FLOWER BUD FORCING IN HUMID TROPIC MANGOES USING DORMANCY BREAKERS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

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KERALA, INDIA

2007

DECLARATION

I, hereby declare that this thesis entitled **"Flower bud forcing in humid tropic mangoes using dormancy breakers"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Dedicated to

My beloved family

And

Pomology and Floriculture department

Acknowledgement

Ohm - I bow my head before the Almighty for the unmerited blessings, which lead me every step of the way. I submit this small venture before GOD with full satisfaction and pleasure from my heart.

I am elated to express my heartfelt gratitude with reverence to my benevolent major advisor, ***Dr.N.K, Parameswaran,*** *Associate Professor, Department of Pomology and floriculture, College of horticulture, Vellanikkara for his enthusiastic spirit, careful scrutiny, critical suggestions, bountiful nature, understanding and warm concern throughout the course of my study period, which enabled me to finish the work satisfactorily. I consider myself fortunate in having the privilege of being guided by him.*

I am very much grateful to ***Dr. P.K, Rajeevan,*** *Professor and Head, Department of Pomology and floriculture, College of horticulture, Vellanikkara and member of my advisory committee for his concrete suggestions, constant encouragement and guidance throughout the investigation, inspite of his busy schedule.*

I take this opportunity to express my indebtedness with veneration and devotion to ***Dr.T.Radha,*** *Professor, Department of Pomology and floriculture and member of my advisory committee for her constant support, valuable guidance, resourcefulness and concern in doing the study.*

I am in dearth of words to express my indebtedness to ***Dr. K, Nandini****, Professor, Department of Plant breeding and genetics for her warm concern, materialistic and moral support during the pheno- physiological studies of my research.*

I also avail this opportunity to pay my sincere obligations and heartfelt thanks to Sri.S.Krishnan, Asst. Prof., Department of Agrl. Statistics for the advice and help rendered in the statistical analysis of the data and in the subsequent interpretations.

I express my profound thanks to Dr. C.P.A.Iyer for his valuable guidance, resourcefulness and suggestions offered during the final viva.

I express my profound thanks to all the teaching, non-teaching staff of Department of Pomology and floriculture for the whole hearted cooperation and encouragement throughout the course of the study.

The valuable advise of my friends Geena, Sai sree, Jisha, Sreevidya, Deepa, Pramod, RatnaPrabha, Deepthy Sreedharan , Dana, Sabeena , Anjali ,Neema, Remya, Deepthy Jose, Nimisha, Shabeer, Praveen, Sneha are kindly acknowledged. My special gratitude to my classmates -Remya R, Hazmin, Riya, Nisha.C, Vineesh, Naveen, Sreekanth.

The timely help and earnest assistance rendered by my seniors Kaveramma, Jalia, Smisha, Meghna, Sreerekha, Gayathri, Mini Baspin, Binisha chechi, Manoj chettan and my juniors Kimi, Jaseena, Anu, Deviprasad and Alok are gratefully acknowledged.

My special thanks are also due to Rashmi chechi to help me in taking photographs required for my thesis submission.

My special thanks are also due to Devaki chechi, Umavathy chechi, Lalita chechi, Subhadra chechi, Rama chechi, Preman chettan, Cicily chechi for the assistance rendered in the research at the college orchard, lab.

I also thank all the teaching staff of the various departments for their kind concern and support. Their friendly attitude and cooperation helped me a lot for the smooth conduct of my research.

The help rendered by Santhoshettan of student's computer club and Jomon, JMJ Computer Centre, Thottappady is duly acknowledged. On my personal ground, I cannot forget the fondness, constant support and encouragement showered by my dearest parents and sisters to whom I feel I must dedicate this small piece of work as a token of eternal love.

I also thank Zeenath, Shabana chechi, Meera, Naijal, Rejna chechi, Raji, Vinodini, library staff, Lissimol Aunty, Jabbar sir for their valuable help, willingness to share information, which mainly contributed to the success of this study.

My gratitude cannot be just captured in words for the unflinching moral support, constant encouragement and warm concern of all the members of Daffodils 2000.

I also thank all the teaching and non teaching staff of the Kerala Agricultural University and G.M.V.H.S.S. Nilambur for their immense help.

Hima K.

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1. INTRODUCTION

Successful floral manipulation or control of flowering allows the growers to harvest their crops at the most profitable times. It adds to increasing the season of availability, improving the competitiveness in a growing national /international market plane and promotes most efficient use of resources as the cost of inputs, viz., fertilizers and pesticides continue to rise.

Floral manipulation is a matter of much relevance in a fruit crop like mango since many –a –mango grower find it difficult to meet the market demands regularly due to the inconsistencies experienced in cropping. Erratic or irregular bearing in mango is a widely worked out aspect ever since mango has been in cultivation. The advances made with regard to use of external stimulants for induction of flowering in mango has been very much positive and put to profitable use in many countries. One of the notable practices in this context is the use of nitrates and their combinations as dormancy breaking chemicals (DBC) for stimulating flowering in mango cultivars in regions of tropical latitude, especially in the wet tropics.

The present investigation on ‘Flower bud forcing in humid tropic mangoes using dormancy breakers’ was taken up at the Department of Pomology and Floriculture, College of Horticulture in this background with the object of trying out the efficacy of nitrates and other compounds for stimulating flowering in mango, under the humid tropical situations of Kerala.

2. REVIEW OF LITERATURE

Floral induction is essentially the starting point for flowering and subsequent process of fruit set and development. Insufficiency in induction meddles with the flowering and fruiting processes and in turn affect the crop yield as a whole. Such a situation is prevailing in many of the commercial mango growing tracts leading to inconsistent crop production. The present set of investigations taken up against this backdrop was aimed at trying out flower bud forcing in the humid tropic mangoes with dormancy breaking chemicals viz., nitrates, micronutrients and thiourea. Since a lot of work has been reported on floral induction in mango involving bioregulators, the review of literature presented hereunder is restricted to those pertaining to nitrate induced floral induction in the crop.

2.1 Dormancy breaking chemicals and flower induction in mango

Ever since the early reports of the use of KNO_3 for stimulating flowering in mangoes in the humid tropic regions by Barba (1974), a considerable work has been reported on this aspect from various countries.

Astudillo and Bondad (1978) noted that the applications of the compounds with nitrates, resulted in greater per cent of induction after 8 days of application. In variety Carabao, Pahutan and Pico five to ten months old branches produces perfect flowers with 1% potassium nitrate and it induces nitrate reductase formation, which is like an enzymatic key in the nitrate assimilation. The results for potassium nitrate sprays were influenced by the physiological age of growth flushes, because five to eight months aged vegetative flushes responded better to potassium nitrate applications than young flushes.

Potassium nitrate used jointly with $Na_2H_2PO_4$ subsequently at the floral emergence stimulate the fruit size and quality at 3 per cent, 6 per cent concentration (Singh and Tripathi, 1978).

Bondad and Linsangan (1979) indicated a significant increase in the number of panicles when potassium nitrate treatments were applied in the initial vegetative flush growth stage compared to the later matured flush stage. Non flowered trees and those with sparse flowering in the previous season responded better to potassium nitrate application than the flowered ones.Both potassium nitrate and ammonium nitrate favours early flower initiation.

Mosqueda-Vazquez and Rosendiz (1985) stated that chemical bud forcing is effective in tropical areas where distinct dry and wet seasons prevail. But the response to nitrates may diminish at latitude higher than 22^{o}North or south.

Nunez-Elisea (1985) reported that foliar application of potassium nitrate, ammonium nitrate or calcium nitrate stimulates shoot initiation of mango in the low latitude tropics and stimulates flowering. Nitrate salt must be applied after the resting stem reaches sufficient age to overcome inhibitory influence they possess on the response to flower.

Foliar applied potassium nitrate, ammonium nitrate or calcium nitrate stimulates shoot initiation in the low latitude tropics (Nunez-Elisea and Caldeira, 1988). Ammonium nitrate is twice as effective as potassium nitrate. In tropics, receptive trees will respond by flower bud initiation within two weeks. Effective spray concentration ranges from 1-10 per cent (Nunez-Elisea, 1988). Calcium nitrate or potassium nitrate should be sprayed on the under side of foliage throughout the tree canopy as 4 per cent solution and 2 per cent ammonium nitrate.

Sharma *et al.* (1990) studied the effects of potassium nitrate sprays at 0,1.5 or 3 per cent significantly increased the fruit set, percent fruit retention and yield, reduces the fruit drop per cent at Jabalpur conditions during the year 1986. In ten year old cv. Langra, 4 per cent urea, 3 per cent potassium nitrate and 40 ppm NAA treatments produced greatest number of fruits per plant, TSS, lowest acidity of 0.26 per cent using 4 per cent urea with 3 per cent potassium nitrate.

The mechanism responsible for potassium nitrate inductions appears to be mediated hormonally but the exact relationship between the endogenous hormones in mango and potassium nitrate are still unknown (Fierro and Ulloa,1991).

The effect of potassium nitrate on flowering is not mediated by ethylene (Davenport and Nunez-Elisea, 1991). Chacko (1991) explained that the effects of diverse chemicals with growth regulating properties have been limited to certain cultivars and geographical locations.

Goguey (1993) asserted that the response of plants to various flower inducing treatments differs as per the cultivars, climate, geographical locations.

Mosqueda-Vazquez *et al.* (1993) reported that in cv. 'Manila' mango trees, potassium nitrate and ammonium nitrate induced flowering. 434.7 degree days with a base temperature of $12^{o}C$ were required for the inflorescence elongation and base temperature of $0.33^{o}C$ were needed for the fruit maturity.

According to Oosthuyse (1993), out of the various applied treatments - potassium nitrate, low biuret urea, GA_3, CPPU, Wuxal boron; the only treatment to increase fruit retention, average fruit mass, yield and monetary return is the application of potassium nitrate.

Rojas (1993) observed in ten year old cv. Haden, 6% potassium nitrate increased the % of flowering shoots and the number of mixed panicles, vegetative shoots, axillary branch.

Whiley (1993) attributed low mango yield in the tropics to the failure of floral induction. Environmental stimuli dominates the yield potential with respect to reproductive process of the plant. Day/night temperature below $20/14^{o}C$ results in floral induction.

Foliar sprays of calcium nitrate or potassium nitrate, potassium sulphate, Wuxal calcium suspension at 0.3% and 0.6% were applied thrice at two weekly intervals to the post harvest flush in trees of mango cultivar Sensation. All potassium nitrate sprays were effective in inducing flowering (Mckenzie, 1994).

Batten and Mcconchie (1995) attempted flower bud forcing in litchi (*Litchi chinensis*) and mango (*Mangifera indica*.L) by manipulating temperature variations of the atmosphere. They noted that on the buds of potted plants of litchi and mango, floral initials could be visible within 39 days of transfer to low temperature and 30 days in mango.

Rojas and Leal (1997) stated that 10 mg/l potassium nitrate application induced mango flowering. Potassium nitrate spray application to Tommy Atkins mango trees whilst the inflorescence were in full bloom increases the fruit retention, reduce fruit size and increases the tree yield and tree revenue (Oosthuyse,1996). He reported that 4 per cent potassium nitrate applied was slightly phytotoxic to leaves and inflorescence, causing necrosis at distal margins, extremities of inflorescence branches.

Oosthuyse (1996) studied the effect of potassium nitrate sprays to flowering mango trees and reported that such sprays are effective on increasing the fruit retention, fruit size, yield and fruit quality. The studies showed greatest increase in tree yield corresponding with the highest fruit retention.

Davenport and Nunez-Elisea (1997) reported that in the low and mid-latitude tropics, receptive trees responded by initiating floral buds within two weeks after treatment and the effective spray concentration ranged from 1 to 10% potassium nitrate with the optimum concentration varying with the tree age and climate .

Shongwe *et al*. (1997) reported that on 3 year old plants of Julie (semi dwarf cv.) and two vigorous cvs. Graham and Tommy Atkins, 6 per cent potassium nitrate and 50 per cent methanol when applied during the off season; Julie flowered in June and in

August, produced more panicles in response to potassium nitrate than on control. In Julie, chemical potassium nitrate produced higher water use efficiency and related to the ability to affect flowering.

