CHAPTER 7

POTASSIUM NITRATE AND UREA SPRAYS AFFECTED FLOWERING AND YIELDS OF 'TOMMY ATKINS' MANGO IN ETHIOPIA.

7.1 ABSTRACT

The effects of applications of potassium nitrate (KNO_3), alone and in combination with urea at different concentrations on flowering, fruit set and fruit quality of 'Tommy Atkins' mango grown in the rift valley of Ethiopia were evaluated. The trees were characterised by erratic flowering, continuous and high intensity of vegetative growth as well as irregular bearing. Uniform trees were selected for a randomised complete block design experiment with three replications and three trees per plot. Spraying was conducted initially on the immature post-harvest flushes and then repeated after the flushes had matured and dark green leaves. Potassium nitrate concentrations especially in combination with urea (5 litre solution of 4% KNO_3+0.5 g urea tree^{-1} and 5 litres of 4% KNO_3+1 g urea tree^{-1}) produced better results for most of the flowering and yield parameters. There was a non-significant difference for the qualitative parameters between the treated and non-treated trees. The supplementation of nitrogen through the spraying of KNO_3 and urea is believed to be the reason for the greater flowering and yields results of the sprayed relative to the unsprayed trees.

Key words*:* mango, potassium nitrate, urea, flowering, fruiting

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7.2 INTRODUCTION

Subsequent to the discovery and use of ethephon to replace smudging and stimulate flowering of mango, Barba (1974) reported the use of potassium nitrate (KNO_3) for the same purpose. In subtropical regions, where winter conditions are sufficiently inductive for flowering in mangoes, flowering enhancement by KNO_3 has not been reported (Oosthuyse, 1996). KNO_3 sprays, however, have been used to stimulate off-season flowering of mango, especially in tropical regions (Bondad & Linsangan, 1979; Nunez-Elisea, 1985). Goguey (1993) asserted that the responses of plants to different flower inducing treatments differ according to cultivar, climatic conditions and geographical location.

KNO_3 has been shown to affect the date of flowering and number of panicles per tree formed in mango in some tropical regions (Fierro & Ulloa, 1991). Results concerning the effects of KNO_3 treatments on flower promotion and fruiting have not been consistent in India (Pal *et al.*, 1979, cited by Fierro & Ulloa, 1991) and Australia (Winston & Wright, 1986), or even negative in Florida as reported by Davenport (1987). Similar inconsistent results were obtained in experiments involving date of application, interval between applications, concentrations or component salt effects (Fierro & Ulloa, 1991; Machado & Sao Jose, 2000).

In the low- and mid- latitude tropics, receptive trees responded by initiating floral buds within two weeks after treatment, and the effective spray concentration ranges from 1 to 10% KNO_3 with the optimum concentration varying with the age of the trees and climate (Davenport & Nunez-Elisea, 1997). KNO_3 concentrations of 2-4%

or 1-2% ammonium nitrate (NH_4NO_3) have been found to be effective for initiating floral buds under tropical climatic conditions (Nunez-Elisea, 1985; Nunez-Elisea & Caldeira, 1988). Rojas & Leal (1996) stated that the concentration of KNO_3 used to induce mango flowering varies between 10-60 mg l^{-1}. Maas (1989) found that foliar spraying with a 2% KNO_3 solution proved to be very effective for inducing mango trees to bloom. Oosthuyse (1996) reported that KNO_3 application especially at 4% level was slightly phytotoxic to the leaves and inflorescences and caused the distal margins of some to the leaves and the extremities of some of the inflorescence branches to became necrotic. Some authors attribute the above-mentioned inconsistencies to the following factors: (1) inefficient application of the product; (2) physiological maturity of the plants; (3) yield of the previous harvest and (4) age of the shoots. The inconsistent results obtained with KNO_3 in different cultivars, climatic conditions and geographical locations necessitated further investigation of the effects of KNO_3.

The effect of urea on mango is also not well documented. In Ethiopia, erratic flowering, intensive vegetative growth and irregular bearing are typical of most orchards. The two flowering periods experienced in Ethiopia (being located near the equator) also lead to poor and unreliable yield. The cost of production is also high due to the two cycles of tree management and harvesting per year. Thus, the reputed beneficial effects of KNO_3 and urea as a remedy for flowering and fruiting would be invaluable. In this report, the results for the effects of KNO_3 and urea on different flowering, quantitative as well as qualitative aspects of 'Tommy Atkins' mango are discussed. The results may also give answers to some of the controversies in previous experiments.

