International Journal of Plant & Soil Science

34(1): 80-93, 2022; Article no.IJPSS.79721
ISSN: 2320-7035

Effect of Potassium Nitrate Spray on the Flowering and Fruiting of Mango Varieties Grown in Uganda

Annet Katwesige [a*], Gabriel Ddamulira [b] and Sylvester Katuromunda [c]

[a] Ministry of Agriculture Animal Industry & Fisheries, Entebbe, Uganda.
[b] National Crops Resources Research Institute Namulonge, Kampala, Uganda.
[c] Department of Agricultural Production, College of Agriculture and Environmental Sciences, Makerere University, Kampala, Uganda.

Authors' contributions

This work was carried out in collaboration among all authors. Authors AK and GD designed the study, wrote the protocol and managed the experimental process. Authors AK and SK wrote the draft of the manuscript and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i130827

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/79721

Original Research Article

Received 20 November 2021
Accepted 25 January 2022
Published 26 January 2022

ABSTRACT

Aims: To evaluate the effect of potassium nitrate (KNO_3) on flowering and fruiting of mangoes in Uganda.
Study Design: Randomized complete block design in a split plot arrangement.
Place and Duration of Study: National Crops Resources Research Institute Namulonge, National Semi–Arid Resources Research Institute in Serere and Bulindi Zonal Agricultural Research and Development Institute in Hoima in 2015 and 2016.
Methodology: The study was superimposed on eight-year-old mango orchards which were simultaneously planted at the three sites. Main plot treatments comprised three mango varieties (Bire, Tommy Atkins, Zillate), while sub-plot treatments comprised four concentrations of KNO_3 (zero as control, 1, 2 and 4%). Data was collected on number of terminal buds induced after applying KNO_3, percentage flowering, number of fruits set per 20 panicles and fruit yield per tree.
Results: Trees sprayed with KNO_3 produced higher (P < .05) numbers of terminal buds than the control. Across sites, Bire produced higher numbers of buds (64.8) than Tommy Atkins (46.3) and Zillate (17.8). Flowering response was higher in Bire (28.6%) than in Tommy Atkins (20.8%) and Zillate (17.8%). Flowering response of trees sprayed with 2% KNO_3 (31.4%) was higher than that of trees sprayed with 1% KNO_3 (24.7%). Mean number of fruits induced per 20 panicles in trees

**Corresponding author: E-mail: annetkatwesige@yahoo.co.uk;*

sprayed with 4% KNO_3 (8.24) was higher than that of trees sprayed with 1% KNO_3 (4.8). Fruit yield of Tommy Atkins (23.01 kg/tree) was higher than that of Bire (10.97 kg/tree). Mean fruit yield of trees sprayed with 2% KNO_3 (27.36 kg/tree) was higher than that of trees sprayed with 1% KNO_3 (15.93 kg/tree).

Conclusion: For better fruit yields, farmers at Bulindi should grow Tommy Atkins and apply 2% KNO_3. Farmers at Namulonge can grow any of the three mango varieties and apply 2 or 4% KNO_3, while those at Serere can grow Tommy Atkins and Zillate, and should apply 4% KNO_3.

Keywords: Mango varieties; potassium nitrate; flowering response; fruit yield.

1. INTRODUCTION

The mango (*Mangifera indica* L.) is a tropical fruit tree belonging to the genus *Mangifera*, and family *Anacardiaceae*. The mango originated from India, but is currently cultivated in the tropical and warmer subtropical regions of the world [1]. It is one of the most important fruits worldwide, and is ranked fifth in overall fruit production [2]. Mango is mainly grown for the fruit that is rich in carbohydrates, essential minerals especially iron and zinc, proteins, and vitamins A, B6 (Pyridoxine), B9 (Folic acid), C and K [3]. The mango fruit also offers several health benefits including fighting cancer, strengthening body immunity, controlling cholesterol and alkalising the body. The fibrous part boosts the digestive function and regulates body weight [4].

In Uganda, mangoes are mainly grown by small scale farmers for home consumption, and excess fruits are sold for cash in the local markets. But most of the varieties grown are the indigenous types, low yielding and their fruits are of inferior quality with little commercial value. Their flowering and fruit production is irregular, and sometimes not yielding any fruit in some years. Many improved varieties have been introduced and promoted countrywide. However, the quantities of mango fruits produced are not enough to meet the demand. A number of fruit processing factories have been set up in different parts of the country, and they are not operating at full capacity due to insufficient supply of fruits. During harvesting, most areas are saturated with mango fruits, and thus, consumers offer very low prices that make commercial mango production unprofitable [5]. Conversely, when mango fruit production is out of season, people resort to imported mangoes which are sold expensively.

Thus, mango fruit production has the potential of improving household incomes if the fruits were produced during off-season when the supply is low. The irregular supply of mango fruits in Ugandan markets is attributed mainly to the fact that the varieties grown are more or less of irregular flowering nature. Mango fruits flood the market during the harvesting season leading to a fall in prices, and the prices increase during off-season periods due to scarcity resulting in importation of fresh mango fruits and the concentrate.

Effective flowering is necessary for attainment of high fruit set and consequently the yield increase. Flowering in mango is unreliable due to inconsistency of the environmental signals for floral initiation. Floral initiation in trees is controlled by a range of factors which may include environmental stimuli, varietal attributes like growth and fruit bearing patterns, nitrogen and carbohydrate reserves and other interactions with vegetative growth and plant growth regulators [6]. Although chemical substances that induce flowering have been tested for promoting flower production in mango in different countries, their effects have been limited to certain cultivars and geographical locations.

