



RESEARCH ARTICLE

Fruit quality, physiology and leaf nutrient content of banana cv. Grand Naine as influenced by split application of nitrogen and potassium

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Abstract

While nitrogen (N) and potassium (K) fertilisers are most commonly used in banana cultivation for improving plant growth and productivity, the interactive effects of these nutrients on banana fruit quality, physiology and leaf nutrient contents are not clearly understood. The interactive effects of N (0, 150 and 300 g/pseudostem) and K (0, 250, 350 and 450 g/pseudostem) fertilisers on banana fruit quality, physiology and leaf nutrient content were investigated. Application of N at the rate of 300 g/pseudostem and potassium at the rate of 450 g/pseudostem significantly increased fruit total soluble solids (TSS), photosynthetic rate and transpiration rate. Increasing dose of N significantly increased the N content in leaf. However, higher amount of N did not significantly affect titratable acidity in banana fruit. Accordingly, application of N at the rate of 300 g/pseudostem and K at the rate of 450 g/pseudostem was suggested as the optimum treatment that could increase fruit quality and improve fruit physiology and leaf nutrient content.

Keywords: banana; fruit quality; nitrogen; potassium

Introduction

Banana is one of the leading fruit crops and is considered as the “Apple of Paradise”. It is also known as “Adam’s fig”. Banana (*Musa* spp.) originated in tropical south and Southeast Asia with India considered one of its centres of origin (1).

Banana is a fast-maturing plant which needs continuous supply of water and nutrients for quality production. Some of these nutrients may be provided by the soil and through their cycling within banana plantation, but fertiliser application is usually needed to satisfy plant necessities to get profitable production. Bananas require large quantities of nutrients, i.e. nitrogen (N), phosphorus (P) and potassium (K) (2–4). The banana yield and quality depends upon the nutritional status of soil and plants. It needs high amount of nutrients which must be supplied through fertilisation to obtain optimum yields. Fertilisation also improves soil nutrient status as well as increase plant productivity (5). Balanced fertiliser application is essential for maximising yield. Incorrect fertiliser management regarding source, quantity and application frequency can adversely affect plant nutrition and crop productivity. Thus, a balanced nutrition must be followed (6). In

banana apart from of cultivars, climate, soil and the whole amount of N taken up by the plant is closely associated with the production of total dry matter content (3). Banana plants are unable to store N; therefore, this nutrient is regularly supplied into small doses even when the crop is grown on highly fertile soils. Nitrogen is the most important nutrient, considerably affecting growth of plants and at a lesser extent fruit production. It also plays an important role as a component of nucleic acids, proteins, enzymes (7) and major element in the chlorophyll structure which affects photosynthesis and plant growth (8). Potassium is another necessary nutrient for plant growth and fruit production and is often known as the quality element for the production of crop (9). It can regulate function of enzymes in plants which control water behaviour including the process of transpiration. Nitrogen and K are mobile nutrients and hence is subjected to leaching. It is required at high amounts by plant and may be applied through the use of organic or chemical fertilisation (10). Leaf is the principal site of metabolism and its analysis has proved to be the best for formation of proper nutritional and fertilisation scheduling (11). Leaf analysis is a tool which not only determines the total quantity of nutrient removed from the soil but also as a biological method

for assessing soil fertility. Leaf nutrient status varies with factors such as leaf age, position, growth stage and location. Analysis of soil and leaf can be utilised to determine the nutritional status of the plants and availability of nutrients in the soil to provide the trees with nutrient necessity (12). To the best of our knowledge, no information is available on the efficacy of N and K on photosynthetic activity of banana crop. The objective of this study was to examine fruit quality, yield, photosynthetic activity and leaf macro nutrient status influenced by different levels of N and K fertilisation at different split doses on alluvial soil of Bihar, India. The findings of this study may help develop nutrient management recommendations for banana cultivation under similar agro-climatic conditions.

