenced the total number of leaves per plant. The highest number of leaves per plant was found with N (500g urea/plant) treatment and the lowest number of leaves per plant was found with N (300g urea/plant) treatment. This result is in agreement with Venkatesam et al. (2017) and Teixeira et al. (2001) as they, reported a rise in the number of green leaves in conjunction with an increase in the supply of nitrogen and potassium.

1.4. Leaf area at bunch shooting (cm^2):

Results illustrated in **Table (2)** showed that there was a non-significant difference in leaf area at bunch shooting between the three nitrogen treatments. Likewise, the three potassium treatments recorded similar results and there was non-significant difference in the first season. While, the highest significant value was recorded for the (N-600) treatment, which was (12.1and 11.8 cm^2) and the lowest significant was for the control treatment was (6.4 and 7.2 cm^2) in the two seasons, respectively.

The highest significant value was recorded for the Rahan cultivar, (10.6 and 10.6 cm^2) in the two seasons, respectively, and the lowest significant value was recorded for the Jaffa cultivar, with a value of (8.8, and 9.0 cm^2) in the two seasons, respectively.

The (N-600) treatment of the Rahan cultivar recorded the highest significant, which was (13.3 and 13.2 cm^2) in the two seasons, respectively. The control treatment recorded the lowest significant value in the first season with the Rahan cultivar (6.2 cm^2) and with the Java cultivar (6.6 cm^2) in the second season.

1.5. Assimilation area at bunch shooting per plant (cm^2):

The results showed that the highest significant values for the assimilation area recorded for the (N-600) treatment (163.2 and

171.3 cm^2) in the two seasons, respectively, and the least significant was recorded for the control treatment (76.5 and 85.8 cm^2) in the two seasons, respectively.

Meanwhile, cultivar Rahan recorded the highest significant value in measuring the actual area with a value of (153.3 and 155.0 cm^2) in the two seasons, respectively.

The (N-600) treatment of the Rahan cultivar recorded the highest significant value, which was (199.5 and 201.9 cm^2) in the two seasons, respectively. The control treatment recorded the lowest significant in the first season with the Rahan cultivar (68.2 cm^2) and with the Jaffa cultivar (79.2 cm^2) in the second season.

This finding is in line with the findings of Hossain and Haque (2013) and Islam, *et al*., (2020), who observed that higher vegetative growth results from various doses of nitrogen (N) in addition to uniform dosages of potassium (K_2O) and phosphorus (P_2O_5) per plant.

2. Fruit-physical characteristics.

2.1. Bunch length (cm):

Bunch length measurement in **Table (3),** showed that (K_2O-400) treatment had the highest value (155.7 cm), and there was no statistically significant between the potassium treatments. At the same time, (N-600) treatment had the highest value (109.8 cm) there are also non significant between the nitrogen and control treatments.

Meanwhile, the Jaffa cultivar recorded the highest bunch length, (162.3 cm), followed by Rahan, (111.0 cm), and finally Grand Naine, (104.8 cm), in the first season, while the cultivar Rahan, (117.7 cm), recorded the highest bunch length, in the second season, followed by Jaffa (115.4 cm), and the least significant for Grand Naine cultivar (109.6 cm).

Regarding the interaction between treatments and cultivars, it was noted that the highest significant bunch length was recorded for the K_2O-400 treatment with the Jaffa cultivar (236.6 cm), and the lowest significant was for the N-900 treatment with the Grand Naine cultivar, (91.2 cm) in the first season, while the K_2O-400 treatment recorded the highest significant value with the Rahan cultivar, (132.7 cm). The N-900 treatment had the least significant with the Grande Naine cultivar, (94.3 cm), in the second season.

This experiment's results either entirely or partially concur with those of Hossain and Haque, (2013). Furthermore, Jambulingum et al. (2011), found that higher potassium application levels shortened crop length and improved early flowering and maturity, corroborating this conclusion.

2.2. Bunch weight (kg):

According to the results of **Table (3),** it is clear that the highest bunch weight was recorded for the K_2O-800 treatment, followed by K_2O-400, (53. 6 and 51.5 kg), with no significant differences in the first season. The K_2O-800 treatment recorded the highest bunch weight, (53.3 kg) in the second season, and the control treatment recorded the smallest weight, (39.1 and 38.8 kg) in the two seasons, respectively.

