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Effect of NPK fertilizer on growth and yield of banana in Northern Oman

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Banana is the leading fruit crop in tropical and subtropical regions of the world. It represents the second most important fruit crop after date palm in the Sultanate of Oman, a subtropical arid country in the Middle East. Banana is grown as an intercrop throughout Oman but it is commercially cultivated on a large scale in the Dhofar (southern) region of and in Al-Batinah (coastal) region in the North. A field experiment was carried out in the traditional banana growing district, Al-Suwaiq, in Al-Batinah Region, during 2005-2006. The objective of the study was to determine the proper rate of NPK fertilizers that would maximize the potential yield of commercially-grown banana (*Musa acuminata* Colla, Cavendish cv. 'Williams'). Three levels of chemical fertilizers were applied, viz. N (300, 600 and 900 g/ mat/yr), P (50, 100 and150 g/mat/yr) and K (250, 500 and 750 g/mat/yr) in addition to non-fertilized control (no NPK applied) treatment. The results indicated that vegetative growth parameters (that is, leaf number, leaf area, stem height, and stem circumference) of non- fertilized control plants were neither significantly different nor produced better vegetative growth when compared to fertilized plants. The fertilizer treatment T3 consisting of N (600 g/mat /yr), P (100 g/mat /yr) and K (500 g/mat /yr) numerically influenced the yield and fruit characteristics like total bunch weight, middle-hand weight and number of fingers per middle-hand, of 'Williams' banana as compared to other treatments. Hence, this fertilizer dose of NPK was recommended for cultivation of 'Williams' banana in northern coastal region of Oman.

Key words: Bunch weight, fingers, nitrogen, potassium, phosphorus, *Musa* spp. arid-region, Oman

INTRODUCTION

Banana and plantain represent the largest fruit crop produced in the world. They are cultivated in 130 countries, mainly in the tropical and subtropical regions of the southern hemisphere (FAO, 2008). Banana is grown over a harvested area of approximately 10 million hectares worldwide, with an annual production of over 81.2 million tones (FAO, 2008). Banana is grown under various types of cropping systems generating crop yields ranging roughly between 5 and 70 tones/ha/yr (INIBAP, 1999). The vast majority of producers are small-scale farmers growing the crop either for home consumption or for local market. Besides being a cheap and easily produced source of energy, it is rich in vitamins A, C, B6, and is a good source of minerals. Vegetative and floral structures of banana were comprehensively described by Morton (1987), Stover and Simmonds (1987) and Robinson (1996).

Oman is an arid country and has a diverse topography and climate that allow for the cultivation of various types of fruit crops including banana and plantains (Al-Yahyai and Al-Khanjari, 2008). Banana production in Oman is 34,000 tones annually from an area of approximately 2,344.8 hectares (Table 1). Banana is commercially cultivated in two main regions of Oman, Salalah plains in the southern Dhofar region of Oman and Al-Batinah region in the north. Most of the cultivars grown in Oman belong to the "Cavendish" (*Musa sapientum)* group and are called by several local names. Dwarf Cavendish is the major cultivar grown in Oman, locally known as '*Malendi'*, '*Khasab'*, '*Somali'*, '*Nagal'*, 'Red banana', '*Fard'* and 'Williams' (MoA, 2001). The most widely grown is

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Table 1. Area (ha) and production (tones) of major fruit crops in Oman for the period from 2002 to 2004.

Fruit crops	2002		2003		2004	
	Production (MT)	Area (ha)	Production (MT)	Area (ha)	Production (MT)	Area (ha)
Dates	291,97.2	846,27	757,83.4	846,19	231,000	291,72.4
Banana	32,915	2,250	28,752	2,160	34,000	2,344.8
Coconut	4,470	353.4	4,326	343.4	4,000	344.8
Lemon	8,385	1,388.6	6,830	1,241.4	2,875	9,93.1
Mango	10,910	1,238.6	9,841	1,227.9	8,700	1,206.9
Papaya	5,745	1,06.9	2,404	92.4	2,900	120.7
Total	354,397	90,926.6	127,936.4	92,775	283,457	340,027

Source: MoA, 2005.

'Williams' cultivar that produces an average of 62.3 tons/ ha compared to 'Dwarf' and 'Giant Cavendish' (39.7 and 33.6 ton/ ha, respectively) (MoA, 2006).

Banana is a fast-growing plant which requires continuous supply of nutrients and water for high yield. These nutrients may be partly supplied by the soil and through cycling within banana plantation. But fertilizer application is generally needed to satisfy plant requirements for obtaining profitable production. Banana requires large amounts of macronutrients, that is, nitrogen, phosphorus and potassium (Twyford and Walmsley, 1974a, b, c; Lahav and Turner, 1983; Lahav, 1995). Poor agricultural and field management practices, especially high-density planting, over-irrigation, lack of fertilizer application, pruning and desuckering, in developing countries such as Oman lead to large losses in yield and fruit quality.