Thus it is envisaged that off-season mango fruit production in Uganda can be achieved by applying chemical substances that are capable of altering the flowering and fruiting patterns of the existing mango varieties [7]. It is presumed that foliar-based chemical substances that are commonly used to induce flowering in fruit trees elsewhere are likely to also induce flowering and fruiting in mango varieties grown in Uganda [8,9]. It has also been reported that mango leaves have the capacity to absorb growth regulators and nutrients after foliar application, which are then translocated to actively developing organs within the plant system [6, 8, 10]. However, hardly any technology of inducing off-season mango fruit production has been tested under the prevailing environmental conditions in Uganda. Therefore, this study was carried out to investigate the possibility of inducing flowering under local conditions in the locally available mango varieties using the chemical inducing substance, potassium nitrate (KNO_3), and ultimately produce mango fruit off-season that would ensure all the year-round supply of mango fruit on the Uganda's markets. Selection of KNO_3 for this study was based on reports of researchers notably Parauha and Pandey [8], Sudha et al. [10], Sarkar and Rahim [11], and Stino et al. [12] who applied different chemical substances on mango plants to study their effects on flowering and fruiting in mango, and observed that KNO_3 was the most effective in enhancing fruit yield.

2. MATERIALS AND METHODS

2.1 Study Sites

The study was carried out at three sites representing three agroecological zones of Uganda. These sites were National Crops Resources Research Institute (NaCRRI) Namulonge in Wakiso district, National Semi–Arid Resources Research Institute (NaSARRI) Serere in Serere district and Bulindi Zonal Agricultural Research and Development Institute (BUZARDI) in Hoima district.

The NaCRRI Namulonge is in the central region of Uganda, and is located within the bimodal rainfall region at latitude 0° 3" N and longitude 32° 37" E, at an elevation of 1150 meters above sea level (m. a.s.l.). It has a tropical wet and mild dry climate with slightly humid conditions (mean RH is 65%). The average annual temperature is 21.7 ºC, and the annual minimum and maximum temperatures are 16 and 28 °C, respectively with average annual rainfall of 1242 mm. The vegetation is wooded savannah with tall trees and tall grasses. Soils are dark, reddish brown, sandy loam with pH range of 5.5-6.2.

The NaSARRI is in the eastern agroecological zone in Serere district, and is located within the tropical wet-dry climate at latitude 1° 5" N and longitude 33° 43" E, and at an elevation of 1100 m. a.s.l. The maximum and minimum temperatures are 29.5 and 18.0 °C, respectively and the average rainfall is 1365 mm. The dry spell especially after second rains can be very hot with daily temperatures exceeding 30 °C. Soils are petric plinth sols, acric reddish brown sandy loams and loams on laterite.

The BUZARDI lies at latitude 1° 45" N and longitude 31° 45" E, and at an elevation of 1036 m. a.s.l. It receives 1309 mm of rainfall annually in a bimodal distribution pattern, the rainy seasons occurring in March-June and August-November. The maximum and minimum temperatures are 27.7 and 16.8 °C, respectively. The soils are of acric ferrosoils and are mostly dark, red, clay loams. The mean monthly rainfall and the mean monthly temperatures for the three sites during the study period are shown in Figs 1 and 2.

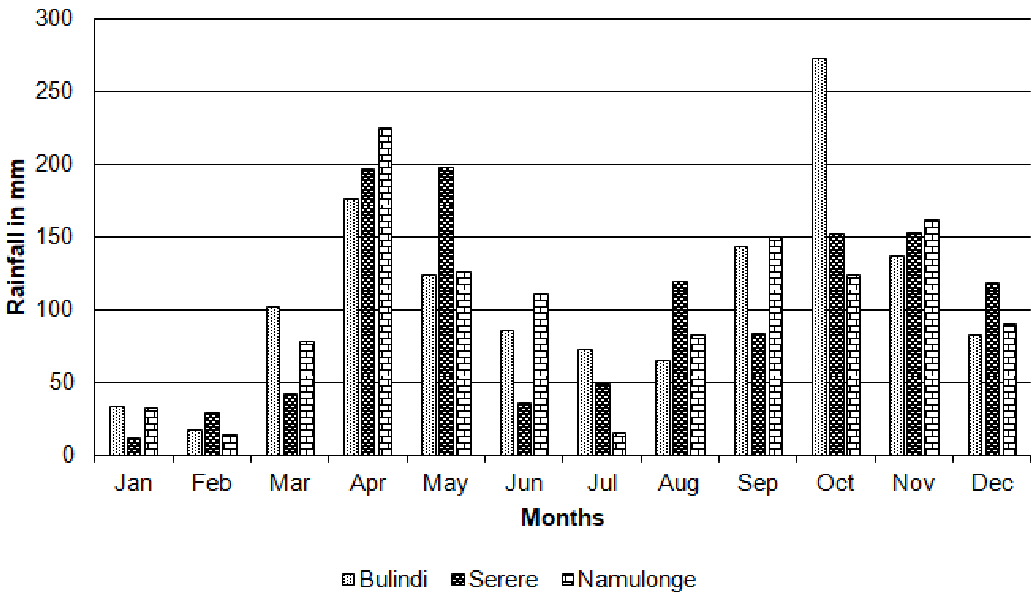

Fig. 1. Mean monthly rainfall of experimental sites during the study period (2015-2016)

