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Gibberellic Acid and Naphthalene Acetic Acid Affect Fruit Retention, Yield and Quality of Keitt Mangoes in the Coastal Savanna Ecological Zone of Ghana

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ABSTRACT

Mango production in Ghana is highly reduced by low fruit set. This research was undertaken to apply plant growth regulators to increase fruit set and yield. The present investigation was carried out during two successive years of 2008 and 2009 on "Keitt" mango trees in order to study the effect of gibberellic acid (GA_3) and Naphthalene Acetic Acid (NAA) sprays of different concentration on fruit retention, fruit quality and yield. Trees were sprayed at full bloom stage. The three hormone levels and two location effects were factorially combined and replicated three times in a Randomized Complete Block Design (RCBD). In order to obtain season or year effect, data were analysed as a split-split plot design with season as the main plot, location as sub-plot and cultivar as sub-sub plot. All sprayed chemicals significantly increased fruit retention and tree yield in both seasons. GA_3 (25 ppm) and NAA (25 ppm) gave the best results in terms of increasing fruit set, fruit retention, number of fruits per cluster and per plant, fruit weight and yield. No significant differences were observed between the quality of fruits harvested from treated and control trees. 25 ppm of GA_3 and 25 ppm NAA can be employed for spraying mango flowers at full bloom to increase mango fruit set, retention and yield of growers.

Key words: *Mangifera indica*, gibberellic acid, naphthalene acetic acid, GA_3-NAA, fruit retention, yield

INTRODUCTION

According to Nakasone and Paul (1998) and Purseglove (1972), mango *(Mangifera indica* L.), a member of the Anacardiaceae family is considered to be one of the top and significant fruit crops in many tropical and sub-tropical countries. Without doubt, the fruit is used in the immature, mature or ripe stage and can also be processed into products such as jellies, jams, juices, cut fresh fruit, dried chips, fruit concentrate and fruit leather (Hayes, 1966; Nakasone and Paull, 1998; Litz, 1997; Steven, 2007).

In Ghana, the turpentine and Jaffna cultivars were the first to be introduced by the early Portuguese missionaries while the exotic and highly valuable cultivars ('Keitt', 'Kent', 'Haden',

'Tommy Atkins' and 'Palmer') were introduced from Florida, USA to the country in the 1960s. This crop showed phenomenal increase in area and production. Presently, Keitt is the leading cultivar produced in large quantities for both the local and export markets in Ghana.

The mango has few flower retention and low fruit set (Singh and Singh, 1995). The flower and abscission is result of fruit complex physiological phenomena which occurs in many mango cultivars at all stages of development, but is more explicit during the first 3-4 weeks after pollination and accounts for over 90% loss of set fruitlets (Bains *et al*., 1997; Wahdan and Melouk, 2004).

Flower drop and fruits is being attributed to lack of pollination and failure of fertilization, ovule abortion, embryo degeneration, hormone content, high temperatures inadequate soil moisture and low photosynthate level (Whiley, 1986; Bains *et al*., 1997; Nkansah and Ito, 1994).

The use of plant growth regulators such as NAA, GA_3 and indole-3-butyric acid (IBA) by many researchers have shown reduced flower drop, high flower retention, increased yield and fruit quality in mango and other fruit species such as citrus, apple and guava (Hairdry *et al*., 1997; El-Shewy, 1999; Iqbal *et al*., 2009). Muarya and Singh (1981) and Dutta and Banik (2007) observed that foliar applications of GA and NAA significantly increased fruit length, diameter and fruit weight.

The inconsistent flowering behaviour of mango trees probably is consequence of the climate change which is affecting production regions in Ghana and other parts of the world. Recent investigations has been conducted to increase the retention of flowers and fruits using plant growth regulators like GA_3 and NAA. The present study was conducted to investigate the effect of NAA and GA_3 sprays at the flowering stage to improve mango fruit retention, yield and fruit quality in Keitt cultivar.