Little research has been conducted on banana fertilizer application in both timing and doses of application in subtropical arid climates, such as that of Oman. This research aimed to study the vegetative growth, yield, and fruit characteristics of 'Williams' banana as affected by fertilizer application to achieve the following objectives: (1) to study the effects of mineral fertilizer (NPK) on growth and yield of 'Williams' banana under field conditions in a subtropical arid climate, and (2) to determine the proper fertilizer rate for Cavendish banana appropriate for the northern coastal region of Oman.

MATERIALS AND METHODS

Location and plant materials: All field trials were established at Al- Suwiaq in Al-Batinah region in northern Oman, (23.87°N latitude and 57.23°E longitude). The region is characterized by a warm and humid tropical climate. It is located at an altitude of 27 m above sea level. Banana (*Musa acuminata* Colla, Cavendish cv. 'Williams') plants were grown in the field at a spacing of 1.8 m between mats and 2.0 m between rows. The mats were planted in three lines with two (guard) borderlines and each mat had a maximum of two suckers. Other standard practices such as pruning dry leaves, desuckering, propping, bell or male flower removal and weeding were regularly done.

Soil and water characteristics: Twenty four homogenized soil samples were randomly collected from different locations at the site of the research field prior and after the experiment to determine soil characteristics and nutrient contents. All samples were taken at a depth of zero – 30 cm and they were packed in plastic bags after labeling. The banana field was irrigated from a bore-well using drip irrigation system at a rate of 25 L/day. Water samples were collected from the water source after 10 min of pumping. Soil and water samples were analyzed in a specialized analysis lab (Soil and Water Laboratory at the Directorate General of Agricultural and Livestock Research in Rumais, Oman) following standard physical and chemical soil and water analysis methods according to AOAC (1999). Results of the soil physical and chemical analysis of the experiment site are shown in Tables 2 and 3, respectively. Irrigation water pH was 6.6 and EC was 0.860 µmhos/cm.

Fertilizer treatments: The field was laid out according RCBD design with three replications and four mats per replication. The following N-P-K fertilizer treatments were applied: T1 = no fertilizer applied; T2 = 300-50-250 g/mat/yr; T3 = 600-100-500 g/mat/yr; and T4 = 900-150-750 g/mat/yr. Fertilizer application rate was based on a generally proposed fertilization program (600-100-500 g/mat/yr N-P-K) for banana plantations grown in southern Oman (MoA, 2006). The fertilizers used in this experiment were urea as source of nitrogen, triple super phosphate as a source of phosphate, and potassium chloride as a source of potassium. Fertilizer treatments were divided and applied in 5 doses distributed throughout the cropping cycle. Treatment fertilizers were applied in 20 cm depth circular bands at 30 cm distance from the banana mat. Following application, fertilizers were covered with soil and the plants were irrigated through drip irrigation system for 30 min. In addition, organic compost (20 kg /mat) was applied twice during the same period and supplemental micronutrient foliar spray (Fetrilion Combi, 300 ml per 200 L H_2O) was applied 3 times before flowering, at flowering and during fruits maturation. Details of the dosage are shown in Table 4.

Vegetative measurements: Vegetative growth of banana was measured monthly and included the following parameters: (1) plant height from soil level to the last 2 leaf curvatures using a tape measure; (2) stem girth at 30 cm above soil level using a tape-measure; (3) leaf area of three functional leaves using the formula (leaf length x leaf width x 0.8) (Summerville, 1944 and Obiefuna and Ndubizu, 1979); (4) number of functional leaves; (5) days from flower initiation to bunch harvest were counted as the period of flowering; and (6) number of days from establishment to bunch harvest.

Reproductive measurements: The bunch characteristics viz. (1) bunch weight; (2) number of hands per bunch; (3) total number of fruits (fingers) per bunch; and (4) defruited stalk weight and hand characteristics viz. (1) middle-hand weight; (2) number of fingers

Table 2. Soil physical characteristics at the experiment site in Al-Batinah, Oman.

Texture	Gravel	Coarse sand	Clay	Silt
%	0.71 – 1.35%	1.0 – 2.82%	4.86– 7.1%	9.46-15.12
Soil type	Loamy Sand			

Table 3. Soil chemical characteristics at the experiment site in Al-Batinah, Oman.

	EC µmhos/cm	pH	N (%)	P (ppm)	K (ppm)
Before the experiment	1.14	7.8	0.04	9.77	8.62
After the experiment	1.62	7.62	0.041	12.65	24.06

Table 4. Distribution of fertilizer dosage to banana cv. 'Williams' grown at Al-Batinah region of Oman during the cropping cycles of 2005-2006.