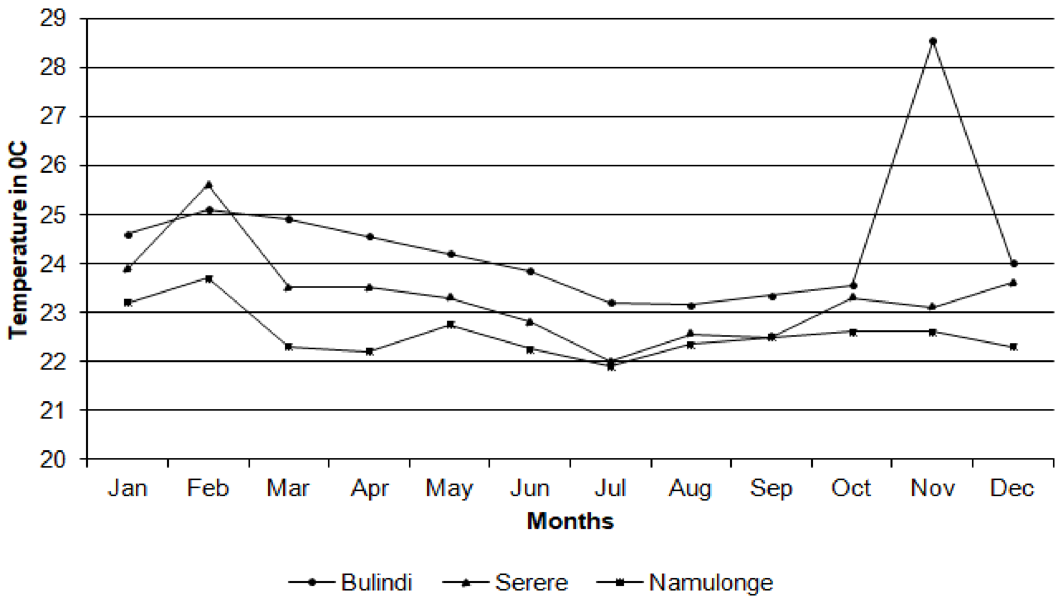

Fig. 2. Mean monthly temperatures of experimental sites during the study (2015–2016)

2.2 Plant Materials for the Study

The mango varieties, namely Bire, Tommy Atkins and Zillate existing as mother plants in the three sites were used as test crops. The varieties were introduced, evaluated for yield, and then released in Uganda as commercial varieties with improved yield and fruit quality.

2.3 Experimental Design and Treatments

The experiment was superimposed on already established mango orchards in the three sites, namely BUZARDI, NaSARRI and NaCCRI. It was laid out in a two factorial randomized complete block design in a split plot arrangement and replicated three times on each site. Main plot treatments comprised three mango varieties, namely Bire, Tommy Atkins and Zillate, while the sub-plot treatments comprised four concentrations (zero as the control, 1, 2 and 4%) of potassium nitrate (KNO_3). Each unit plot contained two mango trees. Each treatment was carried out on two trees for each replication.

Potassium nitrate was mixed with water, whereby motorized spray pump of 12 liters was half-filled with six liters of water, then a given quantity of KNO_3 (0, 150, 300 and 450 gm) representing 0, 1, 2 and 4 % respectively, was added to another six liters of water and stirred until the KNO_3 dissolved completely. The solution was applied to the tree canopies with newly developed dark green-coloured leaves. Each tree canopy was sprayed with the solution totally wetting the leaves. The spraying began with the upper most branches then downwards making sure that all the leaves were wet. Potassium nitrate was applied one month before (December 2015) and one month (February 2016) after the normal flowering season. Second spraying for the second season was carried out in June and August 2016 on another set of mango trees at the three sites. Weeds in the orchards were controlled by slashing once every month.

2.4 Data Collection

Data collected included the number of terminal buds induced, percentage flowering, number of fruits set per 20 panicles and fruit yield per tree. The number of terminal buds induced on each tree were counted and recorded. Branches with terminal buds induced were tagged with coloured polythene papers for easy identification and counting the total number of terminal buds of tagged branches for the entire tree. Only tagged branches from the start of the experiment were used to collect data on the parameters that were measured. Percentage flowering was calculated as the number of shoots that flowered over the total number of shoots tagged. On each tree, 20 panicles were counted randomly and tagged with polythene papers. Fruits that formed on these panicles were counted at pea stage and were recorded as number of fruits set per 20 panicles per tree.

Total fruit yield per tree was determined by counting all mango fruits on a tree and multiplying by the average weight per fruit in grams and changing into kilograms (kg) per tree. Any fruit harvesting that was done from the mango trees for each treatment was recorded from the onset of harvesting up to the end of the experiment.

2.5 Data Analysis

The data collected were subjected to the analysis of variance (ANOVA) using GenStat Discovery Version 14. Treatment mean comparisons were done using the Least Significant Difference (LSD) at the 5% level of significance.

3. RESULTS

3.1 Number of Terminal Buds Induced

Generally, there were highly significant ($P < .001$) differences among the treatments, the varieties and across sites, as well as their interactions (Table 1). At Bulindi, trees of all the varieties that were sprayed with KNO_3 performed better ($P < .05$) than the control, apart from those of Zillate that were sprayed with 1% KNO_3 (Table 1). For Bire and Zillate, trees that were sprayed with 2 and 4% KNO_3 performed better than those sprayed with 1% KNO_3. But for Tommy Atkins, trees that were sprayed with 1% KNO_3 performed better ($P < .05$) than the rest.

At Namulonge, the performance of all trees of Bire at all treatments was lower ($P < .05$) than that of the control (Table 1). However, treatments 1% and 2% KNO_3 performed better than the one that received 4% KNO_3. For the case of Zillate, there were no significant differences between trees that were sprayed with 1% KNO_3 and the control. But those which were sprayed with 2 and 4% KNO_3 performed poorer than the control.

At Serere, trees of all the varieties that were sprayed with KNO_3 performed better ($P < .05$) than the controls. For Bire, trees that were sprayed with 1% and 4% KNO_3 performed better than those that were sprayed with 2% KNO_3. Trees of Tommy Atkins that were sprayed 1% KNO_3 and those of Zillate that were sprayed with 2% KNO_3 performed better ($P < .05$) than the rest.

Results also revealed that at Bulindi, the mean number of terminal buds induced by KNO_3 in Bire (118) was significantly ($P < .05$) higher than that of Tommy Atkins (65.5) and Zillate (70.4). However, the mean number of terminal buds that were induced in Tommy Atkins was not significantly ($P > .05$) different from that of Zillate (Table 1). At Namulonge, the numbers of terminal buds induced in all the three varieties were similar ($P > .05$). At Serere, Tommy Atkins had a higher mean number of terminal buds (44.8) induced than Bire (33.0) and Tommy Atkins (31.8).