MATERIALS AND METHODS

Study sites: The present study was carried out during 2008 and 2009 growing seasons on 7-year old mango (*Mangifera indica* L.) cv. Keitt trees at two locations. The locations were GLAACO Farms, Sogakope and JTC Farms, Akuse near Kpong. Glaaco Farms located in the Coastal Savanna zone of Ghana. Sogakope, Volta Region which is in the Coastal Savannah belt is on latitude 06·1824605N and longitude 0.1062630E. The soil type is Ferric Luvisol with an annual rainfall amount of about 800.1 mm. (FAO/UNESCO, 1990). JTC Farms, Kpong, Eastern Region which is in the Coastal savanna zone of Ghana is on latitude 06.10127°N and longitude 0.03851°E. The soil type is Ferric Acrisol with an annual rainfall of about 1138.7 mm. The selected areas fall within the Southern Horticultural Belt of Ghana where most mango crop is grown.

Experimental design and treatments: The experimental design employed was Randomized Complete Block with factorial combination of three hormone levels and two locations replicated four times. However, in order to obtain information on the effects of season, the results in both seasons were analyzed as a split-split plot design with season as the main block, location as sub-plot and hormone as sub-sub plot.

The treatments were as follows: 1. Control treatment was sprayed with water, 2) GA_3 25 ppm+NAA 25 ppm and 3) GA_3 50 ppm+NAA 50 ppm. The aqueous solutions containing the plant growth regulator's solution were sprayed in the entire tree foliage at the flowering stage. Trees were sprayed with GA_3 (25 ppm) and a week later another spray was made with NAA (25 ppm). Control treatments on trees were sprayed with water at the same time. Spacing of trees used was 10×10 m apart and subjected to the same cultural management practices in many orchards.

Parameters measured: Fruit set was recorded as fruit/panicle when all the flowers dried but remained attached to the panicle. Fruit set was recorded from 10 randomly selected panicles around each experimental tree. Fruit retention was recorded as fruit/panicle at fruit maturity at the time of harvesting. The yield (number of fruits/tree and kg/tree) was calculated. Fruit physicochemical characteristics in terms of quality were determined using random samples of five fruits from each treatment. Fruit total acidity was determined according to AOAC (1995). In the laboratory the sugar content (Brix) was determined with a digital pocket refractometer (ATAGO POCKET PAL-1) and pH determined with a digital pH meter (ATAGO DPH-1). Sugar content in fruits was evaluated using 5 individual mango fruits per treatment and replicated three times.

Data analysis: Data collected was analyzed (split-split plot design with season as the main block, location as sub-plot and hormone as sub-sub plot) using analysis of variance (ANOVA), GenStat version 11. and means separated using the Least Significant Differences (LSD) at p = 0.05. The three hormone levels and two location effects were factorially combined and replicated three times in a Randomized Complete Block Design (RCBD). In order to obtain season or year effect, data were analysed as a split-split plot design with season as the main plot, location as sub-plot and cultivar as sub-sub plot.

RESULTS

Main effects of location, season and hormone on fruit set, retention and yield of Keitt mangoes: Results of this study showed that fruit set showed a significant difference between the two locations, Kpong and Sogakope (Table 1). Fruit set at Sogakope was significantly higher (25.5%) than at Kpong (23.2%) (Table 1). Fruit set showed significant difference in the two seasons and was higher in 2009 season (24.9%) compared to 2008 season (23.2%) (Table 1). Fruit set showed significant variation among the hormone treatments 25 ppm hormone application recorded the highest value of 29.0%, followed

Table 1: Main effects of location, season and hormone concentration on fruit set, retention, number and weight of Keitt mango

Treatment	Fruit set (%)	Fruit retention (No. panicle^{-1})	Fruit number (No. plant^{-1})	Fruit weight (g)
Location (L)				
Kpong	23.2	2.02	90.0	67.0
Sogakope	25.5	2.19	191.3	139.2
Significance	*	ns	*	*
Season (S)				
2008	23.2	1.98	138.7	100.2
2009	24.9	2.23	142.5	106.0
Significance	*	ns	ns	*
Hormone (H)				
0 ppm	16.5	1.39	80.7	67.1
25 ppm	29.0	2.57	177.6	132.1
50 ppm	27.6	2.36	163.6	110.1
Significance	*	*	*	*
Interactions				
L×S	*	ns	*	*
L×H	*	*	*	*
S×H	*	*	*	*
L×S×H	*	*	*	

ns: Non significant, *Significant at p = 0.05

by 50 ppm treated plants (27.6%) while the control had the lowest value of 16.5% (Table 1). Interactions of the three factors had significant effect on percent fruit set (Table 1).