The highest bunch weight was recorded for the Jaffa cultivar (53.2 and 51.7 kg) in the two seasons, respectively. Rahan cultivar recorded the lowest bunch weight (45.6 and 43.4 kg) in the two seasons, respectively.

The highest bunch weight was recorded for the K_2O-800 treatment with the Jaffa cultivar (68.3 and 65.6 kg) in the two seasons, respectively. The control treatment with the Rahan cultivar recorded the lowest weight for the bunch, (38.3 and 31.0 kg) in the two seasons, respectively.

Islam et al. (2020) found that applying 450g K/plant treatment produced the best bunch weight, whereas 250g K/plant treatment produced the lowest bunch weight. Furthermore, the results were corroborated by Jagirdar and Ansari (2016). By applying 450g N/plant, Singh and Kashyap (2010) also achieved the best bunch weight. Chandrakumar et al. (2001) reported similar outcomes. Similar results were also noted, with the highest bunch weight being obtained by applying 300g of nitrogen and 300g of potassium (Sahilendra et al., 2015).

Table (3). Effect of fertilization treatments of different nitrogen and potassium on the bunch length (cm), bunch weight (kg), and number of hands/ bunch, of Rahan, Jaffa and Grand Naine banana cultivars in the two seasons (2022-2023 and 2023-2024).

Treatments	First season (Mother plant)				Second season (Second ratoon)			
	Cultivars			Mean A	Cultivars			Mean A
	Rahan	Jaffa	Grand		Rahan	Jaffa	Grand	
1- Bunch length (cm).								
Control	99.6	101.0	95.3	98.6^{B}	96.6	101.3	96.3	98.1^{D}
N-300	100.0	104.3	105.0	103.1^{B}	130.0	108.3	112.3	116.8^{ABC}
N-600	107.8	113.3	108.3	109.8^{B}	106.6	120.3	120.0	115.6^{BC}
N-900	109.6	117.6	91.2	106.1^{B}	112.3	124.0	94.3	110.2^{C}
K_2O-400	121.0	236.6	109.6	155.7^{A}	132.7	106.0	111.6	113.7^{ABC}
K_2O-800	126.3	230.0	104.0	153.4^{A}	129.3	119.0	109.0	119.1^{AB}
K_2O-1200	112.6	233.3	120.3	155.4^{A}	117.0	129.3	123.6	123.3^{A}
Mean B	111.0^{B}	162.3^{A}	104.8^{B}	A*B= 21.72	117.7^{A}	115.4^{A}	109.6^{B}	A*B=12.59
2- Bunch weight (kg)								
Control	38.3	40.6	38.6	39.1^{C}	31.0	41.0	44.6	38.8^{C}
N-300	47.3	46.0	49.0	47.4^{AB}	40.3	41.0	50.3	43.8^{C}
N-600	47.0	42.0	46.3	45.1^{B}	46.0	42.0	46.6	44.8^{C}
N-900	49.3	48.3	43.6	47.1^{AB}	50.0	47.3	48.6	48.6^{B}
K_2O-400	43.6	66.0	45.0	51.5^{A}	40.6	64.0	46.3	50.3^{B}
K_2O-800	47.6	68.3	45.0	53.6^{A}	49.0	65.6	45.3	53.3^{A}
K_2O-1200	46.3	61.3	46.0	51.2^{AB}	47.0	61.6	46.0	51.5^{AB}
Mean B	45.6^{B}	53.2^{A}	44.8^{B}	A*B= 10.33	43.4^{C}	51.7^{A}	46.8^{B}	A*B= 5.37
3- Number of hands/ bunch								
Control	11.6	12.6	10.6	11.6^{C}	12.1	14.0	12.0	12.7^{B}
N-300	13.3	15.3	11.3	13.3^{B}	13.3	15.3	12.0	13.5^{B}
N-600	16.6	16.3	12.3	15.1^{A}	16.0	16.0	13.3	15.1^{A}
N-900	16.6	18.3	12.0	15.6^{A}	16.6	17.6	13.0	15.7^{A}
K_2O-400	17.0	17.0	15.0	16.3^{A}	17.0	14.6	14.6	15.4^{A}
K_2O-800	15.3	17.0	12.6	15.0^{A}	14.3	14.0	12.6	13.6^{B}
K_2O-1200	19.0	17.0	12.3	16.1^{A}	18.0	12.3	14.6	15.0^{A}
Mean B	15.6^{A}	16.2^{A}	12.3^{B}	A*B= 3.06	15.3^{A}	14.8^{A}	13.1^{B}	A*B= 2.07