Material and Methods

Experimental layout, environmental conditions and plant material

The experiment was conducted at the Tooth bagan, Horticultural garden, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India. Sabour is located approximately 10 km east of Bhagalpur city, Bihar, India. The experimental site is located south of the River Ganga at 25°15'40" N latitude and 87°02'72" E longitude and at an altitude of 45.72 m above the mean sea level in the huge alluvial Gangetic Plain of India. Sabour falls under subtropical condition categorises as semiarid, with hot desiccating summer. However, the winter is frostless. Tissue cultured plants of banana cultivar Grand Naine were brought from the tissue culture unit, Bihar Agricultural University, Sabour, Bihar. Trial procedure includes fertilisation of banana plants with No fertiliser (T₁), NO N + 250 g K (T₂), NO N + 350 g K (T₃), NO N + 450 g K (T₄), 150 g N + NO K (T₅), 150 g N + 250 g K (T₆), 150 g N + 350 g K (T₇), 150 g N + 450 g K (T₈), 300 g N + NO K (T₉), 300 g N + 250 g K (T₁₀), 300 g N + 350 g K (T₁₁), 300 g N + 450 g K (T₁₂). Three levels of N are applied in equal five split doses at 30, 75, 120, 165 and 210 days after transplanting. Four levels of K are applied into six split doses at 30, 75, 120, 210 days after transplanting, at shooting and 25 days after shooting and distributed using the factorial randomized complete block design (FRBD) with 4 replications. Plants are planted at a distance of 2 × 2 m and each treatment consisted of four plants.

Soil condition

Banana orchard was established on alluvial soil with average pH (7.93), EC (0.22 ds/m), organic carbon (0.64 %), available N, P and K (208.98, 11.6 and 215.21 kg/ha respectively) and iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) (1.96, 0.55, 1.47 and 0.61 ppm respectively) taken from three depth (0–15, 15–30 and 30–45 cm) with the help of soil auger.

Fruit quality

Total soluble solids (TSS) present in the fruit pulp were recorded at room temperature using hand refractometer and expressed as °Brix. The values were corrected at 20 °C with the help of temperature correction chart (13). Titratable acidity content was determined by using titration method (13). For this 2 g of fruit sample was weighed and added to 50 mL water. It was thoroughly mixed and then filtered. The filtered sample was titrated against 0.1 N NaOH using a few drops of 1 % phenolphthalein solution as indicator. The observed titre value was used for calculating acidity and the results were expressed as percentage of citric acid. The formula used for its calculation was expressed as grams of anhydrous citric acid per 100 g of pulp. The formula used was:

Titrate acidity (%) =

$$\frac{\text{Volume of 0.1 N NaOH consumed}}{\text{Volume of pulp taken}} \times \frac{64}{1000} \times 100$$

Photosynthetic activity

Photosynthetic rate ($\mu\text{mol CO}_2 \text{ m}^{-2}\text{sec}^{-1}$), stomatal conductance ($\text{mol H}_2\text{O m}^{-2}\text{sec}^{-1}$) and transpiration rate ($\text{mmol H}_2\text{O m}^{-2}\text{sec}^{-1}$) were analysed by portable photosynthesis system (LICOR - 6400 XT, Lincoln, NE, USA) by using IRGA (Infra-red gas analyser). The observations were recorded during 9:00 am to 11:00 am during sunny days.

Leaf nutrient status

Leaf samples were collected from banana plant at the time of flowering. Top from third leaf is selected for sampling. 10 cm wide strip of leaf are taken from both side of midrib. The taken leaf sample are brought to laboratory and thoroughly washed with tap water and rubbing softly by hand to remove dust and other foreign particle and then dipped into 0.1 N HCL solutions. Again, after oven drying at 68–70 °C till constant weight was obtained. Then, dried samples were homogenised in a grinder and kept in butter paper bags for the nutrient chemical analysis. The total N content was determined by Kjeldhal method (14). The P content was determined by using ammonium molybdate: ammonium metavanadate (15). The colour intensity was measured spectrophotometrically at 440 nm (HALODB-20S UV-Vis double beam spectrophotometer, Australia). Potassium and Ca was determined with flame photometry technique using flame photometer, U K (16). The Mg, Zn and Fe content were estimated by using atomic absorption spectrophotometer.

Results

Total soluble solids (°Brix)

TSS (°Brix) was significantly influenced by N and K treatments. The highest TSS (21.53 °Brix) was found when plants treated with 350 g N per pseudostem followed by N 150 g per pseudostem (20.74°Brix) and both results are statistically at par with each other, however, the lowest TSS (20.47°Brix) was found with control plants (Table 1). The different doses of K also affect significantly on TSS and the highest TSS (22.78°Brix) was taken when plants receive 450 g K which was statistically significant to all other treatments, however, the lowest TSS (17.89°Brix) was related to control plants.