According to Tongumpai *et. al*. (1997) on three year old trees of cv. Nam Dok Mai when treated with 0.5, 1 per cent thiourea. (uniform terminal bud break were produced within 14-16 days after treatment), but in the control it was after 31 days only. 1 per cent thiourea induced severe defoliation. But in the cv. Khiew Sawoey, 0.5 per cent thiourea treated at the full leaf expanded state, induced new shoot growth within 2 weeks.

On five year old 'Haden' trees at Venezuela, 36g/l potassium nitrate was effective to maintain the high yield during two consecutive years, but control trees exhibited low yield and strong biennial bearing (Sergent *et al*., 1997).

Medina and Nunez- Elisea (1997) imposed certain cultural treatments tested to promote the summer production of vegetative shoots in mango to increase the early bloom with ammonium nitrate sprays applied during the fall, in Haden and Tommy Atkins. The results were inconclusive as the early flowering was discouraged by untimely rains in November, during ammonium nitrate spraying.

Guzman Estrada *et al.* (1997), while elaborating the importance of mineral nutrition in the crop management in mango, undertook leaf chemical analysis at Cotaxtla experimental station. The results showed that nitrogen was between an adequate to an excessive range. Increase and decrease in the nutrient concentration were independent of the phenological phases, season and fertilizer application. Foliar concentration were not related to flower, fruit production.

Rojas and Leal (1997) reported that in cv. Haden, Criollo, potassium nitrate spray caused a slight promotion in October and a heavier one in December, on the unpruned trees. Potassium nitrate compensated the adverse effects of pruning on flowering.

Oosthuyse (1997) tried 2-4 per cent KNO3 under the South African situation, on cvs. Sensation, Irwin, Keitt, Tommy Atkins during the flowering period. In Tommy Atkins , greatest increase in fruit retention occurred applying 4 per cent potassium nitrate. In Heidi cv., two applications at 4 per cent each gave greatest increase and in cv. Kent, two applications at 2 per cent potassium nitrate each increased fruit retention. Potassium nitrate increased the tree yield and in turn greatest adoption of potassium nitrate is practiced commercially in South Africa.

Davenport and Nunez- Elisea (1997) observed that the flowering flushes occur during cool winter months in the high latitude tropics, and are asynchronous in the tropical climate. Inflorescence develops when shoots initiates growth at cool temperature (18^oC day temperature /10^oC night temperature).

Protacio (2000) suggested the model for potassium nitrate induced flowering in mango. Potassium nitrate acts by elevating nitrogen levels over a nitrogen threshold thereby synchronizing bud break from apices with existing floral initials. He discussed the need of nitrogen for flowering in mango. Potassium nitrate application triggers flowering by exceeding the threshold for nitrogen concentration. In a mature tree already flowered or in the grafted trees, potassium nitrate is an agent initiating flowering from competent tissues ready to flower i.e., it may be a stimulus for flower initiation.

In Mexico, November and December foliar sprays of ammonium nitrate were successful to promote flowering of several mango cultivars, but failed to promote in the cv. Tommy Atkins. Lack of response was attributed to the presence of immature shoots at the time of treatment application (Perez Barraza *et al*., 2000).

According to Ataide and Jose (2000) in Senhora, 3 per cent potassium nitrate treated cv. Tommy Atkins trees presented higher number of fruits per tree without affecting the average fruit weight. It promoted higher production per tree and greater benefit/cost relation.

Nartvaranant *et al*. (2000) tried paclobutrazol application followd by thiourea for bud forcing in mango. They noted that when paclobutrazol was applied (in the specified doses) followed by a spray of 0.5% thiourea after 120 days; the inflorescence could be visible within 2.5 to 4 months, depending on the cultivar.

Davenport (2000) observed that floral stimulation using nitrate application depends upon the cultivar and night temperature.

Mendova *et al*.(2001) reported that in the cv. Tommy Atkins of Brazil, greatest flowering of 81.75 per cent and the number of fruits (=86) were observed by applying 2 per cent calcium nitrate and 1500mg PBZ/l and 3 per cent calcium nitrate and 1500mg PBZ/l respectively.

In Tarai region of Uttar Pradesh, India, fifteen year old Dashehari trees sprayed with 1, 2 and 3 per cent of thiourea, potassium nitrate and urea just after the fruit harvest in July. But the foliar application of chemicals produced some injuries in the leaves. The lowest leaf injury observed using urea and higher injuries in potassium nitrate and thiourea treatments (Tripathi, 2002).

Vijayalakshmi and Srinivasan (2002) reported male to bisexual flower ratio was affected by the application of 1 per cent potassium nitrate to induce flowering in the off year mango cv. Alphonso.

According to Hafle *et al.* (2003) efficient flower induction was promoted by two applications each of 30 g/l potassium nitrate and 0.25 ml/l ethrel and 30 g/l calcium nitrate and 0.25 ml/l ethrel.

Gupta and Brahmachari (2004) conducted a trial during the year 2000-2001 at Sabour, Bihar in the mango cv. Bombai. Maximum fruit size, weight and yield were obtained using 4 per cent urea.

Yeshitela *et al*. (2004) opined that potassium nitrate promoted bud initiation for vegetative growth in non inductive temperature conditions and reproductive growth in the inductive conditions. 35 days are the minimum inductive period at 10/15^{o}C for complete floral induction and development for the cultivars. Tommy Atkins and Keitt. The number of inflorescence developed were affected by the chemical spray and the time trees kept under the inductive conditions. 3 per cent potassium nitrate sprayed on the cv. Tommy Atkins produced the longest inflorescence and longest flushes (21.54 cm). New flush length developed from potassium nitrate sprayed trees were reduced than control trees. The number of new leaves were also low, signifying the negative correlation between the number of inflorescences and the flush length.

Hwang *et al*. (2004) reported that in the cv. Keitt, higher rate of average axillary panicle induction was noted with hydrogen cyanamide 0.75 per cent to 1 per cent than 1 per cent calcium cyanamide. Keitt had a better rate of induction than Irwin.

In mango, higher potassium nitrate (4%) and urea concentration produced a higher fruit set at pea size stage, fruit number and fruit weight per tree. Nitrogen supplement from potassium nitrate (4%) and urea spray may be the reason for increase in the quantitative yield parameters (Yeshitela, 2004).

In cv. Tommy Atkins, five litre solution of 4 per cent potassium nitrate and 0.5 g urea per tree, 4 per cent potassium nitrate and 1g urea per tree produced better results for flower and yield parameters. Nitrogen supplemented through urea is the supposed reason for greater flowering and yield of the sprayed trees than the control trees (Yeshitela *et al.*, 2005).

2.2 Effect of micronutrients on flower bud forcing

Besides the nitrogenous compounds, some of the micronutrients were also found to influence the floral characters including bud break if applied at right stages in mango. Some of the relevant reported literature in this regard is presented hereunder.

Robbertse *et al.* (1988) observed that boron at 1000 ppm applied as foliar spray at the onset of flowering in mango enhanced the growth of mango pollen tube and inturn effecting increased fruit set and ultimate yield.

According to Robbertse *et al*. (1990) highest fruit production per tree was obtained in the treatment of boron at 3000 ppm during the bud stage and two foliar applications at both bud stage and flower opening stage.

In a field experiment conducted by Singh (2003) in Uttaranchal during the year 2000-01, highest yield per tree and yield per hectare of the cv. Dashehari was observed in zinc, boron, copper combination treatment, followed by zinc and boron combination (0.2%). Highest fruit length and weight were observed in the latter treatment whereas highest TSS, reducing sugar, non reducing sugar and total sugars were observed in the former treatment.

Singh and Maurya (2004) reported that when micronutrients were applied at the time of panicle emergence, pea stage and fruit development stage in mango cv. Mallika, the combination spray of 0.4 per cent Zinc sulphate and Ferrous sulphate each, 0.2 per cent Manganese sulphate and 0.2 per cent Boric acid both alone and in combination was found effective in increasing flowering, fruit yield of mango .

Dutta (2004) tried boric acid at 0, 500, 1000, 2000, 3000, 4000 ppm concentrations on mango trees cv. Himsagar at the late bud swelling stage.3000ppm Boric acid was found to be optimum for the cultivar. Maximum panicle length was observed with 3000 ppm boric acid while minimum obtained in the control treatments. The maximum rachis diameter, per cent of bisexual flowers, highest fruit retention (1.93 fruits /panicle), largest fruit weight (280 g), high fruit pulp and TSS, TSS / acid ratio were observed in 3000 ppm boric acid treatment.

Pulschen and Growhow (2004) while concluding the effect of different micronutrient foliar sprays noted that molybdenum requirement in fruit crops like mango is very small. They also opined that foliar sprays with boron are efficient means to improve fruit set and yield of the trees.

2.3 Effect of nitrogenous and other compounds as dormancy breaking chemicals in other fruit crops

Zilkah *et al*. (1987) observed that 2 per cent urea N^{15} applied on the leaves increased the number of the lateral inflorescence per shoot of avocado cvs. Fuerte and Hass. Urea was basipetally translocated from the leaves of current flush to the developing fruit and it increased the fruit set eventually.

Mishra (2003) tried aqueous solutions of 0, 0.5 and 1 per cent calcium nitrate on guava cv. Sardar. N, P, Ca, Mg contents of leaves increased with calcium nitrate foliar spray. Pre harvest calcium nitrate application increased the fruit shelf life, reduced physiological loss in weight, volume, total sugars for more than three days at ambient storage temperature.

Widmer *et al.* (2006) reported that urea or boron applications had no concernible effect on the tree growth, flowering, yield, biennial bearing index and external fruit quality on *Malus domestica* and *Pyrus communis.*

Swietlik (2006) observed that in apple and sour orange**,** 0.5 per cent calcium chloride enhances nitrogen uptake and plant growth. Foliar treatment with urea increases the total leaf area, stem and root dry weight but calcium chloride addition did not increase the response.

2.4 Physiological aspects related to flowering in mango

Physiological base of flowering in mango is widely studied and a better understanding has been evolved out of these early works. Carbohydrates (CHO) and

Nitrogen (N) relationships, photosynthesis and other related processes etc. were all critically analysed during theses earlier investigations. Some of the reported work pertinent to the present investigations are reviewed hereunder.

Singh (1960) opined that in all mango varieties except Baramasi, the higher starch reserve, total carbohydrates and carbohydrates to nitrogen ratio in shoots favoured the flower bud initiation and development. He summarized that the bearing habit of mango cannot be predicted exclusively based on the mineral analysis of the shoots.

Seasonal changes in carbohydrates and nitrogen contents of mango shoots, relating with flower bud initiation have been well explained (Sen, 1962).

Sen (1962) noted a significantly high carbohydrates to nitrogen ratio in the mango bark during the flower bud initiation and differentiation period. Total sugars, carbohydrate and soluble nitrogen contents were found higher in the flowering shoots compared to the non flowering shoots (Sen *et al*., 1965).

Mishra and Dhillon (1978) observed lower carbohydrates to nitrogen ratio and starch to nitrogen ratios in the 'off' year. Suryanarayana (1978) did not observe any relation between nitrogen content and carbohydrates to nitrogen ratio with flower bud formation or number of flowers.

Changes in the biochemical constituents viz. carbohydrates, nitrogen, calcium, magnesium, potassium with respect to flowering were studied in mango by Ravishankar and Rao (1982). A depletion in CHO after the flushing and panicle development in mango was notable. Chacko (1986) reported total nitrogen content was higher in the stem and leaves of mango trees during flowering.

According to Nunez-Elisea (1988), optimum leaf nitrogen levels for mango should be 1.1 to 1.4 per cent to avoid possible second flush. Sufficient nitrogen should be

applied at flowering to provide levels needed to maintain good fruit set and development, without retaining any residual nitrates after harvest that may raise the leaf nitrogen levels.

In mango leaves, insoluble nitrogen, total nitrogen content was high in the flowered branches but the soluble nitrogen and carbohydrates to nitrogen ratio was high in the non flowering branches (Devi and Tyogi, 1991). This accounts for greater carbohydrate accumulation ready for flowering in the next season.