2.3. Number of hands per bunch:

There were no clear significant differences between the treatments in measuring the number of hands per bunch **(Table 3),** unlike the control treatment, which recorded the lowest number of hands per bunch in the two seasons.

Meanwhile, the Jaffa cultivar recorded (16.2 hands/bunch) in the first season, and the Rahan cultivar recorded (15.3 hands/bunch) in the second season, the Grand Naine cultivar, recorded the lowest number of hands per bunch (12.3 and 13.1 hands/bunch) in the two seasons, respectively.

Rahan cultivar with the K_2O-1200 treatment recorded the highest number of hands per bunch (19.0 and 18.0 hands/bunch) in two seasons, respectively. The least significant value was recorded for the control treatment with the Grand Naine cultivar (10.6 and 12.0 hands/bunch) in the two seasons, respectively.

This outcome is consistent with studies by Chandrakumar et al. (2001), reported that the yield and yield characteristics were impacted by the rise in N and K fertilization levels and ratios. Nonetheless, it was also noted that bananas responded favorably to increased potassium and nitrogen applications following flowering. Also, Chattopadhayay et al. (2018) and Islam et al. (2020), revealed that the application of N (500g urea/plant) treatment resulted in the highest number of hands per bunch and that increased K_2O so did the overall number of hands in each bunch.

2.4. Finger weight (g):

Data in **Table (4)** demonstrated that the weight of fingers was affected by nutrients (potassium and nitrogen), as well as how the cultivars reacted to the various elemental concentrations utilized in the investigation. The N-600 therapy produced the highest finger weight (183.5 and 182.3 g) in each of the two seasons, whereas the K_2O-400 treatment reported the least significant measures (167.5 and 165.0 g) in two seasons, respectively.

Table (4). Effect of fertilization treatments of different nitrogen and potassium on finger weight (g), finger length (cm) and pulp weight (g) of Rahan, Jaffa and Grand Naine banana cultivars in the two seasons (2022-2023 and 2023-2024).

Treatments	First season (Mother plant)				Second season (Second ratoon)			
	Cultivars			Mean A	Cultivars			Mean A
	Rahan	Jaffa	Grand		Rahan	Jaffa	Grand	
4- Finger weight (g)								
Control	163.3	177.0	180.6	173.6^{BC}	161.6	175.3	185.3	174.1^{BC}
N-300	166.6	181.0	191.0	179.5^{AB}	166.6	172.3	171.6	170.2^{CD}
N-600	164.7	185.4	200.6	183.5^{A}	167.6	181.6	197.6	182.3^{A}
N-900	179.2	156.7	167.3	167.7^{C}	178.6	160.0	164.3	167.6^{DE}
K_2O-400	162.7	171.0	168.8	167.5^{C}	162.3	168.3	164.3	165.0^{E}
K_2O-800	160.1	173.0	184.2	172.4^{BC}	160.3	172.6	181.6	171.5^{BCD}
K_2O-1200	169.3	185.9	176.2	177.1^{AB}	166.0	185.6	176.0	175.8^{B}
Mean B	166.5^{B}	175.7^{A}	181.2^{A}	A*B= 15.10	166.1^{C}	173.7^{B}	177.2^{A}	A*B= 7.73
5- Finger length (cm)								
Control	17.6	24.3	22.3	21.4^{C}	17.0	23.3	22.0	20.7^{E}
N-300	20.6	25.7	24.0	23.4^{AB}	20.6	25.3	25.6	23.8^{AB}
N-600	22.0	24.5	24.3	23.7^{AB}	22.0	22.0	24.0	22.6^{CD}
N-900	19.6	24.9	30.6	25.0^{A}	22.6	26.0	20.2	23.3^{ABC}
K_2O-400	19.6	25.7	22.7	22.7^{BC}	20.3	26.3	25.3	24.0^{A}
K_2O-800	20.4	22.2	24.1	22.2^{BC}	18.3	23.6	24.6	22.2^{D}
K_2O-1200	18.8	23.2	25.4	22.5^{BC}	18.6	22.3	26.6	23.0^{BCD}
Mean B	19.8^{B}	24.4^{A}	24.8^{A}	A*B= 3.44	20.2^{B}	24.1^{A}	24.1^{A}	A*B= 1.71
6- Pulp percentage (%)								
Control	84.6	86.0	85.4	85.4^{D}	87.0	88.8	87.7	87.8^{DE}
N-300	85.2	84.7	87.3	85.8^{D}	85.3	92.3	93.4	90.3^{B}
N-600	89.3	83.6	92.0	88.3^{A}	88.5	81.2	89.6	86.4^{F}
N-900	82.8	91.6	85.8	86.6^{C}	83.1	94.1	87.2	88.1^{CD}
K_2O-400	86.2	90.4	88.8	88.5^{A}	86.1	96.4	97.1	93.2^{A}
K_2O-800	93.0	86.6	84.2	87.7^{B}	86.8	89.9	85.4	87.4^{E}
K_2O-1200	89.4	88.2	88.0	88.5^{A}	88.6	90.4	86.1	88.4^{C}
Mean B	87.2^{B}	87.3^{AB}	87.4^{A}	A*B= 0.64	86.6^{C}	90.3^{A}	89.4^{B}	A*B= 0.59