Doses	Time of application
1st dose	Mid January
2nd dose + organic	Mid March
3rd dose + organic	Mid June
4th dose	Mid September
5th dose	Mid November

per middle-hand and fruit (finger) characteristics using the middle finger of middle hands like (1) fruit length and diameter; (2) fruit weight, were measured.

Data analysis: All data were analyzed using the PROC GLM of the SAS statistical analysis software (SAS Institute, Cary, N.C.). When differences among treatment means were significant, mean separation was done using Least Significant Difference (LSD) at $p \leq 0.05$.

RESULTS AND DISCUSSION

Vegetative characteristics

Number of leaves per plant: The fertilizer treatment had little effect on the leaf number of 'Williams' banana. The leaf number of all treatments increased slightly from January to February in response to the fertilizer treatment (Figure 1). The adverse climatic conditions (hail and strong winds) occurred during the month of March that led to destruction of the plant leaves. New leaves were produced during the month of March and the data collection was resumed on May when plants had an average of seven leaves. The rise in leaf number continued to reach over 12 leaves per plant in July with no significant effect of the fertilizer treatments on leaf number until flowering (Figure 1). Similar observation was seen in the rate of leaf emergence, where one leaf was produced per 7- 10 days. Fertilizer application had no effect on leaf number and the largest number of functional leaves produced was from T1 treatment, with no fertilizer applied. At the time of flowering, all the treatments produced the same number of leaves (ranged from 10-12 leaf/plant). This exceeded the lowest number of leaves (eight leaves) required at flowering to obtain high yield (Martinez, 1984).

Leaf area: Leaf area of banana plants increased from 2400 cm^2 until it reached its maximum area (13000 cm^2) at flower initiation. Control treatment (T1) had the largest leaf area from May to June compared to T4 which had the lowest leaf area (Figure 2). From August to November, all treatments showed a slight increase in growth of banana leaf area, which did not exceed 1000 cm^2 per treatment per month. Nonetheless, T1 had significantly larger leaf area as compared to all other treatments (Figure 2).

Stem height and circumference: The result indicated that there was a significant difference among fertilizer treatments in stem height (Figure 3) and stem circumference or girth (Figure 4). The stem height in all the treatments showed steady increase throughout the growth cycle of the banana plants. The control treatment (T1) showed the maximum plant height in comparison to other treatments while T3 had the lowest stem height. There was no significant difference between T2 and T4 (Figure 3). Similar studies have shown an increase in plant height and circumference as a result of high plant density per unit area (Langdon et al., 2008) due to competition among plants. Hegde et al. (1991) had similar observation to the results of present study that increasing nitrogen and potassium fertilization had no effect on stem girth