In Table 2, the mean values of plant hormone treatment for fruit set, retention, number and weight in the two locations and seasons is narrated. Fruit set of trees at Kpong sprayed with GA_3 and NAA applications were significantly ($p = 0.05$) higher compared to the control. 25 ppm GA_3+25 ppm NAA recorded the highest fruit set (26.3%) followed by 50 ppm GA_3+50 ppm NAA (24.1%) while the control had the lowest (14.8%) in 2008 season (Table 2). In 2009 season, fruit set of trees treated with 25 ppm GA_3+25 ppm NAA had the highest value (28.2%) while the control recorded the least value of 18.9% (Table 2). At Sogakope, 25 ppm GA_3+25 ppm NAA applications significantly ($p = 0.05$) increased percentage fruit set (32.4%) as compared to the control (16.4%) in year 2008 while in year 2009, the highest value of 32.8% was obtained from 25 ppm GA_3+25 ppm NAA and 26.8% for 50 ppm GA_3+50 ppm NAA and the control gave the lowest value of 16.0% (Table 2).

Results in Table 3 which show analysis of variance (including degrees of freedom) for the mean squares of all the agronomic fruit components and fruit quality characters studied indicate significant location, season and hormone differences for percent fruit set as well as significant location and season (L×S), location and hormone (L×H), season and hormone (S×H) and significant location, season and hormone (L×S×H) interactions for the fruit set (Table 3).

Fruit retention showed no significant variation between the two locations and in both seasons but showed significant differences among the hormone treatments (Table 1). Fruit retention in the

Table 2: Mean values of plant growth regulators fruit set, fruit retention, fruit number and fruit weight of mangoes

	Fruit set (fruit/panicle)		Fruit retention (fruit/panicle)		Fruit number (No. plant^{-1})		Fruit weight (kg plant^{-1})	
Treatment (ppm)	Kpong	Sogakope	Kpong	Sogakope	Kpong	Sogakope	Kpong	Sogakope
2008 Season								
0 ppm	14.8^a	16.4^a	1.1^a	1.2^a	61.3^a	97.8^a	52.0^a	73.4^a
25 ppm GA_3+25 ppm NAA	26.3^b	32.4^c	2.4^b	2.6^b	103.8^b	249.0^c	75.1^b	186.8^c
50 ppm GA_3+50 ppm NAA	24.1^b	28.6^b	2.1^b	2.4^b	100.6^b	219.4^b	70.3^b	143.6^b
2009 Season								
0 ppm	18.9^a	16.0^a	1.4^a	1.8^a	65.2^a	98.4^a	54.2^a	88.6^a
25 ppm GA_3+25 ppm NAA	28.2^b	32.8^c	2.6^b	2.7^b	105.3^b	252.4^c	78.3^b	188.2^c
50 ppm GA_3+50 ppm NAA	26.7^b	26.8^b	2.4^b	2.5^b	103.6^b	232.8^b	72.1^b	154.4^b

NAA application were done 1 week after GA_3 application, Means within columns followed by the same letters are not significantly different according to Duncan's Multiple Range test at $p = 0.05$

Table 3: Analysis of variance showing mean squares of agronomic and fruit quality characters of melons