Titrate acidity (%)

The acidity content found highest (0.32 %) in the control plants followed by plants treated with N at the rate of 150 g/pseudostem and 300 g/pseudostem, respectively but bears no significant difference in between. Potassium did not affect significantly but the highest acidity (0.33 %) was found when plants receive no K followed by 0.31 % when plants treated with K at the rate of 250 and 350 g/pseudostem followed by 0.30 % when plants receive 450 g potassium/pseudostem respectively (Table 1).

Photosynthetic rate ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$)

Nitrogen has a significant effect on photosynthetic rate and highest rate ($12.08 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$) was found with the plants treated with nitrogen 300g per pseudostem and lowest photosynthetic activity ($6.57 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$) was found with untreated plants (Table 2).

Table 1. Effect of nitrogen and potassium on total soluble solids (TSS) (°brix) and titratable acidity (%)

	TSS (°Brix)			Titratable acidity (%)		
	Main crops	Ratoon	Pooled	Main crops	Ratoon	Pooled
Levels of nitrogen						
N ₀	20.14	20.79	20.47	0.32	0.32	0.32
N ₁	20.53	20.96	20.74	0.30	0.31	0.31
N ₂	21.39	21.66	21.53	0.29	0.33	0.31
SEm±	0.32	0.24	0.09	0.005	0.005	0.009
CD at 5 %	0.94	0.70	0.26	0.016	NS	NS
Levels of potassium						
K ₀	17.72	18.06	17.89	0.36	0.30	0.33
K ₁	20.92	21.37	21.14	0.31	0.32	0.31
K ₂	21.60	22.10	21.85	0.29	0.32	0.31
K ₃	22.52	23.03	22.78	0.27	0.33	0.30
SEm±	0.37	0.28	0.23	0.006	0.006	0.007
CD at 5 %	1.09	0.80	0.65	0.019	0.017	NS
Interaction (N × K)						
SEm±	0.66	0.48	0.40	0.011	0.010	0.007
CD at 5 %	1.88	1.39	1.15	0.032	0.029	NS

N: nitrogen; K: potassium.

Potassium also had significant difference on the rate of photosynthetic activity. The maximum rate (10.25 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$) was observed in the plants treated with potassium at the 450 g per pseudostem followed by potassium at the rate 350 g (9.34 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$) and 250 g (7 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$) while, untreated plants shows minimum photosynthetic rate (7.17 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$) during entire course of investigation.

Transpiration rate ($\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$)

The data concerning to transpiration rate of leaf were estimated and their pooled value had significantly higher rate (2.97 $\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) when the plants treated with N at 300 g per pseudostem (2.57 $\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) N at 150 g per pseudostem while lower transpiration rate (2.31 $\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) was observed with control plants (Table 2).

Significant differences were seen among all the K treated plants, the higher rate (3.04 $\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) was observed when plants treated with 450 g per pseudostem followed by (2.64 $\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) with 350 g while, lowest transpiration rate (2.36 $\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) was observed on control plants.

Stomatal conductance ($\text{mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$)

The statistically analysed data related to the photosynthetic rate are presented in Table 2. It is evident from the data the different treatments of N has significant effect on stomatal conductance and the higher conductance was noticed when the plants treated

with 300 g N per pseudostem followed by N 150 g per pseudostem, however, the lowest conductance was found in controlled plants.

Leaf nutrient content

Macro nutrient (nitrogen (N), phosphorous (P) and potassium (K)) content

The mean data related to macro (N, P and K) were presented in Table 3. A significant difference was notice among all the treatments in respect to N content in banana leaves. The highest N content (2.37 %) in banana leaf was found when plants receive 300 g of N per pseudostem which was at par with all other treatments and lowest N content (2.20 %) was found with control plants, as far as concern about effect of K on banana, there was no significant difference in N content of banana related to different K treatments. Nitrogen and K have no significant effect on P content in banana leaf. However maximum P content (0.13 %) was found with N at the rate of 300 g and 150 g per pseudostem and minimum was found with control plants. Nitrogen and P both have a significant effect on K content of banana. The maximum K (3.29 %) was found with N at the rate of 300 g per pseudostem and minimum (3.18 %) was found with control plants. Potassium has also a significant effect on K content of banana leaf and maximum K content (3.37 %) which was significant with all other treatments and minimum K content (3.10 %) was found with control plants.