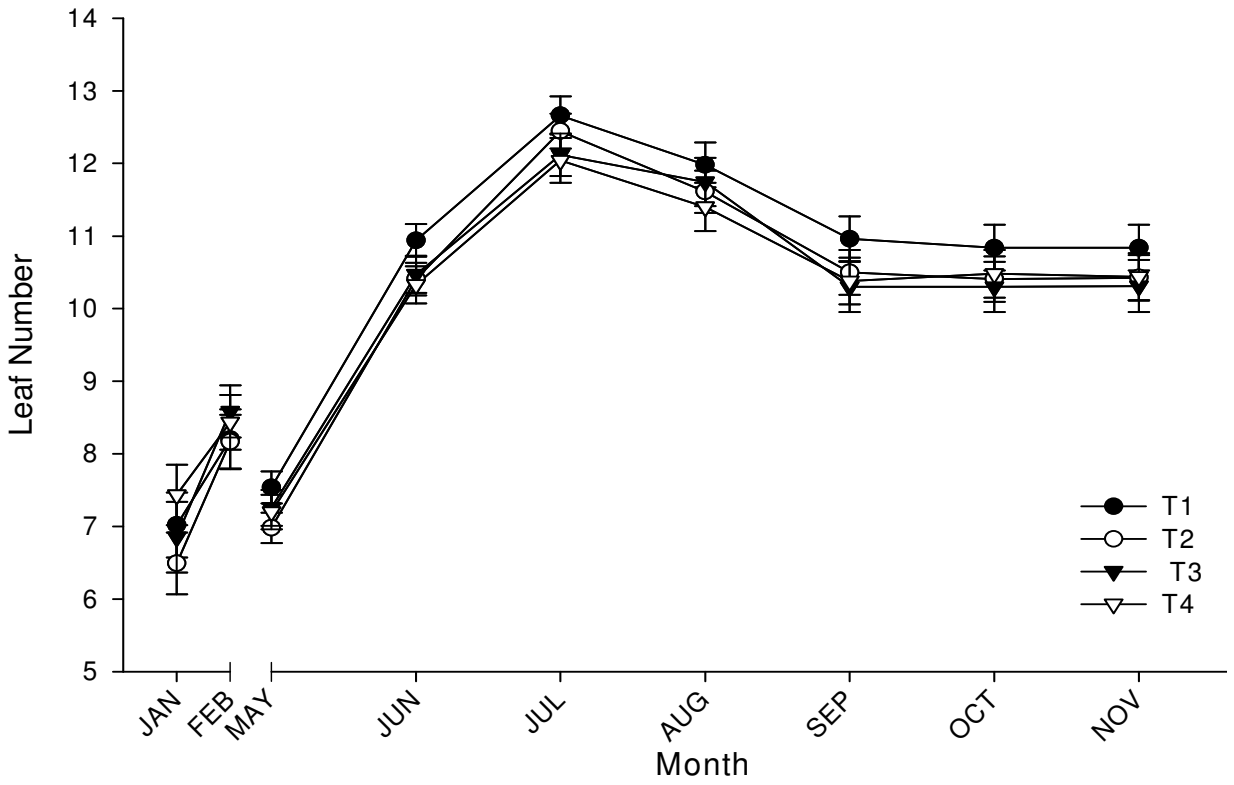

Figure 1. Effect of four rates of NPK fertilizer on the number of leaves of banana cv. 'Williams' grown in northern Oman during the 2005/2006 season. (X-axis gap indicates no data for March and April).

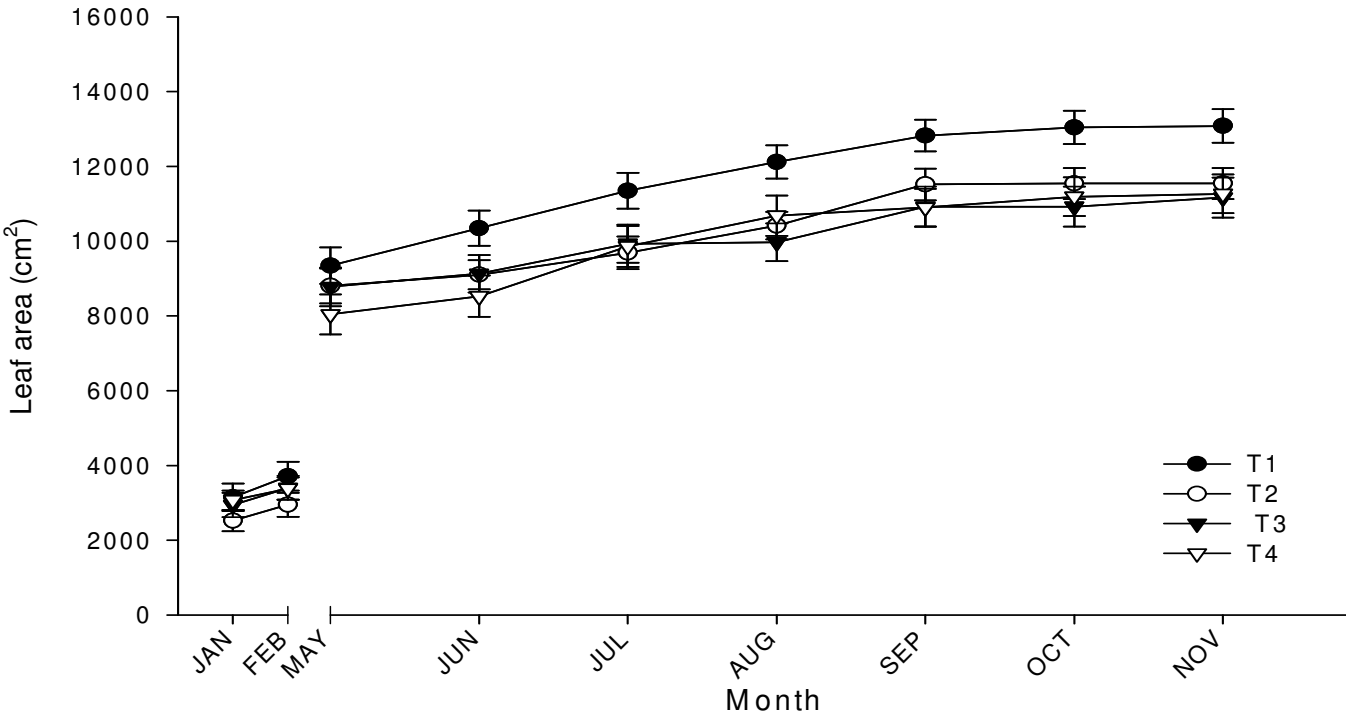

Figure 2. Effect of four rates of NPK fertilizer on the leaf area of banana cv. 'Williams' grown in northern Oman during 2005/2006 season. (X-axis gap indicates no data for March and April).