According to the mean numbers of terminal buds that were induced in mango varieties across sites, Bire with 64.8 performed better ($P < .001$) than Tommy Atkins (46.3) and Zillate (17.8) (Table 2). Also, all the varieties performed better ($P < .001$) than the control when they were sprayed with KNO_3. However, there were no significant ($P > .05$) differences in the numbers of terminal buds that were induced when the trees were sprayed with 1, 2 and 4% KNO_3 (Table 2).

3.2 Percentage Flowering Response in Mango Varieties

There were significant differences among the treatments and the varieties ($P < .001$), but their interaction was non-significant ($P > .05$) (Table 3). The results also showed that the effect of KNO_3 application on the flowering response of mango trees differed across sites ($P = .02$), and its interaction with treatment ($P = .008$) and variety ($P < .001$) (Table 3). At Bulindi, trees of variety Bire that were sprayed with KNO_3 performed better ($P < .05$) than the control. Similarly, for Tommy Atkins, trees that were sprayed with KNO_3 performed better ($P < .05$) than the control, apart from those that were sprayed with 2% KNO_3. For Zillate, only trees that were sprayed with 2% KNO_3 performed better than the control (Table 3). For the case of Bire, trees that received 4% KNO_3 performed better ($P < .05$) than those that received 1 and 2% KNO_3. But for Tommy Atkins and Zillate, there were no significant ($P > .05$) differences between the trees that received KNO_3 treatments.

At Namulonge, all trees that were sprayed with KNO_3 performed better ($P < .05$) than the control (Table 3). For the case of Bire and Tommy Atkins, there were no significant ($P > .05$) differences between trees that received treatments of KNO_3, while for Zillate, trees that were sprayed with 2% KNO_3 performed better than those that received 1% KNO_3.

Table 1. Number of terminal buds induced by KNO_3 in mango varieties at three sites

Treatments	Bulindi			Namulonge			Serere		
	Bire	Tommy Atkins	Zillate	Bire	Tommy Atkins	Zillate	Bire	Tommy Atkins	Zillate
0 (Control)	32.1[c]	30.8[c]	53.8[b]	67.0[a]	42.6[a]	54.4[a]	1.4[c]	2.4[c]	2.7[d]
1% KNO_3	118.7[b]	89.9[a]	51.1[b]	43.7[b]	41.4[a]	49.3[a]	48.9[a]	61.9[a]	39.0[c]
2% KNO_3	167.1[a]	73.1[b]	89.0[a]	39.2[b]	43.8[a]	19.1[c]	34.1[b]	31.6[b]	74.8[a]
4% KNO_3	154.2[a]	68.1[b]	87.7[a]	23.9[c]	38.6[a]	34.2[b]	47.6[a]	31.3[b]	62.6[b]
Mean	118.0	65.5	70.4	43.4	41.6	39.2	33.0	31.8	44.8
F- prob.	Site = < .001, Treatment = < .001, Variety = < .001, Variety × Treatment = .031, Site x Treatment x Variety = < .001								
$LSD_{(0.05)}$	Site = 8.76, Treatment = 10.11, Variety = 8.76, Variety x Treatment = 17.52, Site x Treatment x Variety = 30.34.								

[abc]*Means followed by different superscripts within same column are significantly (P < .05) different*

Table 2. Terminal buds induced in mango varieties by KNO_3 application across the sites

Variety	Concentrations of KNO_3				Mean
	0% (Control)	1%	2%	4%	
Bire	33.5	70.5[a]	80.1[a]	75.1[a]	64.8[a]
Tommy Atkins	25.3	64.4[a]	49.5[c]	46.0[c]	46.3[b]
Zillate	37.0	46.5[b]	61.0[b]	61.5[b]	17.8[c]
Mean	31.9	60.46	63.5	60.9	
F- prob.	Site = < .001, Treatment = < .001, Variety = < .001, Variety × Treatment = .031, Site x treatment x variety = < .001				
$LSD_{(0.05)}$	Site = 8.76, Treatment = 10.11, Variety = 8.76, Variety x treatment = 17.52, Site x treatment x variety = 30.34				

[abc]*Means followed by different superscripts within same column are significantly (P < .05) different.*

At Serere, trees Tommy Atkins and Zillate that were sprayed with KNO_3 performed better (P < .05) than the control, while for Bire, only the trees that were sprayed with 2% KNO_3 performed better than the control (Table 3). For the case Tommy Atkins, the trees that received 2% KNO_3 performed better (P < .05) than the rest. For the case of Zillate, there were no significant (P > .05) differences between trees that were sprayed with KNO_3.

The results also revealed that at Bulindi, Bire was the best performer (45.3%), followed by Tommy Atkins (15.6%) and Zillate was the poorest with 9.4% flowering response (Table 3). At Namulonge, the percentage flowering response of mango varieties followed the same trend as at Bulindi, but that of Bire (30.1%) was higher (P < .05) than that of Tommy Atkins (20.9%) and Zillate (23.0%). At Serere, Tommy Atkins with 25.9% flowering response was the best performer, followed by Tommy Atkins (21.0%) and Bire (10.6%).

The results of mean flowering response in mango varieties across the sites showed that Bire with 28.6% performed better (P < .05) than Tommy Atkins (20.8%) and Zillate (17.8%) (Table 4). Also, all the varieties performed best (31.4%), when they were sprayed with 2% KNO_3, though this performance was not significantly (P > .05) different from that at 4% KNO_3 (28.8%).

3.3 Number of Fruits Induced per 20 Panicles Per Tree

At Bulindi, all trees of Bire, Tommy Atkins and Zillate that were sprayed with KNO_3 produced significantly (P < .05) higher numbers of fruits per 20 panicles than the respective control treatments, except trees of Bire that were sprayed with 4% KNO_3 (Table 5). For the case of Bire, trees sprayed with 1 and 2% performed better (P < .05 than the rest. Trees of Tommy Atkins and those of Zillate that that were sprayed with 2 and 4% KNO_3 respectively, performed better (P < .05) than the rest.