7.3 MATERIALS AND METHODS

7.3.1 Area description

The trial was conducted during the 2002/2003 season at Upper Awash Agro-industry Enterprise in the rift valley of Ethiopia (latitude: 8^0 27'N; longitude: 39^0 43'E; elevation: 1000 m asl.; temperature: mean annual max. 32.6 ^{0}C, mean annual min. 15.3 ^{0}C; mean annual rain fall: 500 mm; soil type: calcic xerosol). The area is situated 180 km S.E. of Addis Ababa.

7.3.2 Plant material

Ten year old 'Tommy Atkins' mango trees, uniform in vigour and size, were selected to study the effects of KNO_3 and urea on flowering, yield and fruit quality parameters. All treatment trees were subjected to the standard orchard management practices as applied by the company.

Before applying the treatments, 100 terminal shoots were marked randomly on each tree prior to spraying for recording the percentage of flowering branches. After inflorescence development, 20 panicles per tree were marked randomly on each tree for recording percentage of hermaphrodite flowers per panicle, whereas an additional 20 panicles per tree were used for monitoring fruit set.

7.3.3 Design, rate and periods of KNO_3 and urea application

A randomised complete block design with three replications and three trees per plot was used. The treatments applied were:

1. 2% KNO_3
2. 2% KNO_3+0.5 g urea
3. 2% KNO_3+1 g urea
4. 4% KNO_3
5. 4% KNO_3+0.5 g urea
6. 4% KNO_3+1 g urea
7. Control

Reagent grades of KNO_3 and urea were used. For all treatments, the required quantities of active ingredients (KNO_3 alone or with urea) were dissolved in 5 litres of water to be sprayed on a single tree. For the sake of convenience, however, only the concentrations of KNO_3 and the quantity of urea used will be mentioned in the paper. The control trees were sprayed with water only.

The first spraying (30th August 2002) of all the chemicals was done about three and half months before the expected regular blooming period, on the immature post-harvest flushes. About two and half months after the first spray, the spraying was repeated on the same trees. During the second spray, it was noticed that the terminal shoots were mature with sclerophyllous, dark green leaves and some trees had started flowering. The spraying was done in the early morning of both application cycles. A mobile canvas shield was also used during spraying operation to prevent spray from drifting to adjacent trees.

7.3.4 Observations

Observations on flowering and fruit set

The percentage of branches that flowered was recorded from the hundred tagged shoots. The beginning of flowering was recorded for all treatments as the number of days between the first spray and the stage where 25 inflorescences from the tagged shoots per tree were at bud break. The total numbers of panicles per tree were counted 40 days after the second spray. Fruit set was quantified at the pea size stage. During harvesting, data on fruit number and weight per tree were recorded for obtaining tree yield.

Determination of fruit quality

Fruit quality was determined nine days after harvest, by sampling 30 fruit per tree, which were ripened at room temperature. Fruit total soluble solids (TSS) was measured with a bench top 60/70 ABBE (No. A90067, Bellingham & Stanley Ltd, England) refractometer with a reading range of 0 to 32 ^{0}Brix. Between readings, the prism of the refractometer was cleaned with tissue paper and methanol, rinsed with distilled water and dried before use. The refractometer was standardised against distilled water (0% TSS). Reducing and total sugars were determined by using the technique of Somogyi (1945). Titratable acid was determined by means of an acid base titration method using a 5 g sample and 0.1 N NaOH with phenolphthalein color indicator.

7.3.5 Statistical analysis

Differences between treatments were determined with Analysis of Variance (ANOVA) using SAS General Linear Model procedure (SAS Institute, 1988). Treatment means were separated using least significant difference (LSD) at the 5% level of significance.

7.4 RESULTS

7.4.1 Effect of the treatments on Flowering

All treatments produced significantly higher values for average number of panicles per tree as compared to the control. There was also a slight relation between increase in concentration of nitrogen in the treatments and improved flowering parameters.

The highest percentage of flowering terminals was observed in the 4% KNO_3+1 g urea treatment (treatment 6) which had a 52% increase in flowering compared to the control trees (Fig. 7.1). The five treatments with higher nitrogen content (treatments 2-6) significantly reduced the number of days required between first spray and flowering as compared to the control (Fig. 7.2).