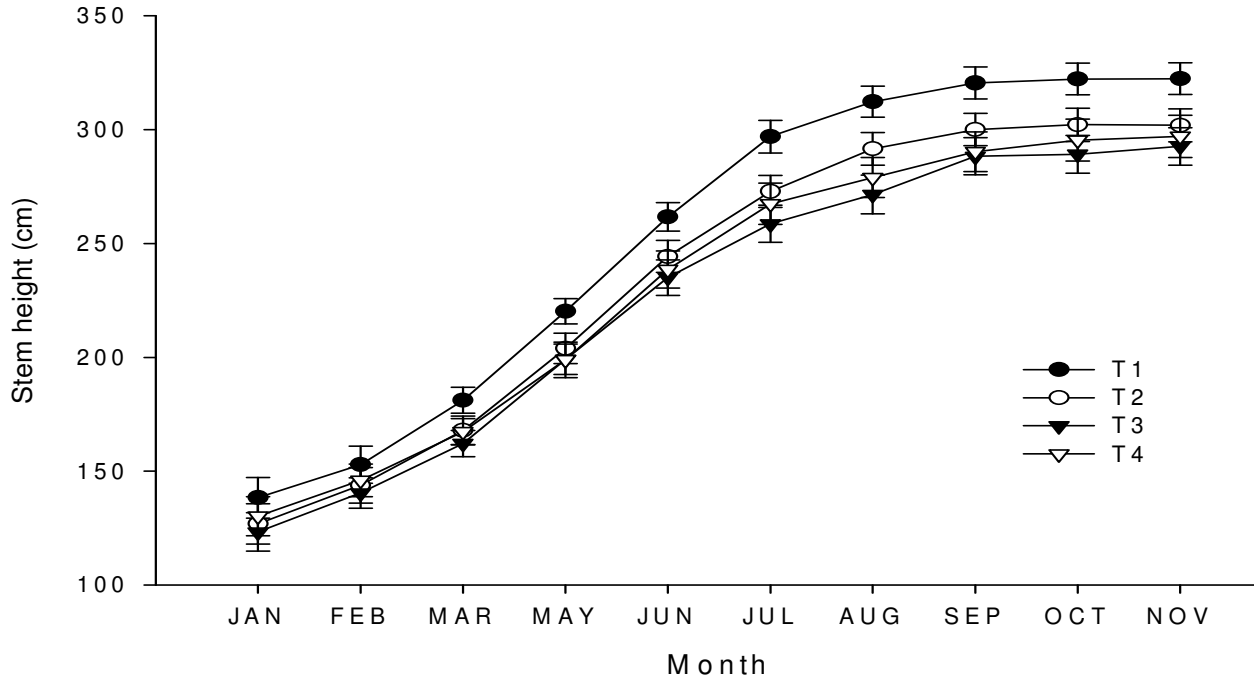

Figure 3. Effect of four rates of NPK fertilizer on stem height of banana cv. 'Williams' grown in northern Oman during 2005/2006 season.