The Grand Naine cultivar recorded the highest finger weight (181.2 and 177.2 g), in two seasons, respectively. Whereas the Rahan cultivar had the least finger weight in the two seasons, measuring (166.5 and 166.1 g), respectively.

The Grand Naine cultivar with the N-600 treatment recorded the highest weight of finger (200.6 and 197.6 g/finger) in two seasons, respectively. The least significant value was recorded for the N-900 treatment with the Jaffa cultivar (156.7 and 160.0 g/finger) in two seasons, respectively.

2.5. Finger length (cm):

In **Table (4),** the N-900 treatment recorded the highest significant finger length (25.0 cm) in the first season, and the lowest finger length was for the K_2O-400 treatment (24.0 cm) in the second season.

The Grand Naine recorded the highest finger length followed by the Jaffa cultivar, and the lowest finger length was recorded for the Rahan cultivar in the two seasons.

The highest significant finger length was recorded for the N-900 treatment with the Grand Naine cultivar (30.6 cm) in the first season, and the K_2O-1200 treatment with the same cultivar, (26.6 cm) in the second season. The lowest significant value was recorded for the control treatment with the Rahan cultivar (17.6 and 17.0 cm) in the two seasons, respectively.

2.6. Pulp percentage (%):

When it came to assessing pulp percentage % **(Table 4),** the K2O-400 treatment showed the highest significant, value (88.5 and 93.2 %) in the two seasons. The control treatment had the lowest significant was (85.4 %) in the first season, and the N-600 treatment recorded (86.4 %) in the second season.

Meanwhile, the Grand Naine cultivar recorded the highest significant value (87.4 %) in the first season, and Jaffa cultivar recorded the highest value (90.3 %) in the second season. And the lowest significant pulp percentage % was recorded for the Rahan cultivar, (87.2 and 86.6 g) in the two seasons, respectively.

The highest significant value recorded for the Rahan cultivar with the K_2O-800 treatment was (93.0 %) in the first season and the Grand Naine cultivar with K_2O-400 (97.1 %) in the last season. The Rahan cultivar with the N-900 treatment showed the lowest significant pulp percentage (82.8 %) in the first season and the Jaffa cultivar with the N-600 treatment (81.2 %) in the second season.

These results corroborate the findings of Saleh (2001). Also, these outcomes are consistent with previous findings (Abd El-Naby and El Sonbaty, 2005, El-Moneim et al., 2008, Vazquez-Ovando et al., 2012 and Baiea and El-Gioushy, 2015). The yield of bananas per hectare was found to be significantly impacted by the treatment of varying potassium levels. These findings are consistent with those of Chandrakumar et al. (2001), who found that higher N and K fertilization levels had an impact on yield and yield metrics. Nonetheless, it was also noted that bananas responded favorably to increased potassium treatment following flowering.