According to Davie *et al*. (1999), problems associated with mango fruit production may be due to the inability of tree to supply sufficient carbohydrates from current photosynthate production, to meet the heavy fruit load demand. The starch reserves remain at their lowest levels during the period of rapid fruit growth.

Starch levels will start to accumulate during the summer flush upto flowering. Thereafter, levels will decline but starch is used to fuel the mango flowering, fruit set and growth (Robbertse and Wolstenholme, 1992).

In mango cvs. Peach, Zill, Kent in Nkwalini valley, starch increased to the pre dormancy peak by May and due to early drought, stress induced flowering concentration reduced to 8 per cent in June in the cv. Peach. Starch concentration during November – January period decreased abruptly than other cultivars (Robbertse and Wolstenholme, 1993). Two peaks in reserve carbohydrates were found i.e., at the beginning of winter tree dormancy and another just after the start of spring, prior to fruit growth. Carbohydrate levels declined gradually during fruit growth and then measure during summer upto a pre dormancy peak.

Low starch reserves in avocado were correlated with lower flowering intensity, fruit set and yield (Van derWalt *et al*., 1993).

Barooah (2004) opined that in fruit plants, nitrogen and carbohydrate reserves play an important role in flower bud initiation. The accumulation of these compounds

may create favourable conditions for the synthesis, action of substances responsible for the floral induction.

Fruit yield of tree crops are determined primarily by the flowering intensity and subsequent fruit set. But climatic conditions, bud age, lack of pollination, competition for carbohydrate /nutrients can lead to physiological drop (Albrigo and Sauco, 2004).

2.5 Photosynthesis and other related attributes

Suryanarayana (1978) observed increased accumulation of starch during the flower bud formation.

According to Vu *et al*. (1986) the minimum values of stomatal conductance in the fully expanded leaves of orange were 0.03 -0.04 cm /sec at low irradiance and the maximum values were 0.25 – 0.29 cm /sec. The field portable closed gas exchange photosynthesis system (LICOR LI-6000) was used to measure the gas exchange of citrus leaves under the ambient oxygen and carbon dioxide concentrations and at naturally occurring solar –irradiance.

Durand (1997) studied the effects of light availability on the architecture in canopy of mango (*Mangifera indica* L) cultivar Manzana trees and concluded that if the tree growth is managed to facilitate light penetration in the canopy, the photosynthetic activity during the fruit growth period might be augmented to increase yield.

Nir *et al.* (1997) opined that chilly nights causes the reduction of carbon dioxide uptake capacity and stomatal conductance in mango trees.

Whiley and Schaffer (1997) reported that in the non cold stressed field grown mango trees, the leaf starch concentration is 14 + 0.03 mg/g.

Davie *et al.* (1999) opined that the problem associated with the mango fruit production is due to the insufficient carbohydrate reserves in the tree structures or the inability of the tree to supply sufficient carbohydrate from the current photosynthate production to meet the demand of heavy fruit load.

In mango cv. Totapuri (regular) and an irregular cv. Langra, photosynthetic rate and stomatal conductance were higher in the non flowering branches compared to the flowering ones. In the regular cv. all the photosynthetic characters of flowering branches were found superior significantly. In the cv. Langra and Totapuri, the saturated photosynthetic rate (μ mol CO_2/m/sec) found was 11, 44.50 and 23.50, 44 for flowering, non- flowering stages respectively (Shivasankara and Mathai, 2000).

Le Roux *et al.* (2001) concluded that the amount of carbohydrate supplied to tree fruits depends upon the amount produced by leaf photosynthesis, which is related to the leaf area and the photosynthetic capacity.

The calculated gross photosynthesis of mango leaves was higher at the flowering stage than at the vegetative stage (Le Thanh-Phong *et al*., 2002). But the photosynthetically active radiation (PAR) and quantum yield of 'Cat Hoa Loc' mango leaves at both stages did not reach light saturation point.

Urban *et al.* (2003) reported that in the presence of fruits, an increase of the photosynthetic capacity of leaves and the amount of leaf nitrogen per unit leaf area increase was observed. According to him, a robust relationship exists between leaf photosynthetic capacity and the total amount of nitrogen per unit leaf area. The presence of developing fruits have positive effect on the nitrogen concentration. The leaf to fruit ratio has a negative effect on the nitrogen concentration per unit area by reducing the leaf nitrogen concentration per unit mass but mass to area ratio constant.

Urban *et al*. (2003) observed that before mango floral bud break in June, stomatal conductance was lower, even lower in August at the beginning of the floral period and

lowest in September at end of the floral period. The amount of nitrogen per unit leaf area, non structural carbohydrate concentration were lower and higher respectively in the low fruit load than in the high fruit load treatment i.e., carbohydrate content may become the driving the driving force behind the photosynthetic acclimation to changing source-sink relationships., like ones resulting from the presence of developing fruits. Urban *et al.* (2003) reported that in peach and Citrus, leaf nitrogen concentration was lower in the fruiting trees than in the non fruiting ones.

Urban *et al.* (2004) opined that the leaves close to inflorescence had lower photosynthetic rate and stomatal conductance than the leaves on the vegetative shoot.

Hegele *et al.* (2004) observed that the treatment of chemicals like morphactin reduces the photosynthesis, transpiration and stomatal conductance of mango trees for atleast two weeks. In Nam Dok Mai mango, after paclobutrazol application, total non structural carbohydrate changed within the shoots (Phavaphutanon *et al*., 2004).

According to Urban and Lechaudler (2005) leaf nitrogen per unit leaf area in eleven year old mango trees was negatively correlated to leaf to fruit ratio. The difference in nitrogen per unit leaf area were reflected in the difference in net photosynthetic assimilation.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present set of experiments on **'Flower bud forcing in humid tropic mangoes using dormancy breakers'** was carried out during March, 2006 to April, 2007 on 20 year old mango trees of cultivars., Muvandan and Priyor planted in the Central Fruit Orchard attached to the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur. The orchard is located at an altitude of 22.25 metres above msl at $10^{o}32`$ North latitude and $76^{o}16`$East longitude with warm humid tropical climate. Weather data for the period is furnished as appendix 1.

The experiments were taken up with the object of studying the effect of different dormancy breakers (Nitrate and other chemical sprays) on flower bud forcing in mango under the humid tropic south-west coast conditions of Kerala. The selected trees were managed under the normal cultural practices.

3.1 Studies on phenological growth stages of shoots:-

History of the growth of the shoots which were sprayed later with chemicals was studied by tagging the shoots at the bud stage, during March 2006.

3.1.1 Duration of flushing

The mean number of days taken for flushing and shoot growth were recorded in all the tagged shoots.

3.1.2 Shoot extension growth

The tagged buds which showed the signs of flushing and growth were observed and the extension growth was expressed in centimeters, during weekly intervals.

3.1.3 Number of leaves

The number of leaves emerging along with the shoot extension growth in some of the tagged buds and those coming out in the mixed panicles were counted and recorded at weekly intervals.

3.2 Floral induction using dormancy breakers

The experiment was laid out in a completely randomized design with 3 replications and nine treatments. Ninety shoots were tagged, selected and treatments were imposed by using an atomizer and spraying to a run off stage at 8 to 10 am. The sprayings were undertaken during October 2006 (6 month stage) and December 2006 (8 month stage) after tagging (Plate 1). A follow up spray of panicles was taken up at flowering during the last week of December 2006.

The treatment details are furnished below.

	Chemicals	
T_1	Potassium nitrate	1.00%
T_2	Potassium nitrate	2.00%
T_3	Combination spray	
	Potassium nitrate	0.25%
	Boric acid	0.40%
	Ferrous sulphate	0.60%
	Sodium molybdate	0.80%
	Zinc sulphate	0.06%
T_4	Ammonium nitrate	0.50%
T_5	Ammonium nitrate	1.00%

Plate 1. Spray application of chemicals

T_6	Combination spray	
	Ammonium nitrate	0.25%
	Boric acid	0.40%
	Ferrous sulphate	0.60%
	Sodium molybdate	0.80%
	Zinc sulphate	0.06%
T_7	Thiourea	0.50%
T_8	Thiourea	1.00%
T_9	Control	

3.3 Post spraying observations

3.3.1 Time taken for panicle emergence

The time lapse between chemical spraying and panicle emergence was recorded in each treatment in comparison with the control.

3.3.2 Number of inflorescence per tagged shoots

The total number of inflorescence opened out at weekly intervals were recorded.

3.4 Panicle growth measurements

3.4.1 Length of the panicle

Growth of the panicles after opening was recorded by measuring the length from the base to the tip and expressed in centimeters.

3.4.2 Girth of the panicle

The girth of the panicle were recorded at the broadest point and expressed in centimeters.

3.4.3 Number of branches per panicle

The number of branches per panicle were recorded at weekly intervals.

3.5 Biochemical studies

3.5.1 Total carbohydrates

Total carbohydrates of leaves and shoots of the both cultivars were analysed, before the treatment application and at the panicle emerged out stage. Mature shoot and leaf samples were collected freshly from the trees. Analysis was carried out using anthrone reagent as per Sadasivam and Manickam (1991) and expressed in per cent.

The amount of carbohydrate present (%)

$$= \frac{\text{Optical Density (sample) x Standard concentration x Total volume x 1}}{\text{Optical Density (Standard) x Volume taken x Sample weight}}$$

3.5.2 Organic nitrogen

Organic nitrogen content in the leaves and shoots of both the cvs. was analysed, before the treatment application and at the panicle emerged out stage. The analysis was performed using the micro kjeldhal digestion method (Jackson, 1958).

$$\text{Nitrogen content (\%)} = \frac{(0.02 \times \text{Titre value} \times 0.014 \times 100 \times 1 \times 100)}{0.5 \times 10}$$

3.6 Measurements on leaf photosynthesis and other physiological parameters

The physiological parameters were measured using LI-6400, LI-COR Portable photosynthesis system (Version 5, Lincoln, Nebraska).

Equipment

The LI-6400 is LI-COR's third generation gas exchange system. The LI-6400 is an open system, which means that measurements of photosynthesis and transpiration are based on the differences in CO_2 and H_20 in an air stream that is flowing through the leaf cuvette.

The system components

The standard parts are listed below

1. Console
2. Sensor head / IRGA- It includes a leaf chamber, handle, coolers and gas analyzers.
3. Cable assembly- It has electrical cables and air flow hoses and connects the console to the sensor head / IRGA.
4. Chemical tubes – During operation, these tubes are used to remove CO_2 and water vapour from the incoming air stream.
5. Rechargeable batteries
6. CO_2 cartridge holder and regulator
7. 2 x 3 chamber

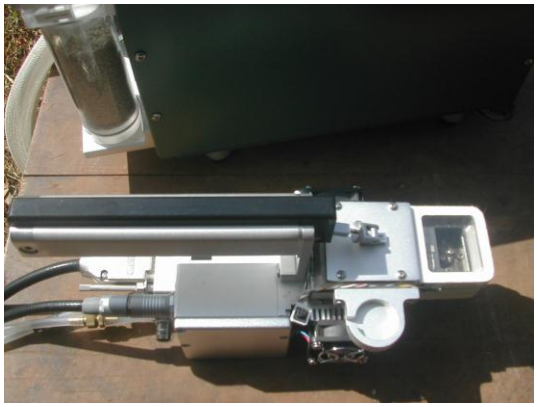
(Plate.2)

Measurements taken:

1. Photosynthetic rate (µ mol CO_2 /m/sec)
2. Conductance to water (mol H_2O /m/sec)
3. Transpiration rate (m mol H_2O /m/sec)
4. Vapour pressure deficit (k Pa)
5. Temperature in sample cell (^0C)
6. Temperature in leaf thermocouple (^0C)

Console

Chemical tubes



Sensor head

Observation recorded during the fruit development stage

Plate 2. The LI-6400 portable photosynthesis system

The recording was undertaken during the morning sunshine hours (from 9 am to 10:30 am) on tagged mature leaves during the flower opening stage (75% anthesis) and the initial fruit development stage (Marble stage).