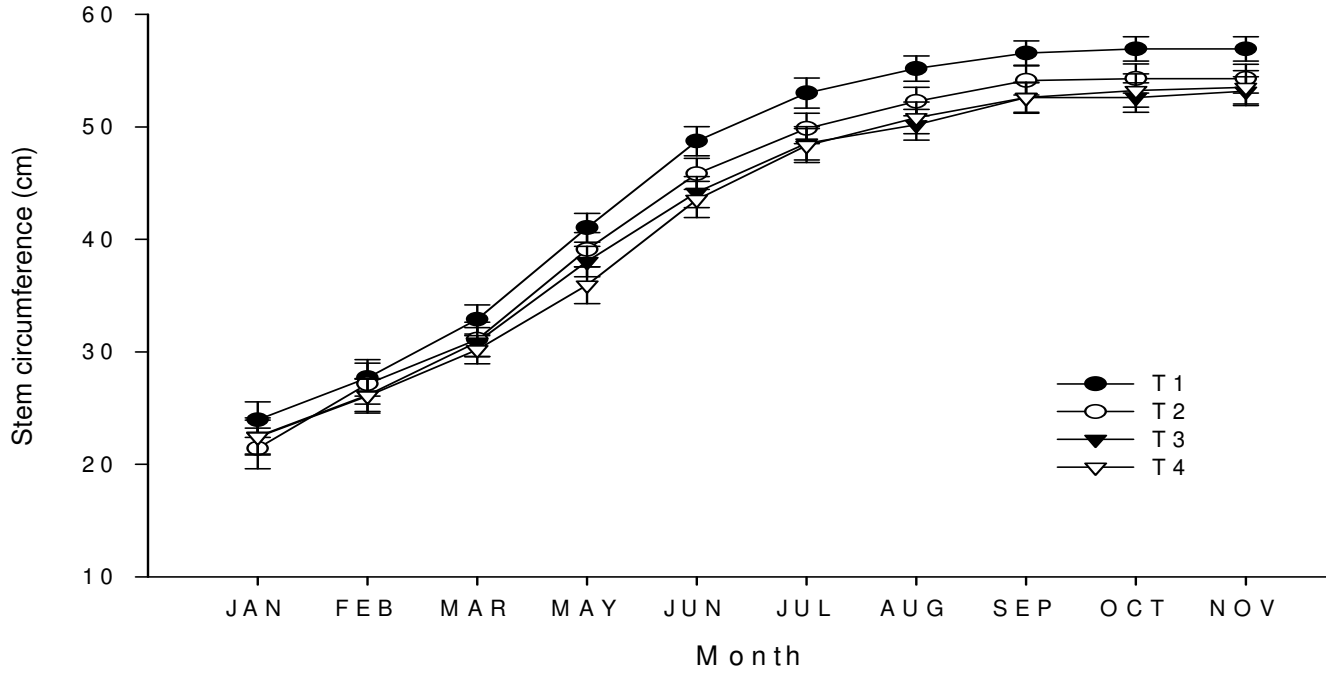

Figure 4. Effect of four rates of NPK fertilizer on stem circumference of banana cv. 'Williams' grown in northern Oman during 2005/2006 season.

effect on stem girth. This perhaps was due to sufficient amounts of soil NPK to sustain vegetative growth as evident in this study.

Reproductive characteristics

Total bunch weight: The largest bunch weight was ob-

Table 5. The effect of NPK fertilizer treatments on bunch characteristics of 'Williams' banana grown in northern Oman during 2005/2006.

	Fertilizer treatments [zy]			
	T_1	T_2	T_3	T_4
Total bunch weight (kg)	9.00 c	10.45 bc	14.98 a	12.21 b
Total fruit weight (kg)	7.88 c	9.42 bc	13.47 a	11.03 b
Total fruit / bunch	97.94 a	102.82 a	116.93 a	113.49 a
No. of hands /bunch	7.91 a	8.46 a	9.6 a	9.00 a
Stalk weight (kg)	1.12 a	1.04 a	1.51 a	1.19 a

[z] T_1: 0N:0P:0K, T_2: 300N:50P:250K, T_3: 600N:100P:500K, T_4: 900N:150P:750K (g/mat/yr).
[y] Similar letters within rows indicate no significant differences among treatments (LSD, $p \leq 0.05$).

tained in T3 treatment as compared to the control (T1). The bunch weight decreased when level of N, P and K decreased below T3 and above T4 or when no fertilizer was applied (T1) (Table 5). The results also showed that the higher dose of fertilizer application (as in T4) may result in small bunch weight. This was also observed by Butler (1960), Martin-Prével (1962) and Martin-Prével and Montagut (1956) where excessive potassium reduced banana yield.

The increase in bunch weight may be caused by high number of fruits per bunch and large number of hands per bunch. The results of this study revealed no significant difference between different fertilizer rates with respect to the total fruit number and the number of hands per bunch (Table 5).

The increase in yield (bunch weight) was attributed to increase in the total fruit weight. The total fruit weight was significantly higher in T3 than in all other treatments whereas T1 had the lowest total fruit weight (Table 5). Similar studies have shown that sufficient soil nutrients are essential in obtaining higher total fruit weight (Bolanos et al., 2003; Butler, 1960; Lassoudiere, 1974). Application of NPK fertilizer had no effect on stalk weight in this study in contrast to the results, although increased nitrogen in the soil has resulted in increased stalk weight in a study by Holder and Gumbs (1983). Lack of fertilizer on stalk weight may be due to the negligible effect of fertilizer on the non-reproductive growth under the conditions of this study.

Middle-hand weight and fruit number: Results of the study showed a significant difference in the middle-hand's weight among different fertilizer rates (Table 6). Mean middle-hand weight was the lowest with T1 in comparison with T3 and T4 treatments, but T1 was not significantly different from T2. There was a significant difference between T3 and T4, in which middle-hand weight in T3 approached 1.37 kg whereas it was 1.12 kg with T4 where the rate of fertilizer was double than that of T3. Similarly, the number of fingers per middle hand was largest (16 fingers) in case of T3 treatment followed by T4 compared to the control (T1) which had the lowest number of fingers (13 fingers) (Table 6).