Source of variation	df	Fruit set (%)	Fruit retention (panicle^{-1})	Fruit (No. plant^{-1})	Fruit weight	Brix (%)	Titratable acidity (%)	TSS/TA	Pulp colour
Location (L)	1	46.6900**	0.284	92375.47**	46872.25**	2.7780	0.16670	735.31**	0.001100
Season (S)	1	11.3300**	0.588	129.96	299.29	0.0540	0.00050	1.174	0.000280
L×S	1	26.6900**	0.001	7.29	102.01	0.0180	0.00380	0.267	0.000280
Error a	4	0.0003	0.133	9.75	33.09	0.0240	0.00870	0.284	0.000007
Hormone (H)	2	560.2700**	4.717**	32966.39**	13146.42**	14.4120**	0.01200	228.11**	0.0144**
L×H	2	19.4700***	0.005	10325.09**	5232.32**	1.1250	0.00312	6.601	0.0011**
S×H	2	17.9400**	0.087	18.51	30.57	0.0390	0.000036	1.421	0.000280
L×S×H	2	19.8400**	0.051	20.16	42.89	0.2120	0.00004	1.414	0.000280
Error c	16	0.0265	0.1217	14.27	33.60	0.1603	0.00780	1.600	0.000069

***.**Significant at $p = 0.05$ and 0.01, respectively

hormone treatments were 2.57, 2.36 and 1.39 per panicle in 25, 50 ppm and the control respectively (Table 1). There were significant interactions with the exception of location and season (L×S) in location and hormone (L×H), season and hormone (S×H) and all the factors on fruit retention (Table 1).

In Table 2, the mean values of hormone treatment on fruit retention is shown. Location wise, at Kpong, mango plants treated with 25 ppm GA_3+25 ppm NAA had the highest fruit retention value (2.4) while the least was recorded by the control (1.1) in 2008 season. Similarly, in year 2009, fruit retention was highest in plants treated with 25 ppm GA_3+25 ppm NAA (2.6) and the least was the control (1.4) (Table 2). At Sogakope and in 2008 season, plants treated with 25 ppm GA_3+25 ppm NAA had the highest fruit retention value (2.6) per panicle followed by plants treated with 50 ppm GA_3+50 ppm NAA (2.4) and the least value of 1.2 was recorded by the control plants (Table 2). In the year 2009, fruit retention was again highest in plants treated with 25 pp GA_3+25 ppm NAA (2.7) followed by 50 ppm GA_3+50 ppm NAA (2.5). The control recorded the least value (1.8) (Table 2).

Analysis of variance for mean square for fruit retention indicated significant differences among the levels of plant growth regulators or hormones applied (Table 3).

In terms of fruit number per plant as indicated in Table 1, it was observed that significant differences were found between the two locations and among the hormone treatments but no significant difference was observed in the two seasons. Fruit number was significantly higher at Sogakope (191.3) than Kpong (90.0) (Table 1). In the hormone treatments, the fruit number per plant was 177.6, 163.6 and 80.7 in 25, 50 and 0 ppm, respectively (Table 1). Interactions of the three factors had significant effect on fruit number (Table 1).

The mean values of plant hormone treatment for fruit number as in Table 2 showed significant differences in the locations and seasons. Fruit number per tree at Kpong in the plant hormone treated plots was highest in trees treated with 25 ppm GA_3+25 ppm NAA (103.8 and 105.3 fruits plant^{-1}) and lowest in control trees (61.3 and 65.2 fruits plant^{-1}) in year 2008 and 2009 seasons, respectively. At Sogakope, number of fruits per tree was highest in plants treated 25 ppm GA_3+25 ppm NAA (249.0 and 252.4 fruits plant^{-1}) and the lowest in control ones (97.8 and 98.4 fruits plant^{-1}) in year 2008 and 2009 seasons, respectively (Table 2). Analysis of variance showing mean squares for fruit number per plant in Table 3 indicated significance for the location, season and hormone.

In terms of fruit weight per plant, Table 1 showed significant differences in the locations, seasons and the hormone treatments as well as significant interactions among the treatments. Fruit weight at Sogakope was higher (139.2 kg) compared to that at Kpong (67.0 kg). In year 2009 fruit weight was 106.0 g compared to that of 100.2 g in year 2008 (Table 1). Fruit weights of 132.1, 110.1 and 67.1 kg were recorded by 25, 50 and 0 ppm hormones treatments, respectively (Table 1). Interactions of the factors were significant (Table 1).

In Table 2, the effect of plant growth regulators on mean fruit weight in the locations and seasons are shown. In Kpong, plants treated with 25 ppm GA_3+ 25 ppm NAA significantly ($p = 0.05$) had the highest fruit weight of 75.1 and 78.3 kg plant^{-1} and the control 52.0 and 54.2 kg plant^{-1} in years 2008 and 2009, respectively (Table 2).