At Namulonge, only trees of Bire and Zillate that were sprayed with KNO_3 performed better than the respective control treatments. For Bire, trees that were sprayed with 2 and 4% KNO_3 respectively performed better (P < .05) than those that were sprayed with 1% KNO_3 as well as the control. Trees of Zillate and Tommy Atkins did not show significant (P > .05) responses to the application of higher concentrations of KNO_3 (Table 5).

At Serere, trees of all the varieties that were sprayed with KNO_3 performed better (P < .05) than the control, with exception of those of Bire which were sprayed with 1% KNO_3. Trees of Bire and those of Zillate that were sprayed with 2 and 4% KNO_3 respectively, performed better (P < .05) than the rest (Table 5).

The results also revealed that at Bulindi the mean number of fruits set per 20 panicles in varieties Tommy Atkins (7.23) and Zillate (7.22), were higher (P < .05) than those induced in Bire (4.39). At Namulonge, the numbers of fruits set per 20 panicles in all the three varieties were similar (P > .05). At Serere, the number of fruits set per 20 panicles in Zillate (5.35) was higher (P < .05) than that of Bire, but was not different (P > .05) from that of Tommy Atkins (4.45).

The mean numbers of fruits induced per 20 panicles per tree in mango varieties across the sites were not significantly (P > .05) different (Table 6). However, all the varieties performed better (8.24) when they were sprayed with 4% KNO_3, though this performance was not significantly (P > .05) different from that of trees that were sprayed with 2% KNO_3 (7.12).

3.4 Fruit Yield Per Tree

Generally, there were significant (P < .05) differences among the sites, treatments and varieties, but the interactions between varieties and treatments as well as between sites, varieties and treatments were non-significant (P > .05) (Table 7). At Bulindi, all mango trees that were sprayed with KNO_3 produced higher (P < .05) fruit yields than the respective control treatments, except for Bire and Zillate trees that received 4% and 1% KNO_3, respectively (Table 7). For Bire, trees that were sprayed with 1 and 2% KNO_3 performed better (P < .05) than those that were sprayed with 4% KNO_3. For Tommy Atkins, trees that were sprayed with 2% KNO_3 produced higher fruit yields than those that were sprayed with 1 and 4% KNO_3. For the case of Zillate, trees that were treated with 4% KNO_3 yielded better than those that were treated with 2% KNO_3, which in turn also yielded better than those that were treated with 1% KNO_3 (Table 7).

Table 3. Percentage flowering response of mango varieties at the three study sites

Treatments	Bulindi			Namulonge			Serere		
	Bire	**Tommy Atkins**	**Zillate**	**Bire**	**Tommy Atkins**	**Zillate**	**Bire**	**Tommy Atkins**	**Zillate**
0 (Control)	22.5^{c}	3.5^{b}	2.9^{b}	1.7^{b}	4.9^{b}	2.3^{c}	1.1^{b}	2.6^{c}	0.8^{b}
1% KNO_3	46.2^{b}	23.4^{a}	9.1^{ab}	39.6^{a}	23.1^{a}	18.9^{b}	8.3^{b}	24.6^{b}	29.1^{a}
2% KNO_3	41.8^{b}	14.6^{ab}	17.2^{a}	38.5^{a}	32.4^{a}	40.9^{a}	24.3^{a}	49.7^{a}	23.4^{a}
4% KNO_3	70.5^{a}	20.7^{a}	8.5^{ab}	40.6^{a}	23.2^{a}	30.0^{ab}	8.5^{b}	26.8^{b}	30.6^{a}
Mean	45.3	15.6	9.4	30.1	20.9	23.0	10.6	25.9	21.0
F- prob.	Site = .02, Treatment = < .001, Variety = < .001, Variety × Treatment = .288, Site x Treatment x Variety = < .001.								
$LSD_{(0.05)}$	Site = 4.03, Treatment = 4.7, Variety = 4.06, Variety x Treatment = 8.12, Site x Treatment x Variety = 14.06								

[abc]*Means followed by different superscripts within the same column are significantly (P < .05) different.*

Table 4. Flowering response of mango varieties to KNO_3 treatments across the sites

Variety	Concentrations of KNO_3 (%)				Mean
	0% (Control)	**1%**	**2%**	**4%**	
Bire	8.4	31.4^{a}	34.9^{a}	39.9^{a}	28.6^{a}
Tommy Atkins	3.7	23.7^{b}	32.2^{ab}	23.6^{b}	20.8^{b}
Zillate	2.0	19.0^{b}	27.2^{b}	23.0^{b}	17.8^{b}
Mean	4.7	24.7	31.4	28.8	
F-prob.	Treatment = < .001, Variety = < .001, Variety x Treatment = .562				
$LSD_{(0.05)}$	Treatment = 5.78, Variety = 5.01, Variety x Treatment = 10.02				

[abc]*Means followed by different superscripts within the same column are significantly (P < .05) different.*

Table 5. Number of fruits set per 20 panicles per tree

Treatments	Bulindi			Namulonge			Serere		
	Bire	**Tommy Atkins**	**Zillate**	**Bire**	**Tommy Atkins**	**Zillate**	**Bire**	**Tommy Atkins**	**Zillate**
0 (Control)	0.85[b]	0.74[c]	0.32[d]	2.96[c]	4.93[a]	1.48[b]	0.00[c]	0.34[c]	0.00[c]
1% KNO_3	8.60[a]	6.64[b]	2.65[c]	5.08[b]	6.52[a]	5.74[a]	0.00[c]	3.11[b]	4.91[b]
2% KNO_3	6.55[a]	15.41[a]	6.50[b]	8.08[a]	5.68[a]	5.74[a]	6.80[a]	5.32[b]	4.02[b]
4% KNO_3	1.57[b]	6.13[b]	19.42[a]	8.57[a]	7.10[a]	6.36[a]	3.54[b]	9.03[a]	12.48[a]
Mean	4.39	7.23	7.22	6.17	6.06	4.83	2.58	4.45	5.35
F- prob.	Site = .110, Treatment = < .001, Variety = .258, Variety × Treatment = .023, Site x treatment x variety = .020								
$LSD_{(0.05)}$	Site = 2.1, Treatment = 2.43, Variety = 2.11, Variety x Treatment = 4.21, Site x Treatment x Variety = 7.29								