As mentioned earlier, excessive fertilizer may lead to a reduction in fruit weight (Lahav, 1972; Martin- Prével, 1962; Martin- Prével and Motaqut, 1956). Conversely, potassium deficiency reduced proper and full growth of banana because of decreased uptake of other essential elements such as nitrogen and phosphorus (Turner and Walmsley, 1973). Similar results were also reported by Twyford and Walmsley (1973 and 1974) who found that potassium deficient 'Robusta' banana plants were unable to continue absorption of nitrogen. This explains the adverse effects of inadequate (T1 and T2) and excessive NPK (T4) on banana bunch and hand weight.

Weight, length and diameter of middle fingers of middle hands: Post-harvest measurement of middle-hand fingers showed no significant differences in finger weight, length and diameter among different fertilizer rates (Table 7). This is perhaps due to the inherent variability among middle fingers of the middle hands among bunches within each treatment (weight cv = 53.25). Although this contradicts the conclusion of Srikul and Turner (1995) that there was a direct relationship between fruit fresh weight and amount of nitrogen applied that is, nitrogen promoted early pulp growth during fruit maturity and this determined its influence on the final fruit fresh weight. For example, in 'Ney Poovan' banana, a gradual increase of nitrogen application increased fresh fruit weight in direct proportion by 10.5% (Srikul and Turner, 1995). This result could be expressed in terms of fruit length and girth as a result of accelerated early pulp growth and cell expansion. In this study on 'Williams' banana, we have not seen of that trend in 'Ney Poovan' among the NPK fertilizer treatments considered, suggesting that fertilizer effects vary among banana cultivars.

Number of days to harvest and flowering period: The total number of days from planting to harvest (Table 8) was not significantly affected by the fertilizer treatments

Table 6. The effect of NPK fertilizer treatments on middle-hand characteristics of 'Williams' banana grown in northern Oman during 2005/2006.

	Fertilizer treatments [zy]			
	T_1	T_2	T_3	T_4
Middle-hand weight (kg)	0.940 c	1.070 bc	1.365 a	1.120 b
No. of fruits / hand	13.10 c	14.40 bc	16.05 a	14.33 b

[z] T_1: 0N:0P:0K, T_2: 300N:50P:250K, T_3: 600N:100P:500K, T_4: 900N:150P:750K (g/mat/yr).
[y] Similar letters within rows indicate no significant differences among treatments (LSD, $p \leq 0.05$)

Table 7. The effect of NPK fertilizer treatments on middle finger of middle-hand characteristics of 'Williams' banana grown in northern Oman during 2005/2006

	Fertilizer treatments [zy]			
	T_1	T_2	T_3	T_4
Finger weight (kg)	0.14 a	0.13 a	0.15 a	0.15 a
Finger length (cm)	13.7 a	15.72 a	16.91 a	15.21 a
Finger diameter (cm)	2.72 a	2.96 a	3.21 a	3.1 a

[z] T_1: 0N:0P:0K, T_2: 300N:50P:250K, T_3: 600N:100P:500K, T_4: 900N:150P:750K (g/mat/yr).
[y] Similar letters within rows indicate no significant differences among treatments (LSD, $p \leq 0.05$).

Table 8. The effect of NPK fertilizer treatments on the number of days from planting to harvest and flowering period of 'Williams' banana grown in northern Oman during 2005/2006

No. of days	Fertilizer treatments [zy]			
	T_1	T_2	T_3	T_4
Planting to harvest	428.67a	450.33a	441.67a	423.33a
Flowering to harvest (flowering period)	111.67a	119.00a	107.67a	110.83a

[z] T_1: 0N:0P:0K, T_2: 300N:50P:250K, T_3: 600N:100P:500K, T_4: 900N:150P:750K (g/mat/yr).
[y] Similar letters within rows indicate no significant differences among treatments (LSD, $p \leq 0.05$).

in this study. T2 showed the longest number of days from planting to harvest (450) and T4 had the lowest numbers of days (423) with a difference of 27 days. This may have an important effect on maturity of banana if all other harvest criteria are met.

The results also revealed no significant differences among fertilizer treatments for the number of days from blooming to bunch harvest (that is flowering period) (Table 8). Nevertheless, the difference in the number of days varied among fertilized treatments. It was shorter in T3 with 107 days whereas T2 had the longest flowering period that reached 119 days. Though the statistical difference might be insignificant, the economic benefit of 12 days may be further explored and studied.

Conclusion

Application of four levels of NPK fertilizer that ranged from none (control) to 900N:150P:750K (g/mat/yr), did not greatly influence vegetative growth studied, that is leaf number and area, plant height, stem circumference, and days from planting or flowering until harvest. However, there were some variables that were greater under no fertilizer treatment (T1) such as stem height and leaf area. This may have been caused by other factors not related to fertilizer application such as within mat competition or sufficient soil nutrients.