At Sogakope, 25 ppm GA_3+25 ppm NAA significantly ($p = 0.05$) had the highest fruit weight of 186.8 and 188.2 kg plant^{-1} and the control 73.4 and 88.6 kg plant^{-1} in years 2008 and 2009 respectively (Table 2). The analysis of variance for fruit weight reported significant differences for the location, hormone and their interactions (Table 3).

Table 4: Main effects of location, season and hormone concentration on fruit quality of Keitt mango

Treatment	Brix (%)	Titratable acidity (%)	TSS/TA	Pulp colour
Location (L)				
Kpong	16.3	0.41	39.5	0.33
Sogakope	16.8	0.55	30.5	0.34
Significance	ns	*	*	ns
Season (S)				
2008	16.6	0.47	35.2	0.34
2009	16.5	0.47	34.8	0.34
Significance	ns	ns	ns	ns
Hormone (H)				
0 ppm	15.3	0.51	29.7	0.30
25 ppm	17.2	0.46	37.7	0.37
50 ppm	17.1	0.46	37.3	0.35
Significance	*	*	*	*
Interactions				
L×S	ns	*	*	*
L×H	*	*	*	*
S×H	*	*	*	*
L×S×H	*	*	*	*

ns: Non significance, *Significant at p = 0.05

Effect of GA_3 and NAA on fruit quality of Keitt mangoes: Results in Table 4 indicate that there was no significant difference in sugar content (Brix) between the two locations and seasons. However, significant difference was observed among the hormone treatments. Plants treated with 25 and 50 ppm GA_3 and NAA had a higher value (17.2 and 17.1) than the control (15.3) (Table 2). A similar pattern was observed in pulp colour. There was no significant differences in locations and seasons but differences were observed in the hormone treatments (Table 2). Titratable acidity and TSS/TA ratio showed no significant differences in the seasons but differences were observed at the two locations and in the hormone treatments (Table 2). Fruits at Sogakope had significantly higher titratable acidity value of 0.55 compared to that of Kpong (0.41). Among the hormone treatments, the control recorded a significantly higher value of 0.51 compared to plants treated with plant hormones (0.46). TSS/TA recorded a similar trend to that of titratable acidity of no significance between the seasons but significant differences in the location and among the hormone treatments were observed (Table 4).

The mean values of plant growth regulators on Brix, acidity, TSS/TA and pulp colour followed a similar trend of no significance in the hormone treatments (25 ppm GA_3+25 ppm NAA and 50 ppm GA_3+50 ppm NAA) but significant differences were observed between the plant growth regulators and the control treatments in both seasons and locations (Table 5). Analysis of variance (Table 3) revealed significant differences in the plant growth regulators or hormones for Brix, TSS/TA and pulp colour.

DISCUSSION

The increase in percent fruit set and fruit retention observed in this experiment may be ascribed to the application of the plant growth regulators (GA_3 and NAA). This observation agrees with reports by Singh and Ram (1983) and Rajput and Singh (1982). Other reports have

Table 5: Mean values of plant growth regulators on fruit quality of mangoes

	Brix (%)		Titratable acidity (%)		TSS/TA ratio		Pulp colour	
Treatment (ppm)	Kpong	Sogakope	Kpong	Sogakope	Kpong	Sogakope	Kpong	Sogakope
2008 season								
0 ppm	15.5[a]	15.0[a]	0.44[b]	0.61[b]	35.2[a]	24.6[a]	0.30[a]	0.30[a]
25 ppm GA_3+25 ppm NAA	16.8[b]	17.8[b]	0.40[a]	0.52[a]	42.0[b]	33.6[b]	0.35[b]	0.35[b]
50 ppm GA_3+50 ppm NAA	16.7[b]	17.7[b]	0.40[a]	0.53[b]	41.8[b]	34.0[b]	0.35[b]	0.40[c]
2009 season								
0 ppm	15.2[a]	15.4[a]	0.43[b]	0.62[b]	35.3[a]	24.8[a]	0.30[a]	0.30[a]
25 ppm GA_3+25 ppm NAA	16.6[b]	17.7[b]	0.40[a]	0.54[a]	41.5[b]	32.8[b]	0.35[b]	0.35[b]
50 ppm GA_3+50 ppm NAA	16.6[b]	17.8[b]	0.40[a]	0.54[a]	41.5[b]	33.0[b]	0.35[b]	0.40[c]