[abc]*Means followed by different superscripts within the same column are significantly (P < .05) different.*

Table 6. Number of fruits induced per 20 panicles per tree in mango varieties across the sites

Variety	Concentrations of KNO_3				Mean
	0% (Control)	**1%**	**2%**	**4%**	
Bire	1.27	4.56	7.14[ab]	4.56[b]	4.38
Tommy Atkins	2.00	5.42	8.80[a]	7.42[b]	5.91
Zillate	0.60	4.40	5.42[b]	12.75[a]	5.80
Mean	1.29	4.80	7.12	8.24	
F- prob.	Site = .110, Treatment = < .001, Variety = .258, Variety × Treatment = .023, Site x Treatment x Variety = .020				
$LSD_{(0.05)}$	Site = 2.1, Treatment = 2.43, Variety = 2.11, Variety x Treatment = 4.21, Site x treatment x Variety = 7.29				

[abc]*Means followed by different superscripts within same column are significantly (P < .05) different.*

At Namulonge, all the trees that were sprayed with KNO_3 performed better than the control, with exception of Bire trees that were sprayed with 1% KNO_3 (Table 7). However, there were no significant ($P > .05$) differences in performance of Bire and Tommy Atkins trees that were sprayed with different concentrations of KNO_3. For the case of Zillate, trees that were sprayed with 4% KNO_3 performed equally well ($P > .05$) as those that were sprayed with 2% KNO_3 but yielded better than those that were sprayed with 1% KNO_3.

At Serere, all trees of Bire that were sprayed with KNO_3 did not yield better ($P > .05$) than the control (Table 7). For Tommy Atkins, only trees that were sprayed with 4% KNO_3 produced more fruits ($P < .05$) than the control. In the case of Zillate, trees sprayed with 2 and 4% KNO_3 performed better than those that were sprayed with 1% KNO_3 as well as the control (Table 7).

The results of mean fruit yields revealed that at Bulindi, the fruit yield of Tommy Atkins (42.2 kg per tree) was higher ($P < .05$) than that of Zillate (24.6 kg per tree) and Bire (19.0 kg per tree). At Namulonge, the fruit yields per tree in all the three varieties were similar ($P > .05$). But at Serere, the fruit yield of Zillate (17.1 kg per tree) was higher ($P < .05$) than that of Bire (3.8 kg per tree), but was not different ($P > .05$) from that of Tommy Atkins (12.9 kg per tree).

According to the mean fruit yields per mango tree across the three sites, Tommy Atkins with 23.01 kg per tree performed better ($P < .05$) than Bire (10.97 kg per tree). But the fruit yield of Tommy Atkins was not significantly (P > .05) from that of Zillate (19.46 kg per tree) (Table 8). Also, all the mango varieties performed best (27.36 kg per tree) when they were sprayed with 2% KNO_3, though this performance was not significantly ($P > .05$) different from that at 4% KNO_3 (26.24 kg per tree).

4. DISCUSSION

4.1 Effect of Potassium Nitrate on the Number of Terminal Buds

The application of KNO_3 had significant effect ($P < .05$) on the number of terminal buds induced compared to the control. When applied, KNO_3 activates growth of dormant buds in fruit trees and hastens flower emergence. It is from the terminal buds initiated that panicles which bear flowers are formed. In flowering plants, flower initiation is the first step towards fruit formation and development. In some studies elsewhere, ammonium nitrate (NH_4NO_3) has been used, and it also promoted early flowering in some mango varieties [6]. Similarity of the results between NH_4NO_3 and KNO_3 indicate that the nitrate ion [NO_3^-] is the active portion in these chemicals. When KNO_3 and NH_4NO_3 are applied as a foliar spray after fruit harvest, they induce early vegetative growth along with early induction of flowering with subsequent increase in yield [13].

In mango, the nature of flower production is complex, and involves a mechanism that controls the balance between vegetative and reproductive phases [6]. The flowering process begins with shoot initiation followed by flower bud induction. When applied in fruit trees, KNO_3 induces flowering by stimulating the activity of nitrate reductase and increasing the production of ethylene [14,15]. Nitrate reductase enzyme is responsible for conversion of nitrate ion to nitrite ion [NO_2^-] in plants, which is then converted to ammonia by nitrite reductase. The ammonia produced is combined with α-keto-glutalate to form the amino acid glutamate, from which all other amino acids are formed. Ethylene is a phytohormone that regulates plant growth and senescence processes.

Studies by Saha et al. [16] showed that when 1% KNO_3 is combined with 1% KH_2PO_4 (mono-potassium phosphate), it becomes even more effective in hastening panicle emergence than other chemicals they used. Faster initiation of panicles and flowering, and shorter duration in these processes (14 days) in mango trees foliarly sprayed with 2% KNO_3 compared to the control (20 days) has also been reported [17]. Sudha et al. [10] reported the highest number of panicles being recorded in mango trees of cultivar Alphonso sprayed with 2% KNO_3, while the minimum was observed in the control. In another study, Sarker and Rahim [11] reported that mango plants of cultivar Amrapali which received 4% KNO_3 produced the highest number of panicles per plant (220.67) over the control plants (107.67).