3.7 Floral characters

The number of hermaphrodite and male flowers opened per panicle were recorded.

3.7.1 Sex ratio

The number of hermaphrodite and male flowers per panicle, opened in definite days were accounted and mean sex ratio worked out.

$$\text{Sex ratio (\%)} = \frac{\text{(The number of hermaphrodite flowers x 100)}}{\text{Total number of flowers}}$$

3.8 Fruit growth and development

The fruit development was studied by recording the length and girth of individual fruits at weekly intervals. The numbers of fruits carried to final maturity for harvest were also accounted.

3.9 Statistical analysis

The experiments were performed in a completely randomized design. The data in the different aspects were analysed using the analysis of variance technique (1-way ANOVA) M-STAT C Package.

RESULTS

4. RESULTS

The results generated from the present set of investigations on **'Flower bud forcing in humid tropic mangoes using dormancy breakers'** are presented below.

4.1 Assessment of flushing phenology of the cultivars and history of the shoots prior to treatments with dormancy breaking chemicals

A flush in mango as mentioned here under can be designated as the initiation of shoot growth from a group of stems borne on linked branches. Flushing phenology was monitored during this investigation to get a history of the shoots on which the application of chemicals was taken up later.

4.1.1 Pattern of flush growth

The flush growth pattern was studied by taking the observations at weekly intervals. In both the cvs., flushing was found to commence from the second week of September 2006 onwards. The mean duration of flushing i.e., opening out of the buds, its subsequent growth with opened young leaves transforming ultimately to mature dark green leaves is furnished along with the extent of flushing noted in the tagged shoots selected on different trees of both cvs. is presented in Table 1.

In the cv. Muvandan, the flush growth emerged as light green bud, remained as light green and gradually maturing into dark green leaves thereafter (Plate 3).

In the cv. Priyor, the vegetative bud emerged as light green, remained as light green and gradually maturing into dark green leaves thereafter within 14 days (Plate 4).

Table 1. Duration of flushing (days) and flushing (%)

Treat-ment	Duration in cv. Muvandan	Duration (days)	Flushing (%)	Duration in cv. Priyor	Duration (days)	Flushing (%)
T_1	Sep.12 to Dec.4	82	80	Sep.20 to Dec.11	81	75
T_2	Sep.11 to Dec.25	104	50	Sep.20 to Dec.11	81	78
T_3	Sep.12 to Dec.4	82	45	Sep.21 to Dec.18	87	50
T_4	Sep.13 to Jan.1	108	85	Sep.20 to Dec.11	81	55
T_5	Sep.12 to Dec.24	102	80	Sep.21 to Dec 18	87	70
T_6	Sep.11 to Dec.11	90	90	Sep.21 to Dec 18	87	75
T_7	Sep.13 to Jan.1	108	80	Sep.25 to Feb.24	149	80
T_8	Sep.11 to Dec.25	104	73	Sep.25 to Feb 21	146	60
T_9	Sep.12 to Jan.15	123	70	Sep.24 to Dec.25	91	65

The flush length was measured at weekly intervals, in both the cultivars from the bud opening stage to the final stage when the leaves changed into dark green colour. The inter-calary unit length was arrived at by summing up the weekly incremental length (Tables 2 and 4).

In the cv. Muvandan, the inter-calary unit length (Flush length) ranged from 3.73 cm to 15.7 cm. In the cv. Priyor, inter-calary unit length ranged from 5.27 cm to 14.1cm.

In the cv. Muvandan, the intercalary unit girth ranged from 1.53 cm to 2.29 cm. In the cv. Priyor, the girth ranged from 1.63 cm to 2.33 cm. The intercalary unit girth at weekly intervals has been furnished in Tables 3 and 5.

The total number of leaves produced per intercalary unit in the cv. Muvandan ranged from 10.00 to 16.00 whereas 9.00 to 16.00 in the cv. Priyor (Table 6 and 7).

The mean internodal length in the cv. Muvandan ranged from 0.37 cm to 0.98 cm and that in the cv. Priyor in between 0.58 cm to 0.88 cm.

Table 2. Flush length (cm) recorded at weekly intervals (Phases) in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10	Phase 11	Phase 12
T_1	6.10	7.57	8.73	9.37	9.57	9.70	9.87	10.40	10.90	11.50	12.10	12.80
T_2	0	0	0	0	0	0	0.33	0.87	2.10	2.40	2.93	3.73
T_3	0	0	0.20	0.60	1.50	2.50	3.83	5.20	6.43	7.20	7.93	8.33
T_4	4.87	8.30	9.10	10.8	11.30	12.10	12.50	13.10	13.70	14.20	15.00	15.70
T_5	3.10	3.90	5.10	6.40	8.10	9.60	10.50	11.30	11.80	12.20	12.80	13.50
T_6	0.53	1.37	2.17	2.70	3.20	3.77	4.70	5.10	5.63	6.67	7.40	8.21
T_7	1.37	2.33	4.60	6.27	7.57	8.70	9.30	10.10	10.40	10.90	11.50	12.00
T_8	3.50	5.83	7.37	8.63	9.40	10.80	11.80	12.20	13.20	13.60	14.10	14.50
T_9	0.33	1.60	2.27	3.00	3.53	4.63	5.23	6.27	7.33	8.40	10.00	10.50

Table 3. Flush girth (cm) recorded at weekly intervals (Phases) in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10	Phase 11	Phase 12
T_1	0.40	0.80	1.40	1.63	1.72	1.81	1.86	1.91	2.03	2.20	2.25	2.27
T_2	0	0	0	0	0	0	0.40	0.70	0.90	1.17	1.37	1.53
T_3	0	0	0.31	0.44	0.77	1.20	1.34	1.38	1.44	1.55	1.63	1.70
T_4	0.17	0.43	0.80	1.10	1.31	1.45	1.53	1.62	1.70	1.81	1.84	1.91
T_5	0.57	0.77	1.21	1.36	1.41	1.47	1.53	1.61	1.69	1.77	1.83	1.89
T_6	0	0.61	0.79	0.99	1.10	1.23	1.31	1.42	1.50	1.66	1.78	1.81
T_7	0.14	0.41	0.51	0.68	0.90	1.03	1.34	1.65	1.76	1.87	2.17	2.29
T_8	0.83	1.25	1.35	1.51	1.53	1.60	1.63	1.78	1.88	1.92	2.03	2.10
T_9	0.37	0.60	0.83	0.90	1.03	1.16	1.21	1.31	1.41	1.51	1.61	1.70

Table 4. Flush length (cm) recorded at weekly intervals (Phases) in cv. Priyor

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10	Phase11
T_1	1.03	2.93	4.83	6.00	7.10	8.20	9.10	10.10	11.00	12.10	12.20
T_2	4.37	7.07	8.13	9.10	10.50	11.2	12.10	12.60	13.10	13.70	14.10
T_3	1.70	2.53	2.87	3.10	3.27	3.60	4.30	4.60	5.33	6.10	7.03
T_4	2.13	4.33	5.30	6.10	7.10	8.17	9.17	10.20	11.30	11.50	12.10
T_5	2.00	4.17	5.10	7.17	8.17	9.10	10.00	11.20	12.20	13.10	14.10
T_6	1.43	2.60	3.10	3.60	4.17	4.67	5.20	5.73	6.23	6.80	7.37
T_7	0.50	1.10	1.73	2.30	2.80	3.03	3.43	3.77	4.40	4.90	5.27
T_8	0.20	0.57	1.10	1.77	2.20	2.80	3.30	3.80	4.20	4.60	5.30
T_9	1.40	2.20	2.70	3.17	4.10	4.70	5.20	5.70	6.10	6.57	7.10

Table 5. Flush girth (cm) recorded at weekly intervals (Phases) in cv. Priyor

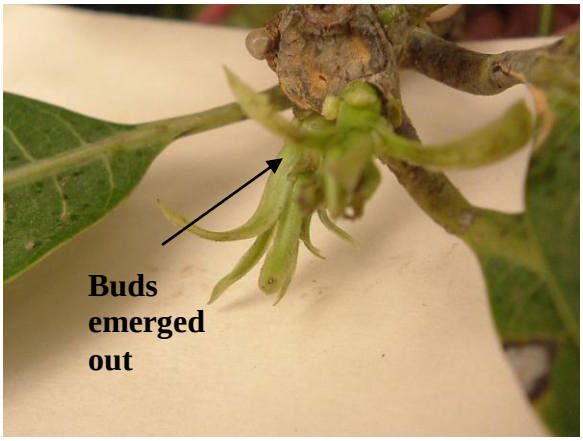
Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10	Phase11
T_1	0.40	0.80	1.00	1.37	1.43	1.47	1.57	1.7	1.87	2.00	2.13
T_2	0.17	0.47	1.00	1.27	1.37	1.43	1.57	1.77	2.00	2.13	2.17
T_3	0.13	0.43	1.07	1.27	1.50	1.77	2.00	2.07	2.17	2.23	2.33
T_4	0.47	1.07	1.27	1.47	1.57	1.67	1.80	2.00	2.10	2.17	2.23
T_5	0.13	0.33	0.53	0.73	0.93	1.07	1.20	1.37	1.53	1.63	1.73
T_6	0.27	0.57	0.77	1.00	1.10	1.17	1.27	1.37	1.47	1.57	1.63
T_7	0.13	0.37	0.67	0.77	0.87	1.03	1.23	1.37	1.53	1.73	1.83
T_8	0.13	0.37	0.67	0.9	1.07	1.23	1.47	1.67	1.77	1.87	2.00
T_9	0.27	0.40	0.67	1.10	1.27	1.33	1.37	1.47	1.67	1.73	1.97

Table 6. Number of leaves per flush in cv. Muvandan

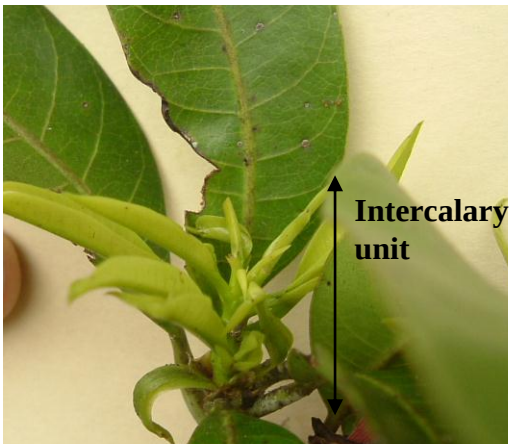
Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
T_1	0	2	6	10	13	14	15	16
T_2	1	3	5	9	10	12	14	15
T_3	0	1	4	7	8	10	12	14
T_4	1	2	5	6	7	9	11	13
T_5	2	4	5	6	7	8	10	12
T_6	1	3	4	5	7	8	10	13
T_7	0	2	5	7	8	9	11	14
T_8	1	3	3	4	5	6	8	10
T_9	1	2	4	5	6	7	9	11

Table 7. Number of leaves per flush in cv. Priyor

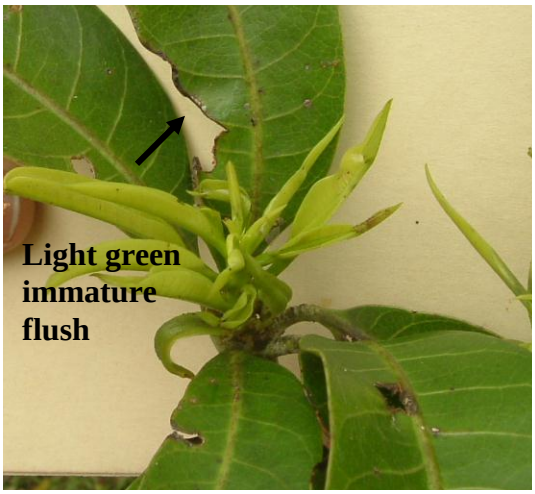
Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
T_1	1	3	5	7	11	12	14	16
T_2	1	2	4	7	9	10	12	14
T_3	0	0	3	5	6	7	8	9
T_4	2	5	6	7	9	11	13	15
T_5	1	3	4	5	7	9	10	11
T_6	0	1	3	5	7	9	11	13
T_7	1	2	5	8	10	12	13	15
T_8	1	3	5	7	9	11	12	14
T_9	1	2	4	5	6	7	8	10



a.



c.