All treated trees produced a significantly higher number of panicles per tree than the control trees (Fig. 7.3). Application of 4% KNO_3+0.5 g urea (treatment 5) had about twice as many panicles than the control. Flowering amongst the treated trees, on the other hand, did not differ significantly (Fig. 7.3). Except for 2% KNO_3, all the other treatments produced significantly higher percentages of hermaphrodite flowers than the control (Fig. 7.4). A 2% KNO_3+1 g urea spray produced the highest percentages of hermaphrodite flowers, which was a 54% increase compared to the control (Fig. 7.4).

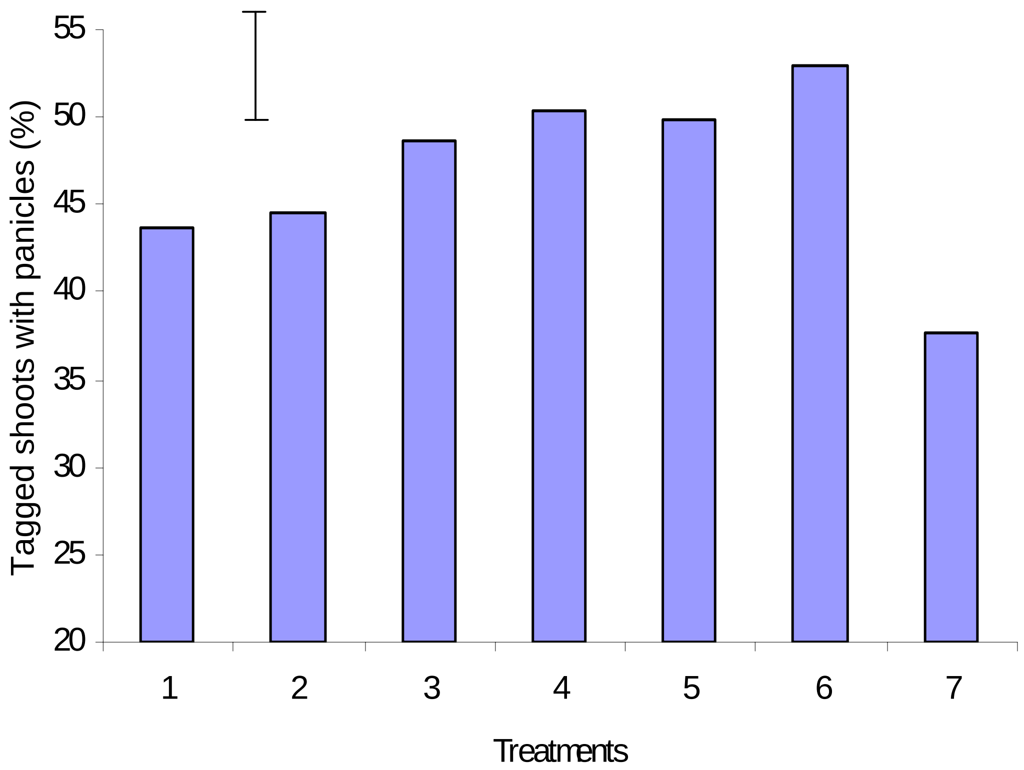

Figure 7.1 **Effect of potassium nitrate and urea spray on the percentage of tagged shoots flowering. The vertical line bars indicate LSD between means at P<0.05 level.**