4.2 Effect of Potassium Nitrate on the Flowering Response

It is evident from the present study that trees of all the varieties sprayed with KNO_3 performed better ($P < .001$) in flowering than the control. Similar observations as well as early flowering and reduced alternate bearing were reported by

Table 7. Fruit yield (kg per tree) of mango trees treated with KNO3 at the three sites

Treatment	Bulindi			Namulonge			Serere		
	Bire	**Tommy Atkins**	**Zillate**	**Bire**	**Tommy Atkins**	**Zillate**	**Bire**	**Tommy Atkins**	**Zillate**
0 (Control)	3.6[b]	0.6[c]	0.3[c]	0.8[b]	5.0[b]	2.5[c]	0.0[a]	2.7[b]	0.0[c]
1% KNO_3	28.0[a]	44.4[b]	7.6[c]	8.6[ab]	18.3[a]	15.7[b]	0.0[a]	10.7[b]	10.1[b]
2% KNO_3	36.1[a]	80.8[a]	31.3[b]	17.4[a]	15.9[a]	20.1[ab]	7.7[a]	10.8[b]	26.2[a]
4% KNO_3	8.2[b]	42.8[b]	59.0[a]	13.7[a]	17.0[a]	28.7[a]	7.6[a]	27.2[a]	32.0[a]
Mean	19.0	42.2	24.6	10.1	14.1	16.7	3.8	12.9	17.1
F-Prob.	Site = < .001, Treatment = < .001, Variety = .014, Variety × Treatment = .089, Site x Treatment x Variety = .281.								
$LSD_{(0.05)}$	Site = 8.25, Treatment = 9.53, Variety = 8.25, Variety x Treatment = 27.00, Site x Treatment x Variety = 9.00								

[abc]*Means followed by different superscripts within the same column are significantly (P < .05) different.*

Table 8. Fruit yield (kg per tree) of mango varieties across the sites

Variety	Concentrations of KNO_3				Mean
	0% (Control)	**1%**	**2%**	**4%**	
Bire	1.40	12.20	20.40	9.83	10.97[b]
Tommy Atkins	2.76	24.46	35.83	29.00	23.01[a]
Zillate	0.93	11.13	25.86	39.90	19.46[ab]
Mean	1.71	15.93	27.36	26.24	
F-Prob.	Site = < .001, Treatment = < .001, Variety = .014, Variety × Treatment = .089, Site x treatment x variety = .281				
$LSD_{(0.05)}$	Site = 8.25, Treatment = 9.53, Variety = 8.25, Variety x treatment = 27, Site x treatment x variety = 9				

[abc]*Means followed by different superscripts within same column are significantly (P < .05) different.*

Dadhaniya et al. [7]. The results also showed that the three mango varieties performed better when sprayed with 2 and 4% KNO_3, and this is in agreement with the findings of other researchers, notably Amarcholi et al. [18], Maloba et al. [19], Afiqah et al. [20] and Sudha et al. [10]. Amarcholi et al. [18] studied the influence of chemicals on flowering characteristics of ‘Kesar’ mango and found that foliar application of 1% KNO_3 gave maximum flowering percentage (26.12%). Maloba et al. [19] noted that spraying the ‘Apple’ and ‘Ngowe’ mango trees with 4% KNO_3 was beneficial for all the flowering and fruiting parameters. Afiqah et al. [20] studied the effects KNO_3 on the enhancement of flowering in the mango clone ‘Chok Anan’ (MA 224) and reported that spraying mango trees with 2% KNO_3 resulted in earlier flowering and superior fruit set. Sudha et al. [10] studied the effect of foliar application of various nitrogenous chemicals on flowering of mango cultivar Alphonso and reported that maximum number of flowering shoots (68.7%) was obtained with foliar spray of 2% KNO_3, while the control gave the least number of flowering shoots (47.0%). Singh et al. [21] reported significant increase in the percentage of flowering shoots when 1% KNO_3 was combined with 1% KH_2PO_4.

The results showed that amongst the three varieties, the flowering response of Bire was superior across the treatments and sites. This could be attributed to the genotypic differences in the mango varieties which might have played some role in influencing the flowering response to KNO_3. It has been reported that varietal traits is one of the factors that govern flowering in mango [6]. Rani [6] further noted that commercial mango varieties grown in India showed the same pattern of bearing, but some varieties like 'Baramasi' exhibited erratic and off-season bearing while others like 'Neelum' and 'Bangalora' showed distinct regularity.

4.3 Effect of Potassium Nitrate on Number of Fruits set per 20 Panicles and Fruit Yield

The application of KNO_3 had a significant effect (P < .05) on the number of fruits set per 20 panicles per tree, and the trees sprayed with 2 and 4% KNO_3 registered superior fruit yield over the control across the sites. This was in agreement with the findings of other researchers [10, 11, 12]. Sudha et al. [10] studied the effect of foliar application of various nitrogenous chemicals on flowering of mango cultivar Alphanso and reported that plants sprayed with 2% of KNO_3 gave the highest (P < .05) number of fruits per tree (146 fruits/tree) over the control (102 fruits/tree), and subsequently produced the highest fruit yield (43.8 kg/tree) than the control (25.5 fruits/tree). In a study by Sarker and Rahim [11], mango plants of cultivar Amrapali that were treated with 4% KNO_3 produced the highest number of fruits per plant (136.67) than the control (62.67). Stino et al. [12] observed that foliar sprays of either 2% KNO_3 or 2% calcium nitrate on mango cultivars Langara, Ewais and Alphonso were the most effective in increasing the number of fruits set per tree, and consequently the fruit yield per tree.

A study by Singh et al. [21] showed that spraying mango cultivars Bombay Green, Dashehari and Langra with a combination of 1% KNO_3 and 1% KH_2PO_4 was excellent over other combinations of chemicals in improving the number of fruits set and fruits retained per tree when compared with the control where the trees were sprayed with water only. Experimental results of another study by Parauha and Pandey [8] indicated that foliar spray of 2% KNO_3 + 30 ppm gibberellic acid on the cultivar Amrapali gave better performance in fruit yield (14.70 kg/tree) than the control (7.91 kg/tree).

5. CONCLUSION AND RECOMMENDATION

Based on the results of this study, it is apparent that floral initiation, fruit setting and subsequent fruit yield in mango varieties viz Bire, Tommy Atkins and Zillate grown in Uganda can be regulated using KNO_3. At Bulindi Tommy Atkins produced better yield than the rest, and this was at all the three KNO_3 concentrations but the best performance was achieved with the application of 2% KNO_3. At Namulonge, there were no differences in fruit yields for all the three varieties. However, Bire performed well with the application of 2 and 4% KNO_3 while Tommy Atkins and Zillate performed equally the same with all the three KNO_3 concentrations. At Serere, Tommy Atkins and Zillate performed well in response to KNO_3. Tommy Atkins performed best at 4% KNO_3, while Zillate performed well at 2 and 4% KNO_3.