Application of fertilizers influenced the reproductive characteristics of 'Williams' banana including total bunch weight, total fruit weight, middle-hand weight and number of fruits per middle-hand. However, fertilizer had no significant effects on fruit (finger) weight and dimensions or number of days to harvest. Where fertilizer application had an effect, treatment T3 was the most productive followed by T4 and T2, while T1 (no fertilizer) had the lowest yield and fruit characteristics.

Results from this study showed that for 'Williams' banana grown under the field conditions of Northern Oman and areas with similar climatic and soil conditions, application of NPK at a rate of 600, 100 and 500 g/mat/yr,

respectively, produced numerically the highest yield. However, long-term studies are needed to determine the residual effects of fertilizer application on soil and plants as well as its interaction with other factors such as irrigation, desuckering and management practices.

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REFERENCES

Al-Yahyai R, Al-Khanjari S (2008). Biodiversity of date palm in the Sultanate of Oman. Afr. J. Agric. Res. 3: 389-395.

AOAC (1999). Official methods of analysis of the Association of Official Agricultural Chemists. 16th Edn. (5th revision). AOAC International Gaithersburg MD (USA)

Bolanos M, BMorates HO, Celisal D (2003). Fertilizer (organic and inorganic) and production of 'Dominico harton'. Infomusa 12: 38-41.

Butler AF (1960). Fertilizer experiments with 'Gross Michel' banana. Trop. Agric. (Trinidad) 37: 31-50.

FAO (2008). Agricultural Production Statistics Database (FAOSTAT), Rome, Italy. (http://faostat.fao.org).

Hegde D, Srinivas K (1991). Growth, yield, nutrient uptake and water use of banana crops under drip and basin irrigation with N and K fertilization. Trop. Agric. (Trinidad) 68: 331-334.

Holder GD, Gumbs FA (1983). Effect of nitrogen and irrigation on the growth and yield of banana. Trop. Agric. (Trinidad), 60: 179-183.

INIPAB (1999). Networking Banana and Plantain: IIBAP Annual Report 1989. International Network for the Improvement of Banana and Plantain, Montpellier, France.

Lahav E (1972). Effect of different amounts of potassium on growth of the banana. Trop. Agric. Trin. 49: 321-325.

Lahav E (1995). Banana nutrition. In: Gowen S (Ed.), Bananas and Plantains. Chapman & Hall, London pp: 258-316.

Lahav E, Tuner DW (1983). Banana nutrition. IPI, Bern p. 62.

Lassoudriere A (1974). Growth and development of the 'Poyo' banana as a function of climatic variation in Ivory Coast. Fruits 29: 432-455.

Langdon PW, Whiley AW, Mayer RJ, Pegg KG, Smith MK (2008). The influence of planting density on the production of 'Goldfinger' (Musa spp., AAAB) in the subtropics. Sci. Hortic. 115: 238-243.

Martin-Prével P (1962). Les elements mineraux dans le bananier et dans son regime. Fruits 17: 123-128.

Martin-Prével P, Montagut G (1956). Interaction in the mineral nutrition of banana. Fruits 21: 19-36.

Martinez GA (1984). Deternincción del area minima foliar en plátano en el trópico húmedo. Revita ICA 19(2) : 183-187.

MoA (2005). Agricultural Census 2004/ 2005. Batinah Region, Sultanate of Oman. Ministry of Agriculture, Oman p. 3

MoA (2006). Evaluation of Different Banana Varieties under the Different Climatic Conditions, Biennial Agricultural Research Report, Ministry of Agriculture, Oman pp: 16-19

Morton J (1987). Banana. In: Fruits of warm climates. Julia F. Morton, Miami, FL. pp: 29–46.

Obieffuna JC, Ndubizu TO (1979). Estimating leaf area of plantain. Sci. Hortic. 11: 31-36.

Robinson JC (1996). Banana and Plantain, CAB International, Wallingford, UK. p. 229.

Stover RH, Simmonds NW (1987). Bananas 3rd Edn. Longmans, London, UK. pp: 53-60.

Summerville WAT (1944). Studies on nutrition as qualified by development in *Musa cavendish* L. Queensl. J. Agric. Sci. 1:1-127.

Turner DW, Walmsley D (1973). Mineral composition of the 'Robusta' banana plant. Plant & Soil, 39: 227-243.

Twyford IT Walmsley D (1973). Mineral composition of the 'Robusta' banana plant. Plant & Soil, 39: 227-243.

Twyford IT Walmsley D (1974a). The mineral composition of Robusta banana plant. II. The concentration of mineral constituents. Plant and Soil, 41: 459-470.

Twyford IT Walmsley D (1974b). The mineral composition of Robusta banana plant. III. Uptake and distribution of mineral constituents. Plant and Soil, 41: 471-491.

Twyford IT Walmsley D (1974c). The mineral composition of Robusta banana plant. IV. The application of fertilizers for high yields. Plant Soil 41: 493-508.