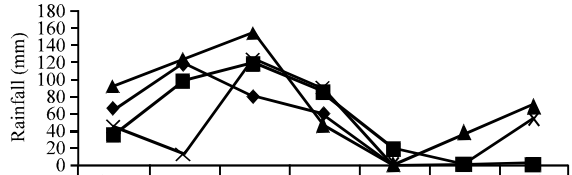
NAA application were done 1 week after GA_3 application, Means within columns followed by the same letters are not significantly different according to Duncan's multiple range test p = 0.05

claimed a correlative relationship of depleted endogenous levels of gibberellins with mango fruit abscission (Bains *et al.*, 1997; Singh *et al.*, 2010). Further findings have also indicated that foliar sprays of gibberellic acid resulted in higher fruit retention (Kabeel, 1999; Wally *et al.*, 1999). Gibberellins have been found to intensify organ ability to function as nutrient sink and also can increase the biosynthesis of IAA in plant tissue which delays the formation of the separation layer and thus enhance fruit retention (Wasfy, 1995).

The increase in the number of fruits and yield in hormone treated plants are in conformity to results obtained by other other researchers (Blumenfeld, 1986; El-Shaikh *et al.*, 1999; Kabeel, 1999; Fathi *et al.*, 2002) who found that spraying persimmon trees with GA_3 and NAA and promalin increased fruit yield. Besides, gibberellins are believed to serve as a mediating process for faster translocation and mobilization of stored metabolites or phothosynthates from source to sink and also play significant role in increasing auxin synthesis in ovaries (Looney *et al.*, 1992). Moore (1979) observed that stimulation of both cell division and cell elongation due to GA_4 foliar sprays reflected in increasing fruit weight and hence fruit yield. Sarkar and Ghosh (2005) mentioned that spray application with GA_3 increased fruit weight, volume and length of fruit. The role of GA_3 was to multiply and to lengthen the meristem cells, which results in increase fruit volume and weight. The application of NAA by other researchers have also shown that it increased fruit number, fruit weight and yield by causing cell elongation by enlargement of vacuoles and loosening of cell wall after increasing cell wall plasticity (Agrawal and Dikshit, 2008).

The increase in sugar content and sugar content/acid ratio as observed in this study confirm those of Gupta and Brahmachari (2004) and Sarkar and Ghosh (2005) who reported that NAA and GA_3 spray applications on mango trees increased soluble sugar content and total sugars and increased total soluble sugars/acid ratio.

It was observed in this study that fruit number, weight and quality were higher at Sogakope than at Kpong probably due to the climatic conditions that prevailed during the study period. Data in Fig. 1 shows that the flowering period which started in August and September was characterised by low rainfall amounts followed by an increase in rainfall at the fruit development stage and a drop at the harvesting period in January and early February.



	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Kpong (2008)	66.2	118.3	80.1	59.2	0	0	0
Sogakope (2008)	35.4	98.7	118.6	85.8	18.3	0	0
Kpong (2009)	92.7	123	154.8	46.5	0	38	69.7
Sogakope (2009)	44	12.1	123.2	89	0	0	53.5

Fig. 1: Rainfall distribution during flowering, fruit development and harvesting period, Source: University of Ghana Kpong Weather station and Sogakope Meteorological station

This trend which is ideal for better mango production was observed in Sogakope in both years and this may have contributed to plants attaining better yields compared to that at Kpong.

CONCLUSION

It could be concluded that, trees sprayed with 25 ppm GA_3+25 ppm NAA was the best and the most effective treatment in increasing fruit set, fruit retention, yield and improving fruit quality of Keitt mango trees. GA_3 and NAA as plant regulator applications seem to play important roles in improving mango production in Ghana.

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