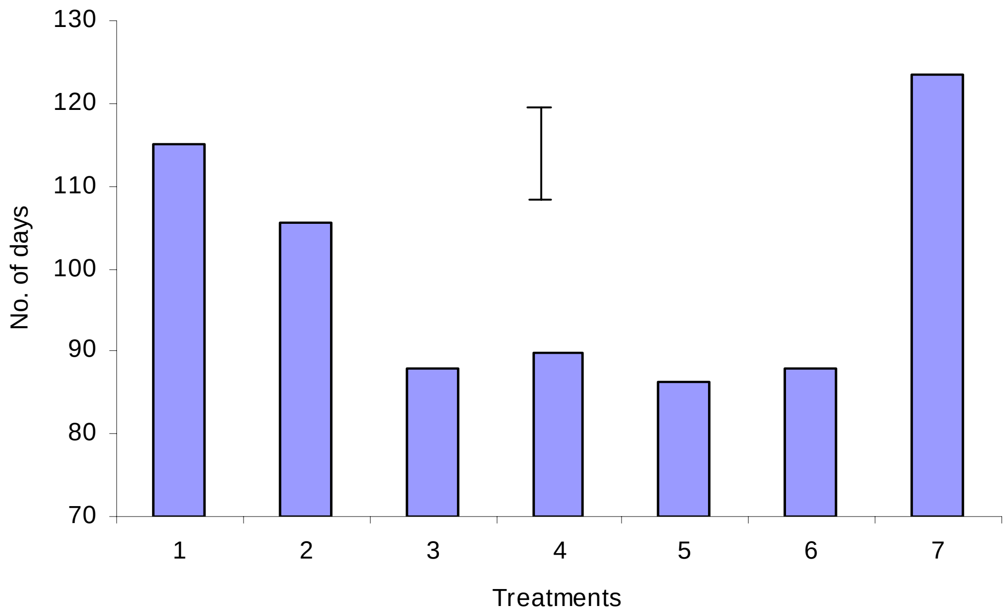

Figure 7.2 Effect of potassium nitrate and urea on days between spraying and flowering. The vertical line bars indicate LSD between means at P<0.05 level.

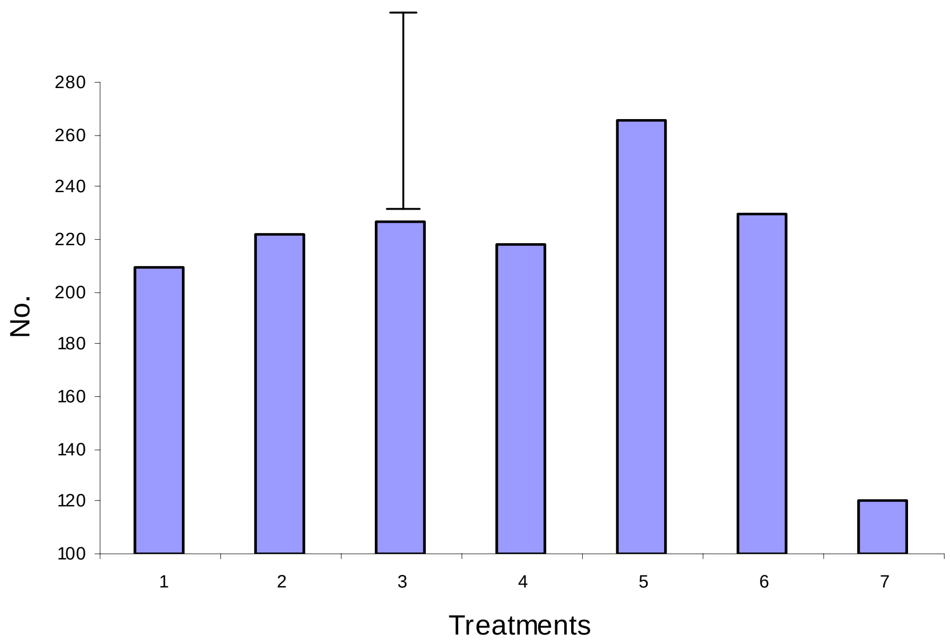

Figure 7.3 Effect of potassium nitrate and urea on the number of panicles produced per tree. The vertical line bars indicate LSD between means at P<0.05 level.

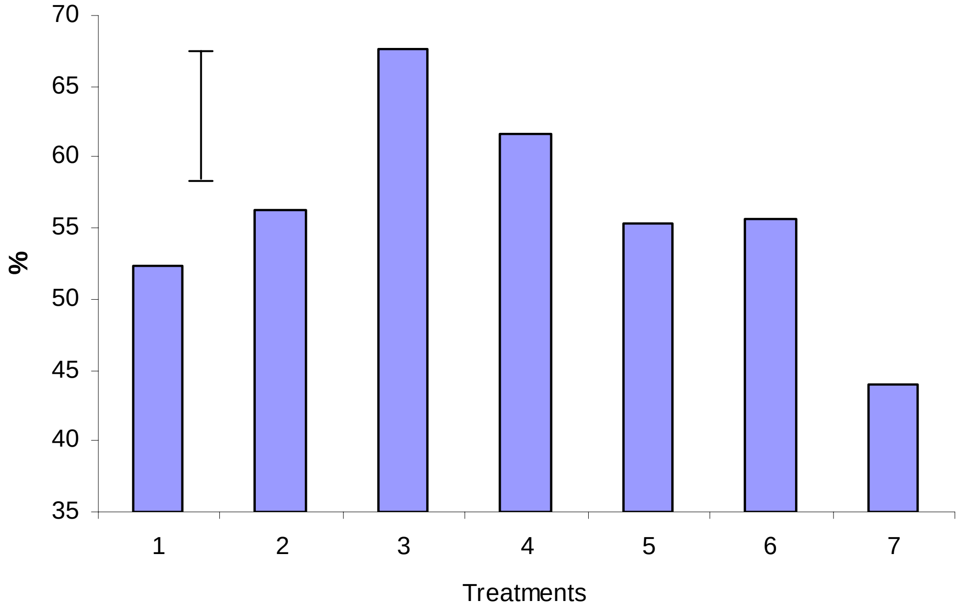

Figure 7.4 Effect of potassium nitrate and urea on the percentage of hermaphrodite flowers. Bars are LSD values between means and indicate significant differences at 5% level.