3. Principal component analysis (PCA):

The study employed principal component analysis (PCA) to identify the significant that account for the observed fluctuations in determining the fertilization requirements of multiple banana cultivars. Additionally, PCA was used to evaluate the growth characteristics and efficacy of nitrogen and potassium fertilization. **(Fig. 1)** The growth characteristics primary component of the total variation is first (PC1 = 65.3%) and second (PC2 = 18.5%), respectively. Meanwhile, the primary components of the total variation in yield characteristics were first (PC1 = 37.7%) and second (PC2 = 38.7%). Higher or moderate N and K fertilization levels and ratios were shown to have an impact on the growth and yield metrics, as demonstrated by the graphic representation of variables. We find that in the measures of growth characteristics, the Rahan cultivar was the most responsive, unlike the Grand Naine cultivar, which was less significant in most characteristics. On the contrary, in the yield characteristics, we find that the Rahan cultivar has always the lowest significant values and the Jaffa cultivar was the most responsive. It was also found that the treatment of varying potassium levels significantly affected the output of bananas.

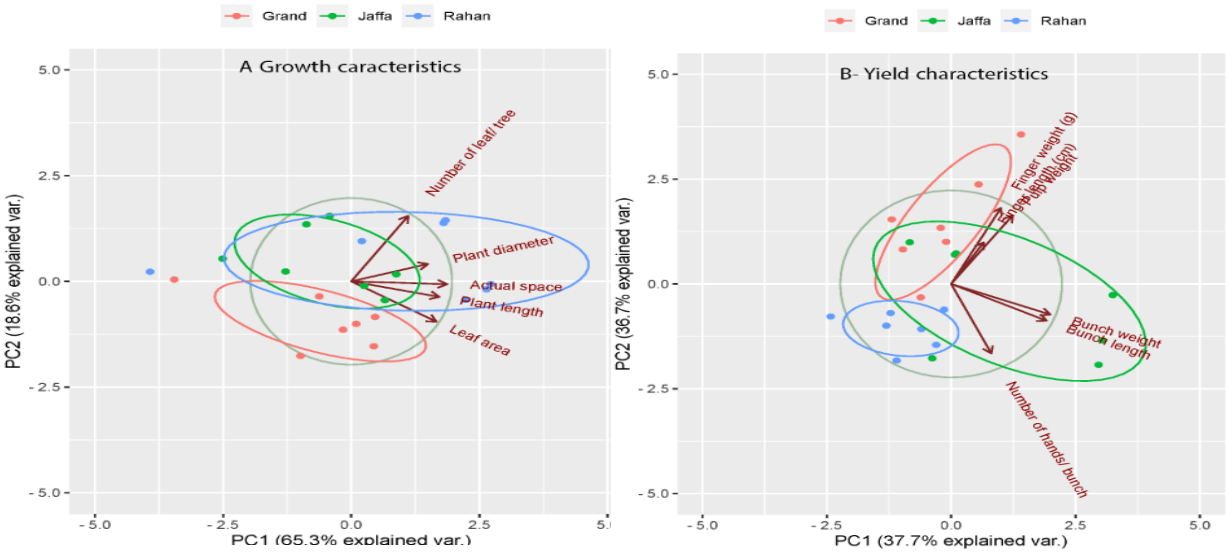

Figure (1). A- Growth characteristics and B- yield characteristics of three banana cultivars (Rahan, Jaffa, and Grand Naine) under different fertilization treatments in two seasons; all results represented by the analysis of PCA to find parameters with larger contributions between characteristics

Heatmap clustering according to morph-physiological traits:

Figure (2) displays a heatmap that illustrates the cluster analysis and relationship between the different characteristics and concentrations of the elements used in the study. The clustering of banana cultivar data into column and row clusters **(Fig. 2),** further demonstrated that the elements under investigation comprised distinct variable groupings. This led to that there was a wide range of variability in the measured vegetative parameters. We conclude that banana cultivars differ in their response to nitrogen and potassium fertilization, which emphasizes the need to investigate the source of nutrients, and that each element has its appropriate timing and quantity required at each stage of growth.