Micronutrient (zinc (Zn), magnesium (Mg) and iron (Fe))

Micronutrient (Zn and Fe) content was presented in Table 4. The

Table 2. Effect of nitrogen and potassium on photosynthetic rate, transpiration rate and stomatal conductance ($\mu\text{mol/m}^2/\text{sec}$)

	Photosynthetic rate			Transpiration rate			Stomatal conductance		
	Main crops	Ratoon	Pooled	Main crops	Ratoon	Pooled	Main crops	Ratoon	Pooled
Levels of nitrogen									
N ₀	6.64	6.51	6.57	2.41	2.31	2.36	0.11	0.11	0.11
N ₁	7.37	7.73	7.37	2.70	2.57	2.64	0.16	0.16	0.16
N ₂	12.20	11.96	12.08	3.11	2.97	3.04	0.18	0.18	0.18
SEm±	0.074	0.100	0.060	0.038	0.040	0.010	0.005	0.005	0.0005
CD at 5 %	0.222	0.289	0.171	0.109	0.116	0.030	0.014	0.014	0.0013
Levels of potassium									
K ₀	7.14	7.20	7.17	2.51	2.40	2.45	0.13	0.12	0.12
K ₁	8.04	7.83	7.93	2.67	2.53	2.60	0.15	0.15	0.15
K ₂	9.43	9.25	9.34	2.82	2.68	2.75	0.16	0.17	0.16
K ₃	10.33	10.18	10.25	2.96	2.86	2.91	0.18	0.17	0.18
SEm±	0.089	0.116	0.072	0.043	0.046	0.031	0.005	0.006	0.004
CD at 5 %	0.257	0.334	0.205	0.126	0.134	0.088	0.016	0.017	0.011
Interaction (N × K)									
SEm±	0.12	0.15	0.09	0.06	0.06	0.03	0.007	0.008	0.004
CD at 5 %	0.34	0.43	0.27	0.17	0.18	NS	0.020	0.023	0.011

N: nitrogen; K: potassium.

Table 3. Effect of nitrogen and potassium on leaf nitrogen (%), phosphorus (%) and potassium (%) content

	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	Main crops	Ratoon	Pooled	Main crops	Ratoon	Pooled	Main crops	Ratoon	Pooled
Levels of nitrogen									
N ₀	2.25	2.31	2.26	0.12	0.13	0.12	3.17	3.19	3.18
N ₁	2.35	2.40	2.36	0.13	0.13	0.13	3.21	3.25	3.23
N ₂	2.43	2.51	2.45	0.13	0.14	0.13	3.28	3.30	3.29
SEm±	0.017	0.01	0.009	0.003	0.004	0.002	0.01	0.01	0.003
CD at 5 %	NS	0.03	0.02	0.01	NS	0.007	0.03	0.03	0.01
Levels of potassium									
K ₀	2.21	2.28	2.29	0.12	0.13	0.12	3.08	3.11	3.10
K ₁	2.31	2.34	2.33	0.12	0.13	0.12	3.18	3.21	3.20
K ₂	2.38	2.45	2.38	0.14	0.14	0.14	3.26	3.28	3.27
K ₃	2.47	2.54	2.43	0.12	0.14	0.13	3.37	3.39	3.38
SEm±	0.020	0.01	0.01	0.004	0.004	0.003	0.01	0.01	0.01
CD at 5 %	NS	0.04	0.04	NS	NS	0.009	0.04	0.04	0.03
Interaction (N × K)									
SEm±	0.03	0.03	0.02	0.007	0.007	0.005	0.037	0.035	0.025
CD at 5 %	0.071	0.07	0.05	NS	NS	NS	0.076	0.073	0.052

N: nitrogen; K: potassium.

Table 4. Effect of nitrogen and potassium on magnesium (%), zinc (ppm) and iron (ppm) content