7.4.2 Effect of the treatments on fruit set and yield

All fruit set and yield results are presented in Table 7.1. Irrespective of the concentrations and different combinations of KNO_3 and urea applied, all treated trees had a significantly higher initial fruit set at pea size stage and fruit number and fruit weight per tree at harvest as compared to the control. There was no significant difference amongst the different concentrations of KNO_3 and urea with respect to initial fruit setting of the panicles.

There was a significantly higher fruit number per tree at harvest on trees sprayed with 4% KNO_3+0.5 g urea as compared with treatments that involve spraying of 2% KNO_3 and 2% KNO_3+ 0.5 g urea as well as the control trees (Table 7.1). The total fruit weight per tree in all treatments was significantly higher than the control (Table 7.1).

There was no significant difference, with respect to average weight of fruit at harvest, between treated and untreated trees. The trend, however, showed that treatments that had higher fruit number at harvest had lower average fruit weight.

Table 7.1 Effects of potassium nitrate and urea sprays on fruit set and yield of 'Tommy Atkins' mango

Treatments	Av. fruit set per 20 panicles (no.)	Fruit number per tree	Total fruit weight/tree (kg)	Average fruit weight (Kg)
Control	3.67b	164.67d	63.61b	0.387a
2% KNO_3	8.33a	208.33c	83.72a	0.403a
2% KNO_3+0.5g U	10.17a	216.33bc	82.71a	0.383a
2% KNO_3+1g U	12.17a	240.33ab	89.26a	0.373a
4% KNO_3	10.67a	238.33abc	88.59a	0.373a
4% KNO_3+0.5g U	10.50a	248.00a	88.86a	0.360a
4% KNO_3+1g U	11.17a	242.00ab	85.49a	0.357a

Means followed by different letters in a column are significantly different by LSD test at $P<0.05$

7.4.3 Effects of the treatments on fruit quality

Apparently, fruit quality was not affected by any of the treatments as indicated by non-significant differences for different parameters (Table 7.2).

Table 7.2 Effects of potassium nitrate and urea spray on fruit quality of 'Tommy Atkins' mango

Treat.	TSS (^{o}Brix)	Titratable Acids (mg/100g)	Reducing Sugar (%)	Total Sugar (%)
Control	13.33a	0.527a	4.00a	11.00a
2% KNO_3	14.20a	0.447a	3.83a	11.23a
2% KNO_3+0.5g U	14.78a	0.747a	3.91a	11.32a
2% KNO_3+1g U	14.71a	0.547a	4.02a	11.06a
4% KNO_3	15.49a	0.513a	4.04a	11.15a
4% KNO_3+0.5g U	13.89a	0.460a	4.12a	11.85a
4% KNO_3+1g U	14.70a	0.413a	4.09a	12.33a

Means followed by different letters in a column are significantly different by LSD test at $P<0.05$).

7.5 DISCUSSION

Some controversy regarding the time of KNO_3 application was noted in previous experiments with KNO_3. Some authors recommended KNO_3 application three months before the expected flowering (Fierro & Ulloa, 1991), that is during the initial stage of shoot growth (flushing), while others (Bondad & Linsangan, 1979; Perez-Barraza *et al*., 2000) obtained better results by applying KNO_3 on matured vegetative flushes. In our trial, the trees were sprayed twice – during the vegetative flush stage, and at the quiescent terminal bud stage of the matured flushes.

In the current study, a more or less ascending trend was noticed for the percentages of terminal shoots flowering as the concentration of KNO_3 and urea increased. This is a clear indication that the total nitrogen content of the spray solution was the critical factor. No phytotoxic effect to the leaves of the sprayed trees was observed I the tropics by the higher concentrations of KNO_3, as opposed to the observations of Oosthuyse in the subtropics (1996). Phatak & Pandey (1978) observed that nitrogen status could be affected by foliar applications of KNO_3 and reported accumulation of nitrogen before flowering. Protacio (2000) mentioned the possibility of a threshold level for nitrogen concentration that, if exceeded, would allow the plant to flower. Consequently, the mechanism of KNO_3 and urea in triggering flowering could be a matter of exceeding this threshold level. In the current experiment, spraying trees with 4% KNO_3+1 g urea produced inflorescences on 53% of the tagged shoots. With the observations of Nunez-Elisea (1985), KNO_3 spray produced inflorescences on 60 and 76% of shoots in 'Haden' and 'Manila' mango, respectively, as compared to 32 and 20% in the corresponding controls.