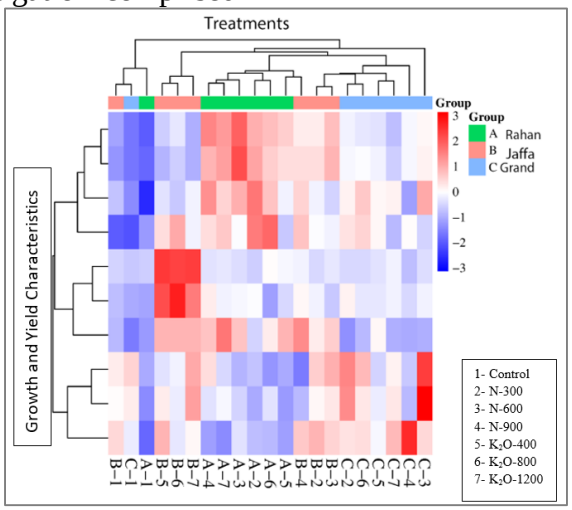

Figure (2). Heatmap explaining morph-physiological parameters of three banana cultivars (Rahan, Jaffa, and Grand Naine) in two seasons, total variability presented in the analysis of PCA and cluster

CONCLUSION:

We can conclude that a broad range of variability was observed in the measured vegetative parameters, which allows a wide range of knowledge about the differences between cultivars in expressing the response to the effect of nutrients. Using high concentrations of nitrogen 600 or 900 during

growth was found to improve the development and yield of banana plants and had a discernible influence on both vegetative growth and pseudo-stem length and girth. Meanwhile, it was observed that bananas reacted well to higher potassium treatments as well as the application of N-600 and K_2O-1200 together. This calls for a thorough investigation of the fertilization of banana plants by important essential elements, the response of each cultivar, and the effects of soil composition and environmental factors on nutrient availability and cultivar-specific responses to growth and yield. This reaffirms the need to investigate the nutrient source, the degree to which the plant requires them, and the stage of growth at which they are needed.

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الملخص العربى

تحسين جرعة النيتروجين والبوتاسيوم لتعزيز نمو وإنتاجية ثلاثة أصناف من الموز المزروعة في التربة الرملية

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تمت الدراسة خلال موسمين 22–23 و 23-2024 في مزرعة بطريق الإسكندرية الصحراوي، لتحديد الاستخدام الأمثل أو مدى احتياج نبات الموز للتسميد بالنيتروجين والبوتاسيوم لثلاثة أصناف من الموز، وتقييم تأثيرها على النمو والمحصول، وقد أظهر تحليل النتائج تباينًا كبيرًا في قياسات الدراسة. نجد ان التركيزات المنخفضة من البوتاسيوم (K_2O-400 او K_2O-800) كانت لهم الافضلية فى قياسات طول ووزن السوباطه وعدد الكف/السوباطة. بينما معاملة النيتروجين المتوسطة (N-600) كانت الاعلى فى كلا من طول ووزن الأصابع. ايضا نجد أن معاملة الكنترول كانت الأقل معنوية فى أغلب القياسات سواء قياسات النمو او الانتاج. وكذلك استخدام التركيز الاعلى من النيتروجين (N-900) كان له اقل النتائج. وفيما يتعلق باستجابة الأصناف، نجد فى قياسات النمو الخضري ان الصنف راهان كان الاكثر استجابة، بخلاف الصنف جراند نان كان أقل معنوية فى أغلب القياسات. على العكس فى قياسات الانتاج، نجد أن الصنف راهان كان دائما الأقل معنوية والصنف جافا هو الاكثر استجابة. بينما الصنف جراند نان كانت له الأفضليه فى بعض القياسات مثل طول ووزن الاصابع ووزن اللب. فى حين، كان الاقل فى وزن وطول السوباطة. ويمكن التأكيد على أن استخدام مستويات مختلفة من الأسمدة النيتروجينية والبوتاسيوم كان له تأثير معنوي وإيجابي على مراحل النمو المختلفة. وهذا يؤكد ضرورة التحقيق في مصدر العناصر الغذائية، وأن كل عنصر له التوقيت والكمية المناسبة واللازمة فى كل مرحلة من مراحل النمو.