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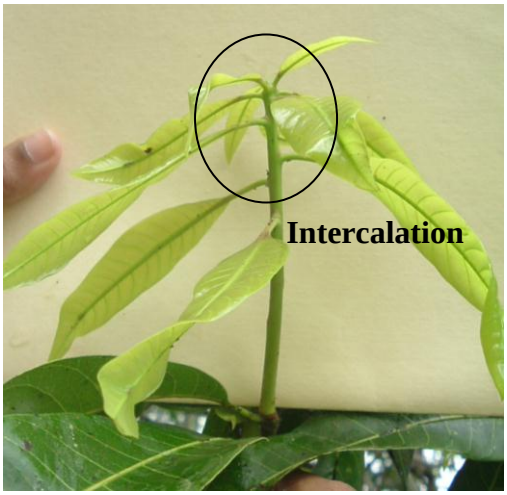


d.

Plate 3. Phenological growth stages during flushing and shoot development in cv. Muvandan

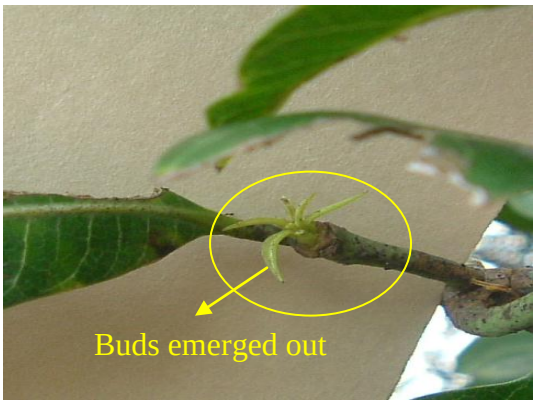
a.

d.

Buds
emerging
out

b.

e.



c.

f.

Plate 4. Phenological growth stages during flushing and shoot development in cv. Priyor

4.2 Application of dormancy breakers and the effect on flower bud forcing in mango cvs. Muvandan and Priyor

The results obtained from the treatments imposed on the trees for flower bud forcing are presented hereunder.

Except for the two sets of treatments namely thiourea 0.5% and 1% imposed on the cv. Priyor, all the other treatments showed a significant positive effect of flowering in both the cultivars.

4.2.1 Time taken for flowering

In both the cvs., treatments induced early flowering compared to the control (Table 8).

Table 8. Time taken (days) for floral bud break in different treatments after second spraying (December 2006)

Treatment	Muvandan	Priyor
T_1	11	10
T_2	20	9
T_3	9	17
T_4	29	11
T_5	21	13
T_6	7	16
T_7	21	0
T_8	17	0
T_9	34	24

The ammonium nitrate combination with micronutrients (T_6) was found significantly superior to all other treatments in the cv. Muvandan, whereas in the cv. Priyor, T_2 and T_1 respectively proved superior with respect to time taken for flowering than the control.

In the cv. Muvandan, the treatment ammonium nitrate combination with micronutrients (T_6), panicle emergence was noted within seven days of spraying whereas in the control it took 34 days to initiate flowering. It took 11 days for T_1 and 20 days for

T_2. T_3 induced the trees for panicle emergence within 9 days after spraying. The results showed 29 days for the panicle emergence in T_4 and 21 days in T_5. The thiourea treatments (T_7 and T_8) recorded 21 days and 17 days respectively for induction of panicle emergence. The panicle emergence was noted only after a time lapse of 34 days in control (T_9).

In the cv. Priyor, the treatments T_1 (Potassium nitrate 1.00%) and T_2 (Potassium nitrate 2.00%) made the shoots to flower within 10 and 9 days respectively. A time lapse of 17 days was found for panicle emergence in T_3) and 11 days in T_4. It took 13 days in T_5 and 16 days in T_6. Both T_7 and T_8 did not make any positive effect on flowering in this cv. But it induced the shoots to put forth vegetative flushes. In comparison with the above treatments, the panicle emergence was noted in the control shoots only after a time lapse of 24 days.

4.2.2 Intensity of flowering (Number of shoots flowered)

The results showed that the treatments with dormancy breaking chemicals induced more number of shoots to flower in both the cvs. The exception noted in this aspect is with respect to the thiourea treatments (T_7 and T_8) in the cv. Priyor, which made the shoots to flush instead of flowering (Table 9).

Table 9. Intensity of flowering (% of shoots flowered) in tagged shoots after spraying in cvs. Muvandan and Priyor

Treatment	Muvandan	Priyor
T_1	57.83^{bc}	77.23^{b}
T_2	45.3^{d}	79.33^{a}
T_3	78.50^{a}	61.58^{c}
T_4	64.16^{b}	59.86^{d}
T_5	53.76^{c}	50.96^{e}
T_6	81.66^{a}	61.51^{c}
T_7	61.36^{bc}	0
T_8	56.40^{c}	0
T_9	42.53^{d}	47.46^{f}

* In each column figures followed by same letter (superscript) do not differ significantly according to DMRT.

In the cv. Muvandan, the treatment ammonium nitrate combination with micronutrients (T_6) was found to be superior i.e., (81.6%) of the tagged shoots was induced to flower, whereas, the control recorded only 42.5 per cent flowering (Plate 5). The treatment T_4 recorded 64.16 per cent flowering, T_7 61.36 per cent flowering, T_8 and T_5 recorded 56.4 per cent and 53.76 per cent respectively. No significant effect was noted in T_2 in which 45.3 per cent of the shoots flowered.

In the cv. Priyor, the T_2 was found to be superior among all the treatments in which 79.33 per cent of the tagged shoots was induced to flower, whereas, in control T_9, only 47.46 per cent of the shoots came to flower (Plate 6).The treatment T_1 was observed as the second most superior recording 77.23 per cent flowering in the tagged shoots.T_3 and T_6 were found to be on par, recording 61.58 per cent and 61.51 per cent respectively. The treatment T_4 recorded 59.86 per cent and the treatment T_5 with 50.96 per cent respectively. None of the shoots in T_7 and T_8 where thiourea treatments were tried put forth inflorescence in this cv. and only vegetative flushing was noted instead.

4.3 Assessment of floral phenology consequent to the treatment imposition

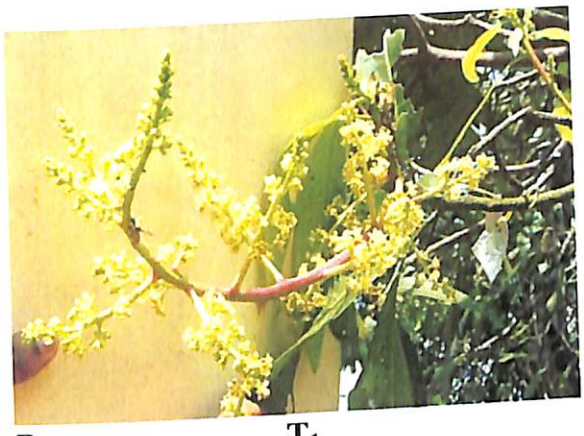
The growth of the inflorescence (panicle) after the emergence consequent to the imposition of different treatments was assessed by taking measurements at weekly intervals, upto the stage of maximum growth (Plates 7 and 8).

4.3.1 Panicle emergence and further growth in cvs. Muvandan and Priyor

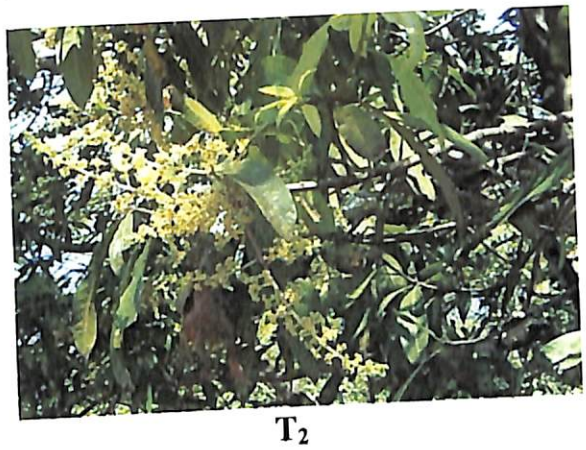
4.3.1.1 Inflorescence length

All the treatments in general were found to enhance the panicle length significantly than the control (Table 10). The maximum growth of inflorescence was noted in T_4 in which the final panicle length was 30.1 cm whereas it was 13.1 cm in the control.T_1 recorded a growth of 19.56 cm, T_2 (24.1 cm), T_3 (27.96 cm), T_5 (28.13 cm), T_6 (12.2 cm),T_7 (19.2 cm) and T_8 (24.7 cm) respectively.

A. Shoots before spray



B. T_1



T_2

T_3

T_4

Plate 5. Effect of different treatments on cv.Muvandan

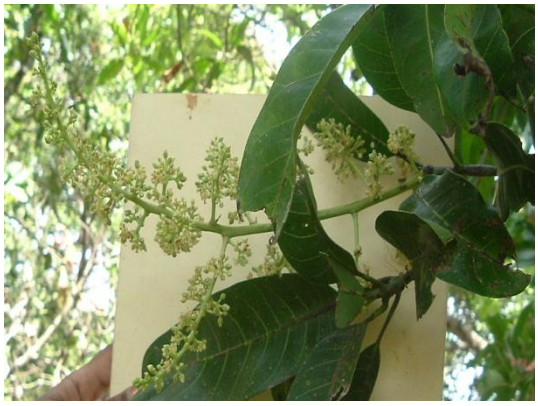
Plate 5 (contd …)

T_5 --NH_4NO_3 1.00%

T_6 -NH_4NO_3 0.25% +micronutrients

T_{7}- Thiourea 0.50%

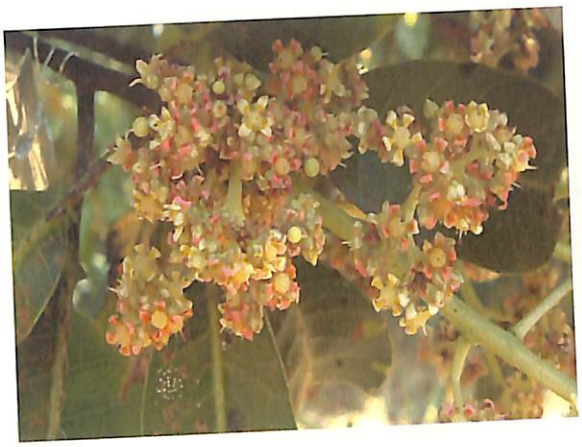
T_{8}- Thiourea 1.00%



T_{9}- Control

A. Shoots before spray
B. Flowering noted in different treatments after spray

A. Shoots before spray



B. T_1

T_2

T_3

T_4

Plate 6. Effect of different treatments on cv. Priyor

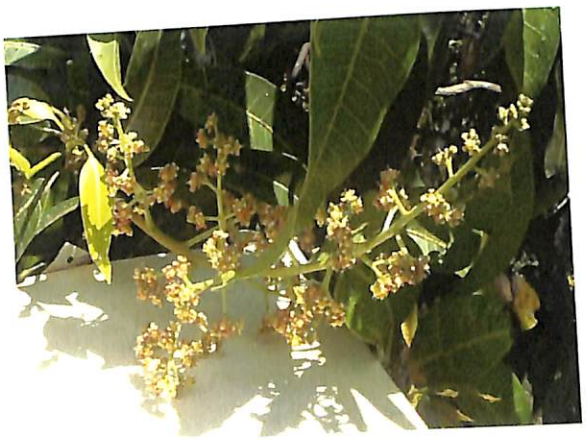
Plate 6 (Contd…)

T_5

T_6

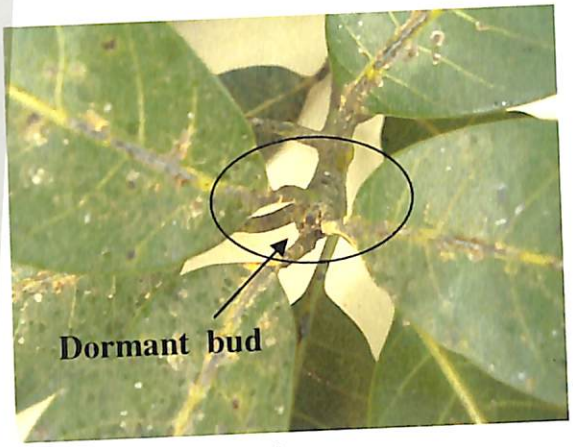
T_7

T_8



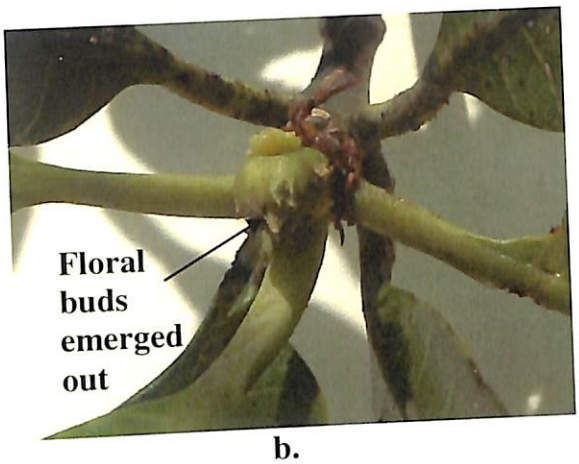
T_9

A. Shoots before spray
B. Flowering noted in different treatments after spraying



a.

d.