Two flowering periods within a year is a common phenomenon in the semi-arid tropical regions such as Ethiopia. Due to the enhanced panicle development and fruiting, which had resulted from higher KNO_3 and urea concentrations, during the main flowering season (November-December), a very insignificant second flowering (April-May), which normally occurs in the same year, was noticed. This in turn has an implication of alleviating alternate bearing through conservation of reserves by reducing the second flowering.

Trees that received 4% KNO_3+ 0.5 g urea flowered 11 days after the second spray compared to the control trees that flowered 48 days after the second spray. This means that treating trees with 4% KNO_3+ 0.5 g urea advanced flowering by about 37 days as compared to the control trees, which is a significant improvement in attaining earlier yield. A negative correlation (r=-0.815*) was observed between duration (number of days taken after spraying) for visible inflorescence development and number of panicles developed (Fig. 7.5). This possibly indicates that more favourable climatic conditions, as well as tree status conducive for flowering, prevailed early in the season but not towards the end of the season. Similar to the results of the current experiment, Sergent *et al*. (1996) observed that high KNO_3 dose (3.6 & 4.6%) induced early flowering and harvesting (30-45 days earlier) as compared to the control trees. Barros *et al*. (1998) also observed 43 days earlier flowering on 'Tommy Atkins' trees. Perez-Barraza *et al.* (2000), however, did not obtain earlier flowering on 'Tommy Atkins' after using NH_4No_3 and ethephon. They speculated that the lack of response could be due to presence of immature shoots at the time of treatment application.

In general, Protacio (2000) hypothesized that, once gibberellin levels fall below a threshold level, starch can start to accumulate, allowing the trees to flower. After sufficient starch has accumulated, floral initiation will ensure. However, the buds will remain quiescent until conditions are favourable for flowering. KNO_3 and urea, especially at higher concentrations (as observed in the current study) may activate those quiescent buds for floral initiation.

Trewavas (1983) also noted that KNO_3 could be used to break dormancy of buds, particularly flower buds, which is one of the direct effects of nitrate. The results obtained for KNO_3 in increasing the numbers of panicles produced and decreasing the days for visible inflorescence emergence are in line with an experiment conducted in controlled growth chambers before the field experiments (Yeshitela *et al*., 2004).

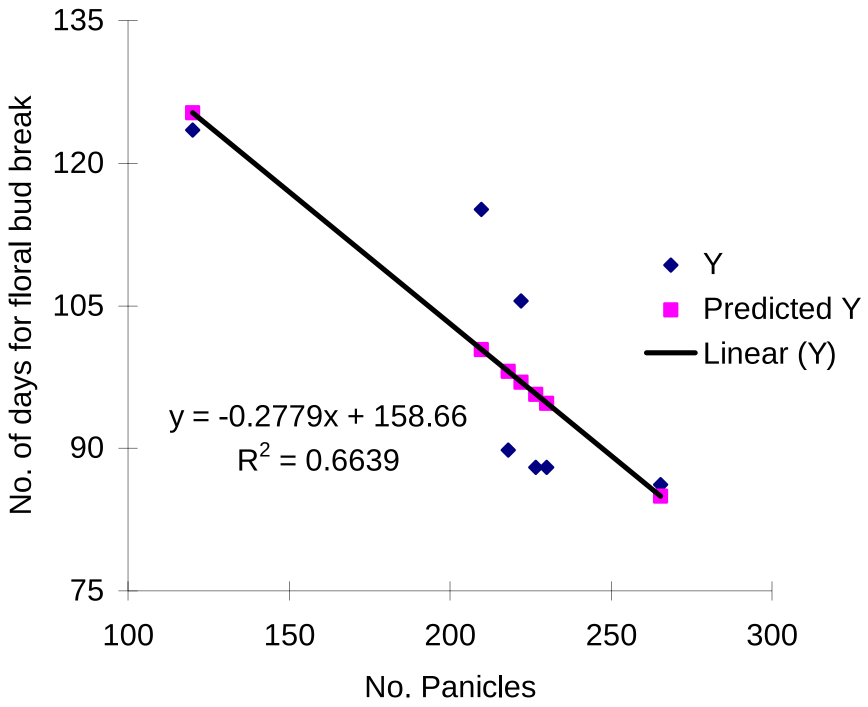

Figure 7.5 A negative correlation between numbers of days required for floral bud break and numbers of panicles developed.