	Magnesium %			Zinc (ppm)			Iron (ppm)		
	Main crops	Ratoon	Pooled	Main crops	Ratoon	Pooled	Main crops	Ratoon	Pooled
Levels of nitrogen									
N ₀	0.27	0.26	0.26	34.40	33.53	33.96	126.40	126.13	126.26
N ₁	0.29	0.28	0.28	37.84	36.14	36.99	129.74	128.96	129.35
N ₂	0.29	0.28	0.29	39.01	38.74	38.87	129.77	132.56	131.17
SEm±	0.003	0.003	0.001	0.26	0.90	0.35	0.36	0.31	0.96
CD at 5 %	0.01	0.01	0.004	0.76	2.59	1.00	1.04	0.90	2.72
Levels of potassium									
K ₀	0.30	0.29	0.29	38.62	37.39	38.01	129.75	130.29	130.02
K ₁	0.29	0.28	0.28	37.61	36.69	37.15	129.01	129.41	129.21
K ₂	0.28	0.26	0.27	36.56	35.61	36.08	128.29	128.79	128.54
K ₃	0.27	0.26	0.26	35.53	34.85	35.19	127.50	128.37	127.94
SEm±	0.004	0.004	0.003	0.30	1.03	0.53	0.41	0.36	0.27
CD at 5 %	0.01	0.012	0.008	0.87	NS	1.49	1.20	1.05	0.76
Interaction N × K									
SEm±	0.005	0.005	0.003	0.40	1.37	0.64	0.55	0.48	1.00
CD at 5 %	0.013	0.013	0.008	1.00	NS	1.60	1.38	1.20	2.30

N: nitrogen; K: potassium.

effect of N and K on Zn and Fe content was found significant with both the nutrients. Maximum Zn content (38.74 ppm) was found when plants treated with N at the rate of 300 g per pseudostem which was significant with all other N treated plants and minimum Zn content was found with control plants. Potassium had no significant effect on Zn content. The maximum Zn content (37.39 ppm) was found with control plants and minimum Zn content (35.19 ppm) when plants treated with K at the rate of 450 g per pseudostem which was statistically similar to K 350 g per pseudostem. As far as concern about Fe content in banana leaf, N significantly affect Fe content and maximum Fe content (131.17 ppm) was found when plants treated with nitrogen at the rate of 300 g per pseudostem which was statistically similar to N at the rate of 150 g per pseudostem and lowest Fe content (126.26 ppm) was found with control plants. Potassium also significantly affects Fe content. The maximum Fe content (130.02 ppm) was found with control plants and minimum Zn content (127.94 ppm) was found when plants treated with K at the rate of 450 g per pseudostem.

Discussion

Quality characters

Results of the present investigation showed that higher doses of N and K had a marked effect on TSS and acidity of banana fruits. The maximum increase in TSS (22.78 °Brix) was recorded with K applied at the rate of 450 g per pseudostem. While, N applied at the

rate of 300 g per pseudostem results in TSS content (21.53 °Brix). The increase in TSS of pulp content is due to the fact that K has the crucial role in promoting synthesis of photosynthates and their transport to fruit. This finding elucidates the reports in peach (17). Improvement in fruit quality of banana due to N and K nutrition has also been observed (18, 19). Total soluble solid increased by K fertilisation is also reported in citrus (20). The probable cause for an increase in TSS is sufficient nutrient availability to the plant, which breaks starch into sugar and helps to increase the fruit TSS. An increase in TSS content with the K fertilisation is linked to their role in the translocation of sugars from the leaves to fruits, which outcomes in superior quality fruits in terms of TSS (21). In the present studies, it seems that K plays an important role in the accumulation of sugars and other soluble solids in the fruits. Current study is supported by early researchers in ber cv. Umran (22), in Pear cv. Pathernakh (23), in plum cv. Satluj Purple (24), in Apple (25) and in strawberry (26). Potassium application increased soluble solids, which can increase the nutritional properties of the fruit. This indicates that K affects metabolism and hence, production of photosynthates in the plant, which ultimately translocated to fruit juice and can contribute to the nutritional values of the fruit (27, 28). When potassium fertiliser supplied in the form of sulphate of potash favours conversion of starch into simple sugars and during ripening process it activates the enzyme sucrose synthetase resulting in higher sugar percentage in banana (29).

In the present study, we did not find any significant effect of N and K in terms of acidity content of fingers. Potassium fertilisation affects fruit acidity. Some workers reported that fertilisation with K

increases the titratable acidity of the fruit (30, 31), others state decrease in fruit acidity (29–32) and some workers also reported that K application has no significant effect on fruit titratable acidity (33), did not find any effect of N on peach fruits over titratable acidity, using smaller quantity N doses (88 kg/ha/year of N) (34).

The role of K in improving fruit chemical properties could be attributed to the formation and accumulation rates of sugars in mango (35, 36).