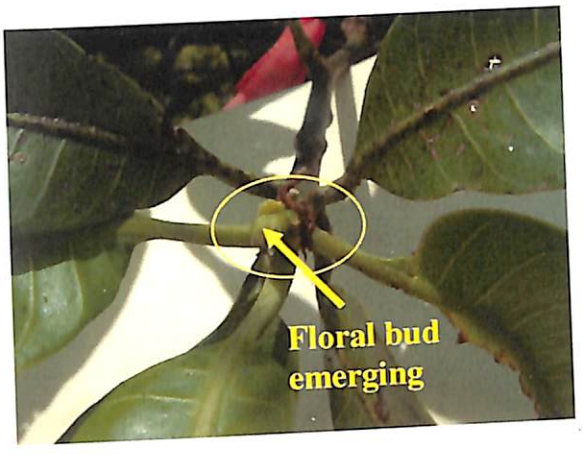
b.

e.

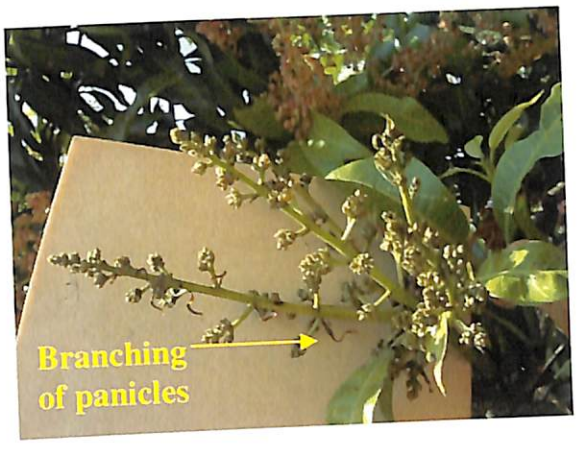
c.

f.

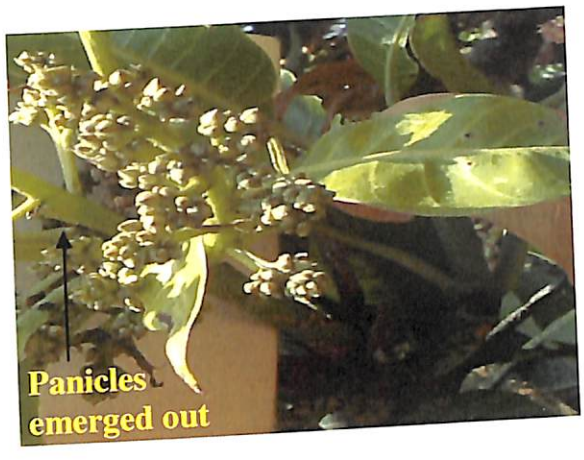
Plate 7. Phenological growth stages during panicle emergence and development in cv. Muvandan



a.



c.



b.

d.

e.

Plate 8. Phenological growth stages during panicle emergence and development in cv. Priyor

In T_3, T_5 and T_6, the panicle emergence and further growth took place at a much earlier phase than the other treatments. The emergence of mixed inflorescence was also noted at random (5-10 %) in the treatments T_3, T_4 and T_6 (Plate 9).

In cv. Priyor, all the treatments except T_7 and T_8 were found to enhance the panicle length significantly than the control (Table 12). The maximum growth of inflorescence was noted in T_6 where the final panicle length was 32.7 cm whereas it was 22.2 cm in the control.T_1 recorded a growth of 31.2 cm, T_2 with 29.63 cm, T_3 and T_4 were found to be on par (27.36 cm). In T_7 and T_8, panicle emergence was absent but remained vegetative.

In addition to the normal panicle development, the emergence of mixed inflorescence was also noted at random (less than 5%) in the treatments T_3 and T_4. These mixed shoots were found to develop both leaves and primary pedunculate inflorescences from the same node (Plate 10).

4.3.1.2 Inflorescence girth

In the cv. Muvandan, all the treatments in general were found to enhance the panicle girth significantly than the control (Table 11). The girth of the inflorescence was maximum in T_4 (2.4 cm), but it was only 1.36 cm in the control T_9. T_1 recorded a girth of 2.1 cm, T_5 (1.85 cm), T_7 (1.46 cm), T_8 (1.9 cm). T_2 and T_3 were on par with an inflorescence girth of 2.06 cm.

In the cv. Priyor, all the treatments in general were found to enhance the panicle girth significantly than the control (Table 13). The maximum inflorescence girth was noted in T_6 where girth was 2.03 cm whereas it was 1.43 cm in the control.T_1 recorded a girth of 1.60 cm, T_2 (2.10 cm), T_3 (1.7 cm), T_4 (1.8 cm) and T_5 (1.5 cm). In the treatments T_7 and T_8, no panicles were noted.

Table 10. Inflorescence length (cm) recorded in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
T_1	2.26^{c}	8.9^{c}	12.20^{c}	17.53^{c}	18.30^{b}	18.80^{a}	19.56^{b}
T_2	0^{d}	0^{f}	0^{g}	7.70^{f}	15.43^{bc}	24.10^{a}	0^{c}
T_3	7.20^{a}	13.93^{a}	18.06^{a}	27.96^{a}	0^{d}	0^{b}	0^{c}
T_4	0^{d}	0^{f}	0^{g}	0^{g}	12.76^{c}	24.70^{a}	30.10^{a}
T_5	3.16^{c}	11.70^{b}	16.10^{b}	21.10^{b}	28.13^{a}	0^{b}	0^{c}
T_6	5.33^{b}	7.26^{d}	9.10^{d}	12.20^{de}	0^{d}	0^{b}	0^{c}
T_7	0^{d}	1.70^{e}	4.70^{f}	10.70^{e}	13.70^{bc}	16.70^{a}	19.20^{b}
T_8	0^{d}	2.73e	7.70^{e}	13.70^{d}	18.73^{b}	24.70^{a}	0^{c}
T_9	0^{d}	0^{f}	0^{g}	0^{g}	2.030^{d}	6.83^{b}	13.10^{b}

Table 11. Inflorescence girth (cm) recorded in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
T_1	0^{b}	0.80^{b}	1.36^{b}	1.66^{b}	2.00a	2.10^{a}	0^{d}
T_2	0^{b}	0^{e}	0^{f}	1.1^{e}	2.06^{a}	0^{e}	0^{d}
T_3	0^{b}	0.76^{bc}	1.40^{b}	2.06^{a}	0^{f}	0^{e}	0^{d}
T_4	0^{b}	0^{e}	0^{f}	0^{f}	1.13^{d}	1.73^{c}	2.40^{a}
T_5	0.86^{a}	0.66^{c}	1.06^{d}	1.26^{d}	1.80^{b}	0^{c}	0^{d}
T_6	0^{b}	1.60^{a}	1.86^{a}	2.06^{a}	0^{f}	0^{e}	0^{d}
T_7	0^{b}	0.16^{d}	0.56^{e}	0.73^{f}	1.06^{d}	1.30^{d}	1.46^{b}
T_8	0^{b}	0.66^{c}	1.16^{c}	1.46^{c}	1.63^{c}	1.90^{b}	0^{d}
T_9	0^{b}	0^{e}	0^{f}	0^{g}	0.86^{e}	1.16^{d}	1.36^{c}

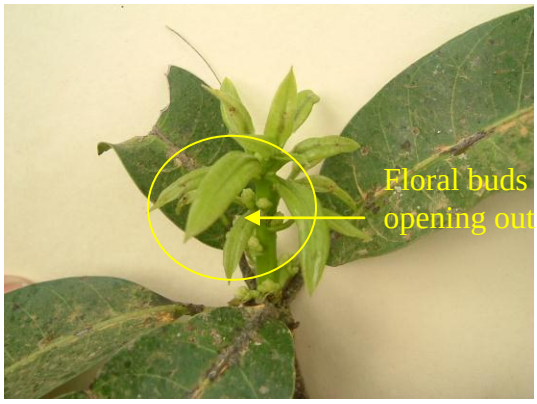
Table 12. Inflorescence length (cm) recorded in cv. Priyor

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
T_1	0^{c}	3.50^{cd}	7.46^{c}	9.73^{cd}	12.83^{c}	31.20^{a}	0^{d}
T_2	1.66^{b}	4.36^{c}	9.33^{b}	15.76^{b}	25.53^{a}	29.63^{a}	0^{d}
T_3	0^{c}	3.00^{cde}	5.46^{d}	8.46^{d}	11.93^{a}	23.06^{b}	27.36^{b}
T_4	2.70^{a}	6.33^{b}	11.93^{a}	18.96^{a}	20.76^{a}	23.30^{b}	27.30^{b}
T_5	0^{c}	1.86^{e}	3.33^{e}	6.06^{e}	14.20^{c}	23.73^{b}	0^{d}
T_6	0^{c}	9.20^{f}	13.20^{a}	19.20^{a}	23.70^{ab}	28.86^{a}	32.70^{a}
T_7	0	0	0	0	0	0	0
T_8	0	0	0	0	0	0	0
T_9	0^{c}	2.43^{de}	7.46^{c}	11.20^{c}	15.56^{c}	19.26^{c}	22.20^{c}

Table 13. Inflorescence girth (cm) recorded in cv. Priyor

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
T_1	0^{b}	0.4^{c}	0.96^{b}	1.20^{b}	1.36^{bc}	1.60^{b}	0^{d}
T_2	0^{b}	0.96^{a}	1.36^{a}	1.60^{a}	1.83^{a}	2.10^{a}	0^{d}
T_3	0^{b}	0.40^{c}	0.80^{c}	1.10^{b}	1.26^{cd}	1.50^{b}	1.70^{b}
T_4	0.50^{a}	0.76^{b}	1.06^{b}	1.23^{b}	1.43^{b}	1.63^{b}	1.80^{b}
T_5	0.50^{a}	0.30^{c}	0.56^{d}	0.90^{c}	1.20^{d}	1.50^{b}	0^{d}
T_6	0.50^{a}	0.40^{c}	0.80^{c}	1.13^{b}	1.30^{cd}	1.60^{b}	2.03^{a}
T_7	0	0	0	0	0	0	0
T_8	0	0	0	0	0	0	0
T_9	0^{b}	0^{d}	0.30^{e}	0.56^{d}	0.83^{e}	1.10^{c}	1.43^{c}