Most of the treated trees in the current experiment had a narrow range of variability (12-16%) with regard to the percentage of hermaphrodite flowers. Singh (1987) estimated that less than 0.1% of the hermaphrodite flowers develop into mature fruit. He reasoned that, assuming there are 100000 flowers and each flower contains 10 µg nitrogen, then each time a tree flowers, it loses 1 kg of nitrogen. The tree will, therefore, need to have adequate nitrogen reserves for flowering and subsequent fruit set. In the current study, the percentages of hermaphrodite flowers produced did not show a linear relationship with the increase in nitrogen concentration. However, except for the 2% KNO_3 treatment, all the other treatments produced higher percentages of hermaphrodite flowers signifying the importance of higher nitrogen level in the process up to a certain threshold level as shown in Fig 7.4.

There was a clear relation between flowering and fruit yield/tree. The amount of fruit set on a panicle and the number of set fruit retained to harvest is more important than the number of panicles per tree. In the current experiment treatments with higher KNO_3 and urea concentrations produced a higher fruit set, fruit number, and fruit weight per tree. Nitrogen supplement from KNO_3 and urea spray may be the reason for the increase in the quantitative parameters of yield.

The effect of KNO_3 on flowering and fruiting was higher when applied with urea, an additional nitrogen source. This is because the trees need to have adequate nitrogen reserves for flowering and subsequent fruit formation. Increased nitrogen fertilization via the soil has also been found to increase fruit retention and tree yield in mango (Smith, 1994). Hence, a nutritional effect cannot be discounted. In fact there should be a certain limit to the increase of nitrogen level, in view of the fact that surplus nitrogen application could cause fruit drop. This is because a higher nitrogen application favours excess vegetative growth and there will be limited assimilate diversion to the fruit.

Relatively higher average fruit weight from the application of 2% KNO_3 and the control trees could be related to lower fruit retention percentage of these trees as compared to trees sprayed with higher concentration of KNO_3 and urea. The result was similar to that of Oosthuyse (1996) and Machado & Sao Jose (2000). In general, similar to the current experiment, a yield increment due to KNO_3 application was also observed by Barba (1974); Bondad & Linsangan (1979); Oosthuyse (1996); Sergent *et al*. (1996); Barros *et al*. (1998); Machado & Sao Jose (2000); Debnath & Kundu (2001). A highly significant positive correlation (r=0.886**), (r=0.949**), (r=0.948**) was observed, from the results of the current study, between the percentage of hermaphrodite flowers and fruit set, fruit set and fruit number as well as between fruit set and total fruit weight per tree respectively. The regression graphs for the relationships of the mentioned parameters are presented in Fig. 7.6, 7.7 and 7.8. This is an indication that treatments that receive a higher concentration of KNO_3 and urea spray also have higher fruit set at pea size stage, higher fruit number, higher total fruit weight per tree at harvest and higher fruit retention potential.

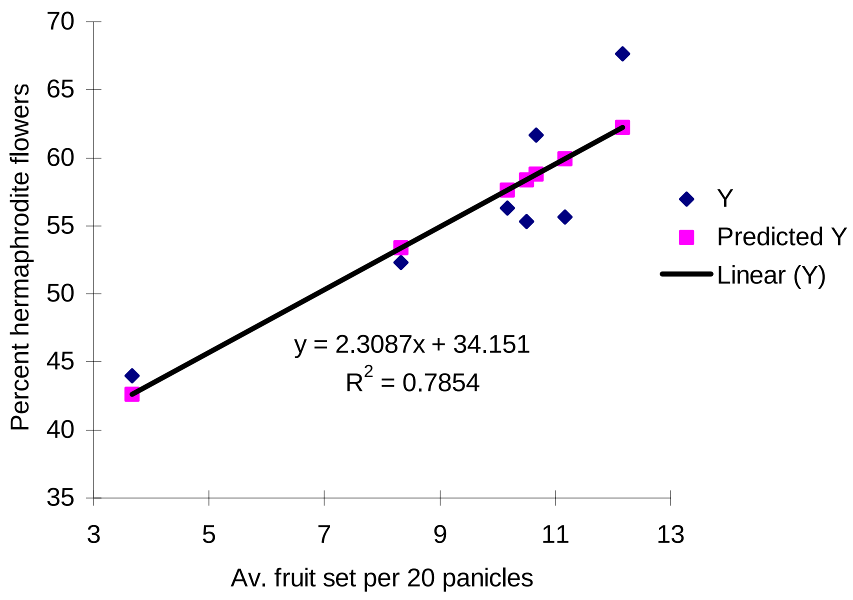

Figure 7.6 A positive correlation between percentages of hermaphrodite flowers and average fruit set per 20 panicles.