Physiological parameters

The results obtained from present experiment revealed, remarkable influence of N and K on photosynthetic rate, transpiration rate and stomatal conductance of banana leaf. Plants with application of N at the rate of 300 g/pseudostem was observed to be the best for photosynthetic rate ($12.08 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ sec}^{-1}$), transpiration rate ($2.97 \text{ mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) and stomatal conductance ($0.18 \text{ mmol H}_2\text{O m}^{-2} \text{ sec}^{-1}$) followed by plants treated with 450 g K/pseudostem. Since, N is directly related to plant growth, its application may improve plant growth, especially leaf size. Increased leaf size might be responsible for improvement in the rate of photosynthesis (37). Similar findings were reported by early researchers, who observed that N fertilisation enhanced in net photosynthesis and leaf growth because N is a component of amino acids, which are necessary for the synthesis of proteins and other related compounds (8). The results are reliable with the findings in papaya (38). Leaf photosynthesis rates are reported to increase with increased leaf K concentrations and this could be one mechanism of increased sugar contents in fruit reported in cotton (39). The increase in net photosynthesis with increased doses of K might be due to its effect on an increase in nitrate reductase activity which is directly involved in the regulation of photosynthetic enzyme (40). Increase in photosynthesis rate due to higher K fertilisation might be due to increase in stomatal conductance that was stimulated with high K that simultaneously improve the intercellular CO_2 inside the leaves (41). The increased doses of K fertilisation can improve the conductance in *Medicago sativa* L. and at the same time improve the uptake of CO_2 that raises intercellular CO_2 levels (42). The function of K in photosynthesis is very complex. The stimulation of enzymes by K and its association in ATP production is more critical in regulating the rate of photosynthesis than their role in stomatal conductance (43). Potassium also regulates stomatal conductance, or the exchange of gases including CO_2 and water vapour, enhancing photosynthetic efficiency in banana plants. This regulation excites the CO_2 uptake, which is essential for Calvin cycle to effectively fix carbon (49, 50). Potassium is also involved in the activation of important enzymes such as ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) and ATPases needed for photosynthetic light and dark reactions which increase chlorophyll synthesis with improved photochemical efficiency (51). Besides, K is also known to restore cellular osmotic stability and thylakoid membrane stability in chloroplasts, thereby ensuring the integrity of photodynamical components under stress conditions (52). From a physiological perspective, K osmotic regulation drives water movement through the xylem and phloem, assisting in nutrient uptake macro-and micro-nutrients. Such a translocation of nutrients underlies metabolic processes

and growth, supporting an increase in biomass accumulation and fruit development (53, 54). In summary, these physiological mechanisms allow banana plants to maintain high rates of photosynthesis and nutrient assimilation which produces better performances in growth.

Leaf nutrient content

The growth and fruitfulness of the plant depend on the nutrient status of a leaf. Leaf constitutes a vital role in plants and accomplishes important metabolic functions relating to maintain growth and reproductive processes. It is the donor organ from which nutrients and other assimilates are translocated to different sinks to support activities and considered as a most imperative index tissue to assess the nutrient status of a plant. Increased doses of K fertilisation improves biomass content and root length, hence helpful in nutrient absorption performance (48).

The data indicated that the application of N and K at different doses significantly affected their respective nutrient contents in leaves. Previous researchers studied strawberry and they stated that leaf N content in strawberries increased with the increase in N dose and they also reported that K application significantly increased leaf N and K content (26). These results are in line with the findings in fuji mango (44). Further, study reported that the application N as side dressing results in increasing N and other elements in the Iris bulbs (45), in *Momordica charantia* L. (46) and in Clementine mandarin (47). Application of N in the form of urea encouraged higher K contents in the leaves, possibly because this source has part of the N in the nitric form, which may have promoted the absorption of the cation K^+ .

Conclusion

It can be concluded that the combined application of nitrogen and potassium significantly improves fruit quality, physiology and leaf nutrient content. Application of 300 g N/pseudostem and 450 g K/pseudostem recorded highest photosynthetic activity, stomatal conductance, transpiration rate, total soluble solids (TSS) and leaf nutrient contents.

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Authors' contributions

MAN conducted the field experimentation, recorded traits and validated the data. RKR, SLB, VK, MAA and SK contributed to data analysis and interpretation; SLB also performed statistical analysis, while SK provided overall analytical oversight and final approval of the manuscript. MFA supervised the study, provided guidance and critically reviewed the manuscript. RKR and SLB participated in manuscript preparation and drafting. AS conducted the literature review, edited the manuscript and provided technical support for data interpretation. VK, SMR and MAA contributed to manuscript

revision, while SMR was also involved in data acquisition. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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