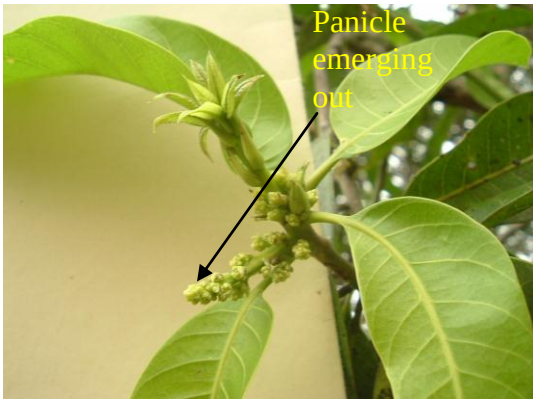
T_3



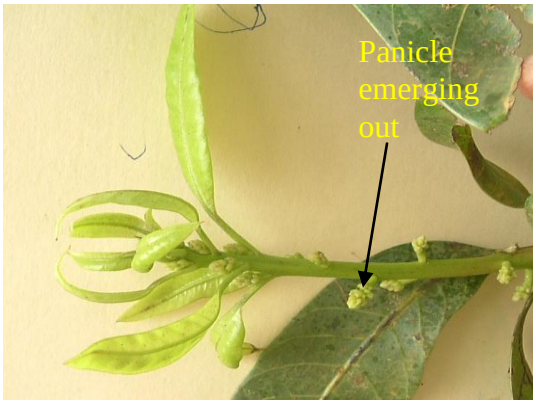
T_6

T_3

T_6



T_4



T_6

Plate 9. Development of mixed panicles in treated shoots in cv. Muvandan

T_3

T_4

T_3

T_4

Plate 10. Development of mixed panicles in treated shoots in cv. Priyor

4.3.1.3 Number of branches per panicle

In the cv. Muvandan, all the treatments except T_4 in general were found to enhance the number of branches per panicle significantly than the control (Table 14). The maximum number of branches per panicle was noted in T_5 with 25 branches per panicle whereas it was 11.66 in the control. The values recorded in other treatments were T_1 (20.33), T_2 (19), T_3 (19.66), T_4 (9.33), T_6 (20.30), T_7 (13.33) and T_8 (21).

In the cv. Priyor, all the treatments except T_6 were found to enhance the number of branches per panicle significantly than the control (Table 15). Maximum branching per panicle was noted in T_4 with 31.66 whereas it was lowest in T_6 with 13.66. T_9 recorded 14.33, T_1, 18.66, T_2, 18, T_3, 18.66 and T_5, 26 branches per panicle respectively. In treatments T_7 and T_8, panicle emergence was not noted and vegetative flushing was observed (Plate 11).

4.3.2 Sex ratio of flowers as influenced by treatments

Sex ratio was arrived at on the selected panicles of different treatments, by counting the number of bisexual flowers and male flowers opened at different intervals during the course of the inflorescence opening. This was done with the object of assessing the impact of different treatment combinations on the production of bisexual flowers (productive flowers) and its ultimate effect on yield. The results are presented in Tables 16 and 17.

The observations showed that the treatments exerted a significant effect on the sex ratio. In the cv. Muvandan, the sex ratio was recorded from the commencing week of flower opening in the selected panicles. T_6 recorded the highest mean sex ratio (50.05%) among the treatments; whereas the control recorded the lowest value (23.92%).The mean sex ratio noted in all the other treatments was also significantly superior than the control.

In the cv. Priyor also, the treatments had a profound influence on the production of bisexual flowers. Among the treatments, T_2 recorded the highest value (54.52%),

Table 14. Number of branches per panicle in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
T_1	0^{b}	6.33^{d}	7.66^{d}	10.66^{d}	14.00^{d}	20.33^{a}	0^{d}
T_2	0^{b}	0^{g}	0^{f}	11.33^{c}	19.00^{b}	0^{d}	0^{d}
T_3	0^{b}	9^{c}	11.66^{c}	19.66^{a}	0^{g}	0^{d}	0^{d}
T_4	0^{b}	0^{g}	0^{f}	0^{e}	2.00^{f}	5.33^{c}	9.33^{c}
T_5	0^{b}	3.66^{e}	8.66^{d}	16.33^{b}	25.00^{a}	0^{d}	0^{d}
T_6	11.66^{a}	14.00^{a}	16.00^{a}	20.33^{a}	0^{g}	0^{d}	0^{d}
T_7	0^{b}	1.33^{f}	2.00^{e}	3.33^{d}	7.33e	9.33^{b}	13.33^{a}
T_8	0^{b}	12.33^{b}	13.66^{b}	14.66^{b}	16.66^{c}	21.00^{a}	0^{d}
T_9	0^{b}	0^{g}	0^{f}	3.33^{d}	6.33^{e}	10.00^{b}	11.66^{b}

Table 15. Number of branches per panicle in cv. Priyor

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
T_1	0^{b}	2.66^{bc}	6.33^{b}	10.00^{b}	15.66^{b}	18.66^{b}	0^{d}
T_2	0^{b}	4.33^{a}	8.66^{a}	14.66^{a}	17.33^{b}	18.00^{b}	0^{d}
T_3	0^{b}	2.33^{c}	3.66^{c}	6.00^{c}	12.00^{c}	18.00^{b}	18.66^{b}
T_4	2.00^{a}	4.33^{a}	7.66^{ab}	11.66^{b}	22.33^{a}	27.00^{a}	31.66^{a}
T_5	0^{b}	3.33^{ab}	6.66^{b}	11.66^{b}	23.33^{a}	26.00^{a}	0^{d}
T_6	0^{b}	4.00^{a}	7.00^{b}	10.00^{b}	11.66^{c}	12.66^{c}	13.66^{c}
T_7	0	0	0	0	0	0	0
T_8	0	0	0	0	0	0	0
T_9	0^{b}	0^{d}	2.33^{d}	6.00^{c}	8.00^{d}	12.66^{c}	14.33^{c}

Table 16. Sex ratio (%) recorded in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Mean
T_1	12.36^{c}	64.96^{a}	35.87^{ab}	53.03^{a}	46.43^{a}	49.43^{a}	43.67
T_2	23.36^{abc}	27.33^{bc}	27.89^{ab}	28.56^{ab}	29.76^{a}	52.50^{a}	31.57
T_3	45.36^{a}	54.86^{ab}	42.22a	49.4^{ab}	39.10^{a}	43.03^{a}	45.66
T_4	23.66^{abc}	23.91^{bc}	21.01ab	22.21^{ab}	46.20^{a}	35.66^{a}	28.78
T_5	26.63^{abc}	28.04^{bc}	36.66^{ab}	31.66^{ab}	37.92^{a}	28.25^{a}	31.53
T_6	43.76^{ab}	35.13^{abc}	46.06^{a}	54.03^{a}	50.63^{a}	70.70^{a}	50.05
T_7	19.13^{c}	21.30^{c}	32.40^{ab}	36.40^{ab}	36.33^{a}	35.66^{a}	30.20
T_8	20.73^{bc}	27.63^{bc}	22.73^{ab}	35.26^{ab}	28.06^{a}	37.20^{a}	28.60
T_9	27.53^{abc}	37.83^{abc}	7.82^{b}	15.71^{b}	25.55^{a}	29.10^{a}	23.92

Table 17. Sex ratio (%) recorded in cv. Priyor

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Mean
T_1	60.68^{a}	45.84^{ab}	28.77^{a}	77.13^{a}	45.43^{a}	18.10^{b}	45.99
T_2	41.50^{a}	82.36^{a}	39.23^{a}	62.40^{ab}	46.56^{a}	55.06^{a}	54.52
T_3	58.97^{a}	35.09^{b}	35.62^{a}	41.00^{bc}	35.46^{a}	62.23^{a}	44.73
T_4	33.06^{a}	22.16^{b}	26.96^{a}	47.76^{bc}	24.23^{a}	39.36^{ab}	32.26
T_5	50.53^{a}	25.44^{b}	18.70^{a}	63.03^{ab}	26.17^{a}	17.66^{b}	33.59
T_6	21.68^{a}	25.13^{b}	33.2^{a}	33.3^{cd}	32.46^{a}	21.83^{b}	27.93
T_7	0	0	0	0	0	0	0
T_8	0	0	0	0	0	0	0
T_9	34.23^{a}	26.66^{b}	20.14^{a}	17.73^{d}	41.55^{a}	33.13^{b}	28.91

a. Purely vegetative shoot (Complete vegetative induction)

b. Mixed shoot (Partial floral induction)

c. Purely generative shoot (Complete floral induction)

Plate 11. Degree of induction as noted in shoots

whereas in the control, it was only 28.91 per cent. The mean values for the other treatments except T_7 and T_8 were also significantly higher than that in the control.

4.4 Fruit growth and development

Measurements on the fruit growth in both the cvs. during the different developmental stages were carefully recorded by noting the fruit length and fruit girth, using a twine and a 'centimetre' scale. The results are furnished in the Tables 18 to 21.

4.4.1 Fruit length

In the cv. Muvandan, all the treatments were found to significantly enhance the length of the fruits than the control. The final fruit length at the pre harvest stage was 11.36 cm in T_3 whereas it was 9.13 cm in the control.T_7 recorded 11.26 cm., T_2 (10.63 cm); T_6 (10.50 cm); T_4 (10.33 cm); T_5 (9.73 cm) and T_1 (9.23 cm) respectively.

In the cv. Priyor, not much significant effect was noted by the treatments with respect to the final fruit length at the pre harvest stage.

4.4.2 Fruit girth

All the treatments except T_7 and T_8 in the cv. Priyor were found to significantly enhance the fruit girth than the control. The results are furnished in the Tables 20 and 21.

In the cv. Muvandan, the treatment T_8 recorded a maximum fruit girth of 20.25 cm at the harvest stage whereas only 15.18 cm in the control T_9.The fruit girth recorded at the pre harvest stage was 19.08 cm in T_3; 19.05 in T_2, 18.87 cm in T_4; 18.70 cm in T_7, 17.94 cm in T_6, 17.20 cm in T_1 and 17.95 cm in T_5 respectively.

Table 18. Fruit length (cm) noted in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10	Phase 11
T_1	0^{c}	1.03^{c}	2.03^{c}	2.96^{c}	3.96^{d}	5.00^{d}	6.10^{c}	6.50^{d}	7.86^{d}	8.33^{cd}	9.23^{d}
T_2	1.03^{b}	1.96^{b}	3^{b}	3.90^{b}	4.90^{e}	6.70^{b}	8.16^{a}	9.43^{a}	10.00^{abc}	10.46^{a}	10.63^{b}
T_3	1.76^{a}	3.46^{a}	4.80^{a}	5.76^{a}	6.93^{a}	7.53^{a}	8.10^{a}	8.80^{b}	9.53^{c}	10.50^{a}	11.36^{a}
T_4	0^{c}	0^{d}	0.36^{d}	1.00^{d}	2.00^{e}	3.10^{e}	4.93^{d}	5.26^{f}	5.53^{e}	8.86^{bc}	10.33^{b}
T_5	0^{c}	0^{d}	0^{d}	0.70^{d}	1.53^{f}	2.00^{f}	2.40^{e}	2.66^{g}	3.03^{f}	6.90^{f}	9.73^{c}
T_6	1.00^{b}	2.13^{b}	3.00^{b}	4.00^{b}	5.00^{e}	6.00^{c}	6.93^{b}	8.13^{c}	9.46^{c}	10.20^{ab}	10.50^{b}
T_7	0^{c}	0^{d}	1.86^{c}	3.00^{c}	4.53^{e}	6.70^{b}	7.96^{a}	9.03^{ab}	10.03^{a}	10.80^{a}	11.26^{a}
T_8	0^{c}	1.03^{c}	2.73^{b}	4.00^{b}	5.50^{b}	7.00^{b}	7.90^{a}	9.10^{ab}	10.26^{a}	10.90^{a}	11.20^{a}
T_9	0^{c}	0^{d}	0^{d}	0^{e}	1.20^{f}	3.03^{e}	4.86^{d}	6.13^{e}	7.50^{d}	7.96^{ef}	9.13^{d}