Therefore, application of KNO_3 on mango varieties is a promising approach for ensuring off-season flowering and enhancing fruit yield in the three agroecological zones of Uganda. For better fruit yields, farmers at Bulindi should grow

Tommy Atkins and apply 2% KNO_3. Farmers at Namulonge can grow any of the three mango varieties, and apply 2 or 4% KNO_3, while those at Serere can grow Tommy Atkins and Zillate, and should apply 4% KNO_3.

ACKNOWLEDGEMENTS

Authors express deepest gratitude to Government of Uganda through NARO's Competitive Grant Scheme (CGS) for the financial support towards this research, Makerere University for the facilities, the Directors and staff of NaCRRI Namulonge, NaSARRI Serere and BUZARDI Hoima for the support while conducting the experiments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Yadav D, Singh S. Mango: History, origin, and distribution. Journal of Pharmacognosy and Phytochemistry. 2017;6(6):1257-1262.
2. Normand F, Lauri PÉ, Legave JM. Climate change and its probable effects on mango production and cultivation. Acta Horticulture. 2015;1075:21-31.
3. Lehman S. Mango Nutrition facts: Calorie count and health benefits. United States Department of Agriculture; 2019.
4. Rymbai H, Srivastar M, Sharma RR, Patel CR. Bo-active compounds in mangoes and their roles in human health and plant defence. Journal of horticultural science and Biotechnology. 2013;88(4):369-379.
5. Greening Uganda. Mango growing in Uganda. Greening Uganda;2019. Available:https://greeninguganda.com/Products/Mango-Growing-In-Uganda (Accessed on July 21, 2019)
6. Rani KU. Advances in crop regulation in mango (*Mangifera indica* L.). International Journal of Current Microbiology and Applied Sciences. 2018;7(9):35-42. Available:https://doi.org/10.20546/ijcmas.2018.709.005
7. Dadhaniya D, Adodariya BA, Mishra P, Purohit H, Solanki R, Kadegiya L, Barad R, Kinjal H, Patel HN, Makwana SM, Jadeja SR. Effect of foliar application of chemicals on flowering of fruit crops. Journal of Pharmacognosy and Phytochemistry. 2018;7(4):2768-2770.
8. Parauha S, Pandey SK. Influence of plant growth regulators and nutrients on fruit retention, yield and quality attributes of mango (*Mangifera indica* L.) cv. Amrapali. Journal of Pharmacognosy and Phytochemistry. 2019;8(2):550-555.
9. Owens CL, Stover EW. Controlling floral initiation and vegetative growth of apple with prohexadione-Calcium (BAS-125W), an experimental GA-biosynthesis inhibitor. Horticultural Science. 1997;32(3):557-558.
10. Sudha R, Balomomhan TN, Sooriansundaram K. Effect of foliar spray of nitrogenous chemicals on flowering, fruit set, yield in mango (*Mangifera indica* L.) cv. Alphonso. Journal of Horticultural Science. 2012;7(2):190-193.
11. Sarker BC, Rahim MA. Yield and quality of mango (*Mangifera indica* L.) as influenced by foliar application of potassium nitrate and urea. Bangladesh Journal of Agricultural. Resources. 2013; 38(1):145-154.
12. Stino RG, Abdel-Wahab SM, Habashy SA, Kelani RA. Productivity and fruit quality of three mango cultivars in relation to foliar sprays of calcium, zinc, boron, or potassium nitrate. Horticultural Science in Ornamental Plants. 2011;3(2):91-98.
13. Patil KR, Burondkar MM, Bhave SG, Nigade PM. Post-harvest chemical induction of vegetative growth and its physiological behavior in relation to regulation of flowering in 'Alphonso' mango (*Mangifera indica* L.). Proceedings of the IX^{th} International Mango Symposium. Acta Horticulture. 2013; 992:193-200.
14. Swamy JS. Flowering manipulation in mango: A science comes of age. Journal of Today's Biological Sciences, Research and Review. 2012;(1):122-137.
15. Davenport TL, Nunez-Elisea. Reproductive physiology. The Mango: botany, production and uses. Wallingford: CAB International. 1997;69-146.
16. Saha DP, Jha KK, Sengupta S, Misra S, Lal HC, Prasad K. Preliminary investigations on the effect of foliar spray of chemicals on flowering, fruit setting and retention of fruits of mango cv. Mallika. International Journal of Science, Environment and Technology. 2017;6(2): 1574-1580.
17. Ubale NB, Banik BC. Effect of Foliar Nutrition on Flowering Characteristics in

Mango (*Mangifera indica* L.). Trends in Biosciences. 2017; 10(40):8284-8286.
18. Amarcholi JJ, Singh V, Sharma KM, Momin SK, Patel RJ. The impact of chemicals on fruiting parameters, quality parameters and B:C ratio of 'Kesar' mango. Multilogic in Science. 2016; 5:279-282.
19. Maloba S, Ambuko J, Hutchinson M, Owino W. Off-Season flower induction in mango fruits using ethephon and potassium nitrate. Journal of Agricultural Sciences. 2017;9(9):158-167. Available:https://doi.org/10.5539/jas.v9n9p158
20. Afiqah A, Nulit R, Hawa ZEJ, Kusnan M. Improving the yield of 'Chok Anan' (Ma 224) mango with potassium nitrate foliar sprays. International Journal of Fruit Science. 2014;14(4):416-423. Available:https://doi.org/10.1080/15538362.2013.819182
21. Singh MK, Singh VB, Singh SS, Singh AK. Floral biology and fruit set of mango (*Mangifera indica* L.) as influenced by different chemicals. International Journal of Current Microbiology and Applied Sciences. 2019;8(1):1106-1117. Available:https://doi.org/10.20546/ijcmas.2019.801.119

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/79721