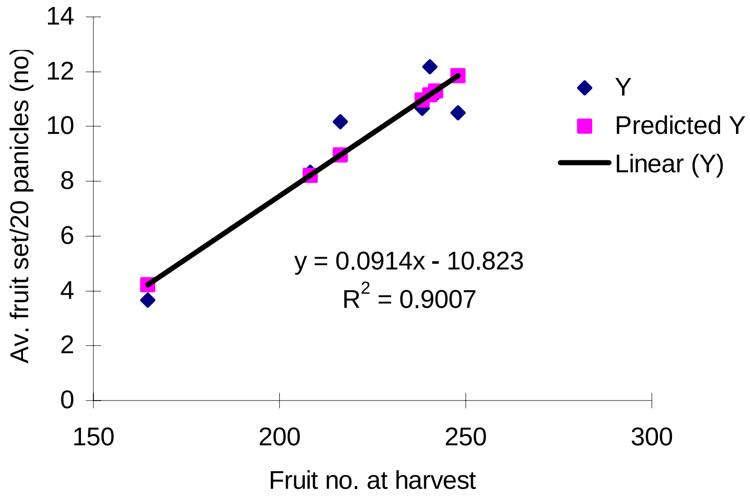

Figure 7.7 **A positive correlation between average fruit set per 20 panicles and total fruit number at harvest.**

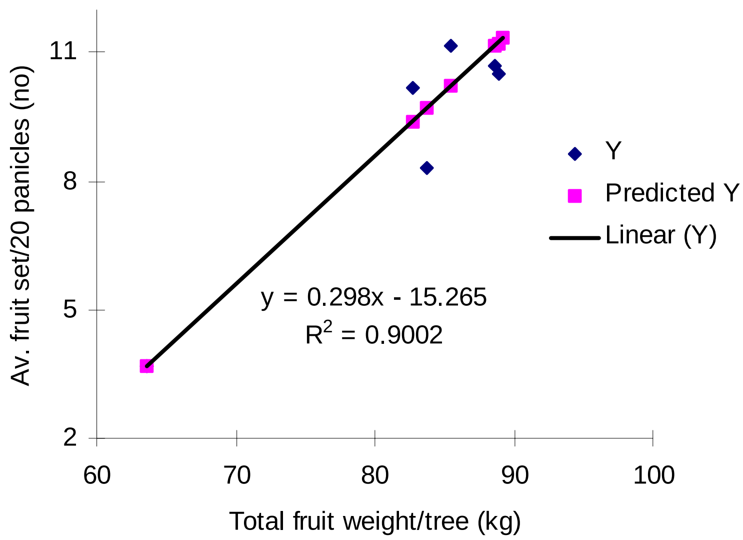

Figure 7.8 **A positive correlation between average fruit set per 20 panicles and total fruit weight at harvest.**

All the qualitative parameters, unlike the quantitative yield parameters, proved not to be affected by application of KNO_3 and urea. It can be deduced, therefore, the supplement of nitrogen through KNO_3 and urea was totally in favour of quantitative parameters and not to the qualitative parameters. As to the observation of Sergent *et al*. (2000), when urea was applied with KNO_3, plants grow larger than that of the control. The result of the current experiment with respect to the effects of KNO_3 on fruit qualitative parameters corresponds with that of Oosthuyse (1996).

7.6 CONCLUSIONS

Spraying 'Tommy Atkins' mango trees with 2% KNO_3+1 g urea or 4% KNO_3 was found to be beneficial for all the flowering and fruiting parameters. At the same time, it is more cost effective to spray these previously mentioned concentrations rather than the higher levels in a large orchard, similar to where this experiment was conducted.

Therefore, it would be possible to diminish the erratic flowering and alternate bearing in mango trees grown in tropical areas such as the Upper Awash Agro-Industry orchard in Ethiopia, by using the above mentioned concentrations of KNO_3 and urea in combination with other proper and modern cultural practices.