Table 19. Fruit length (cm) noted in cv. Priyor

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10
T_1	1.90^{a}	4.43^{a}	5.20^{a}	5.83^{b}	7.03^{a}	8.20^{b}	8.70^{b}	10.06^{b}	11.00^{b}	11.66^{b}
T_2	0^{b}	0^{b}	4.33^{ab}	7.06^{a}	7.70^{a}	8.70^{a}	10.06^{a}	11.03^{a}	11.50^{a}	12.00^{a}
T_3	0^{b}	0^{b}	0^{d}	3.33^{d}	4.46^{c}	6.10^{c}	7.13^{d}	8.26^{e}	10.23^{c}	11.00^{d}
T_4	0^{b}	0^{b}	0^{d}	7.03^{a}	7.66^{a}	8.26^{ab}	8.60^{b}	9.43^{c}	9.80^{d}	10.36^{e}
T_5	0^{b}	0^{b}	2.90^{d}	3.8^{cd}	4.10^{c}	5.13^{d}	6.06^{e}	8.10^{e}	9.06^{f}	9.90^{f}
T_6	0^{b}	0^{b}	3.60^{bc}	4.53^{c}	5.66^{b}	6.5^{c}	7.23^{d}	8.13^{e}	9.40^{e}	9.80^{f}
T_7	0	0	0	0	0	0	0	0	0	0
T_8	0	0	0	0	0	0	0	0	0	0
T_9	0^{b}	0^{b}	0^{d}	0^{e}	3.33^{d}	6.06^{c}	7.60^{c}	8.93^{d}	10.10^{c}	11.26^{c}

Table 20. Fruit girth (cm) noted in cv. Muvandan

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10	Phase 11
T_1	4.30^{bc}	8.00^{a}	10.70^{a}	13.00^{a}	13.60^{a}	13.83^{bc}	14.36^{d}	15.06^{d}	16.83^{c}	17.10^{d}	17.20^{d}
T_2	4.06^{c}	5.06^{de}	7.33^{d}	9.50^{c}	11.00^{bc}	13.00^{c}	14.63^{cd}	16.73^{bc}	18.10^{b}	19.03^{b}	19.05^{b}
T_3	5.00^{b}	6.06^{c}	7.03^{d}	11.26^{b}	13.30^{a}	14.90^{a}	16.63^{b}	17.46^{bc}	18.10^{b}	19.06^{b}	19.08^{b}
T_4	4.43^{abc}	5.53^{cd}	6.90^{d}	8.06^{d}	8.96^{d}	9.46^{e}	12.33^{e}	16.46^{c}	18.33^{b}	18.86^{b}	18.87^{b}
T_5	0^{d}	0^{f}	1.73^{f}	2.26^{e}	3.53^{f}	5.33^{g}	7.40^{g}	10.30^{f}	15.33^{de}	17.93^{cd}	17.95^{cd}
T_6	6.53^{a}	6.93^{b}	8.00^{c}	9.20^{c}	10.70^{c}	11.36^{d}	12.43^{e}	14.16^{ed}	15.60^{d}	17.93^{cd}	17.94^{cd}
T_7	0^{d}	4.60^{e}	8.20^{bc}	9.46^{c}	11.70^{b}	14.43	15.66^{bc}	17.66^{b}	18.30^{b}	18.60^{bc}	18.70^{bc}
T_8	4.30^{bc}	7.40^{ab}	8.76^{b}	9.86^{c}	11.13^{bc}	13.8^{bc}	17.86^{a}	19.06^{a}	19.76^{a}	20.23^{a}	20.25^{a}
T_9	0^{d}	0^{f}	0^{f}	0^{f}	4.50^{e}	7.60^{f}	10.60^{f}	13.56^{e}	14.90^{e}	15.16^{e}	15.18^{e}

Table 21. Fruit girth (cm) noted in cv. Priyor

Treatment	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10
T_1	3.76^{ab}	5.90^{a}	7.43^{b}	10.66^{a}	11.26^{b}	12.46^{b}	14.60^{b}	16.60^{a}	18.20^{a}	19.20^{b}
T_2	4.60^{a}	6.53^{a}	9.10^{a}	10.50^{a}	11.93^{a}	13.93^{a}	15.80^{a}	17.03^{a}	18.43^{a}	19.46^{b}
T_3	2.26^{c}	3.43^{c}	5.70^{de}	7.20^{cd}	8.06^{d}	9.60^{c}	12.26^{c}	17.06^{a}	18.50^{a}	19.20^{b}
T_4	2.23^{c}	3.13^{c}	5.30^{e}	8.93^{b}	11.40^{b}	13.06^{b}	15.06^{ab}	16.73^{a}	18.36^{a}	20.30^{a}
T_5	2.46^{c}	5.90^{a}	6.26^{cd}	7.50^{c}	9.10^{c}	10.13^{c}	11.10^{d}	13.06^{b}	14.96^{b}	17.53^{c}
T_6	2.83^{c}	3.13^{c}	6.46^{c}	7.86^{c}	9.10^{c}	10.40^{c}	11.83^{cd}	13.06^{b}	14.33^{b}	16.16^{d}
T_7	0	0	0	0	0	0	0	0	0	0
T_8	0	0	0	0	0	0	0	0	0	0
T_9	2.96^{bc}	4.66^{b}	5.50^{e}	6.36^{d}	6.93^{e}	7.40^{d}	7.70^{e}	8.06^{c}	8.96^{c}	9.93^{e}

In the cv. Priyor, T_4 recorded a maximum fruit girth of 20.30 cm whereas only 9.93 cm in the control (T_9). The fruit girth recorded at the pre harvest stage was T_2 (19.46 cm), T_1 (19.2 cm), T_3 (19.20 cm), T_5 (17.53 cm) and T_6 (16.16cm) respectively**.**

4.5 Fruit set and retention

In both the cultivars, all the treatments significantly affected the retention of fruits and number of fruits carried to final harvest stage (Table 22 and Plates 12 and 13).

In the cv. Muvandan, the highest fruit yield was recorded in treatment T_6 in which 65 fruits were harvested from the tagged branches whereas, it was only 38 fruits in the control. The number of fruits harvested in T_3 was 64, T_4 (56), T_1 (55), T_2 (47), T_5 (42) and T_8 (40) respectively.

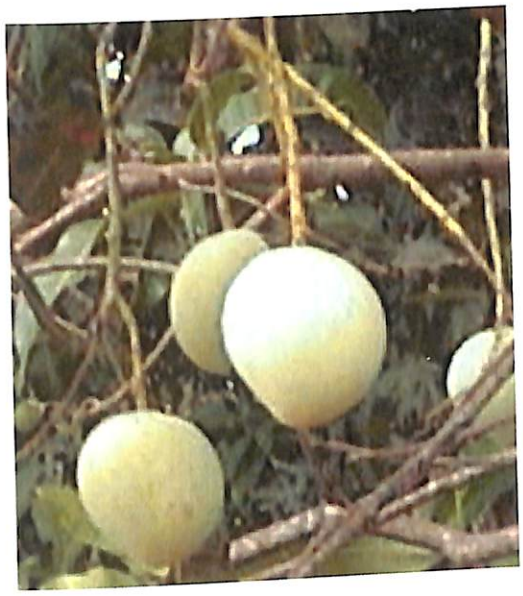
In the cv. Priyor, the different treatments except T_7 and T_8 significantly influenced the final retention of fruits at the harvest stage. The highest yield was recorded in T_2 with 62 from the labeled shoots. The number of fruits retained to final maturity was 35 in the control (T_9).The number of fruits harvested from the labelled shoots in T_1 was 58, 44 in T_3, 41 in T_6, 40 in T_4 and 39 in T_5.

4.6 Fruit characters at harvest

The biometric measurements and the fruit weight recorded at the time of harvest of the fruits from different treatments of the two cvs. are presented in the Tables 23 and 24.

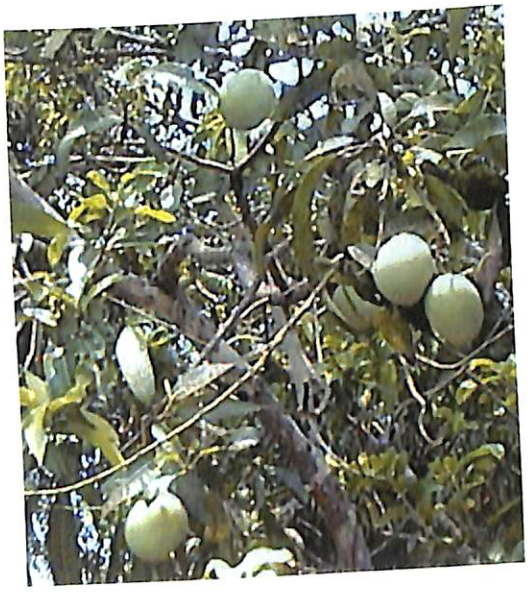
4.6.1 Fruit characters at harvest in the cv .Muvandan

In the cv. Muvandan, the data showed significant effect of different treatments on the fruit length at the time of harvest also.



T_1

T_3



T_2

T_4

Plate 12. Fruits developing to maturity in different treatments in cv. Muvandan

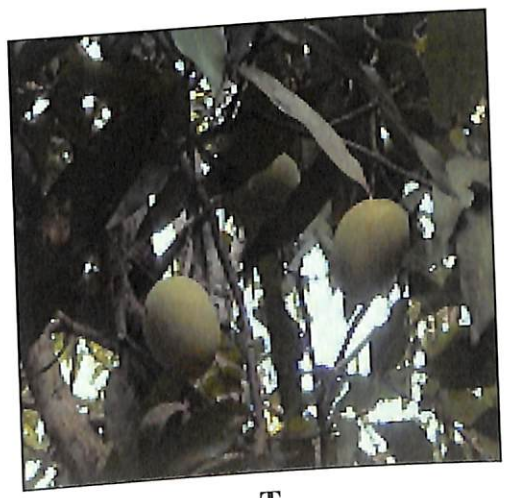
Plate 12 (Contd….)

T_5

T_7

T_6

T_8



T_9

The treatment T_6 recorded a maximum fruit length of 13.26 cm whereas it was only 10.56 cm in the control T_9. The fruit length recorded in the other treatments at the harvest time was 13.03 cm in T_4, 12.23 in T_3, 12.17 cm in T_8, 11.20 cm in T_2 and 10.66 cm in T_7 respectively.

The data showed significant superior effect of treatments on the fruit girth measured at the harvest time. The fruit girth was maximum in T_4 (23.06 cm), whereas only 19.16 cm in the control. The fruit girth recorded at harvest time for other treatments were 22.67 cm in T_5, 22.13 in T_3, 21.46 cm in T_6, 21.40 cm in T_8, 20.20 cm in T_2 ,20.07 cm in T_7 and 18.50 cm in T_1 respectively.

The fruit weight recorded at the time of harvest in the cv. Muvandan also showed significant positive effect of treatments on the individual fruit weight. The individual fruit weight recorded at the harvest time was also found to be significantly influenced by the different treatments imposed. The fruits harvested in all the treatments were significantly higher in weight than the control (T_9). The highest fruit weight was recorded in the treatment T_3 (280.55 g), whereas, it was only 174.17 g in the control (T_9). The fruits harvested in the treatment T_6 weighed on an average 251.85 g; T_8 (216.25 g); T_1 (205.1 g); T_4 (201.68 g); T_5 (182.05 g) and T_2 (178.14 g) respectively.

4.6.2 Fruit characters at harvest in the cv. Priyor

In the cv. Priyor, significant effect was noted only in some treatments with respect to the fruit length measured at the time of harvest. Others were on par with the control. Maximum fruit length was recorded in T_3 (14.43 cm) whereas in the control (T_9) it was 10.60 cm only. The fruit length recorded in the other treatments was 12.85 cm in T_2, 12.51 cm in T_4, 11.88 cm in T_6, 10.55 cm in T_5, 10.54 cm in T_1. No measurements were taken on T_7 and T_8 since the shoots remained vegetative completely.

The data showed significant effect of the treatments on the fruit girth measured at the time of harvest, except in T_7 and T_8. The fruit girth was maximum in T_4 (23.45 cm)

Table 22. No. of fruits carried to final maturity (per 90 tagged shoots)

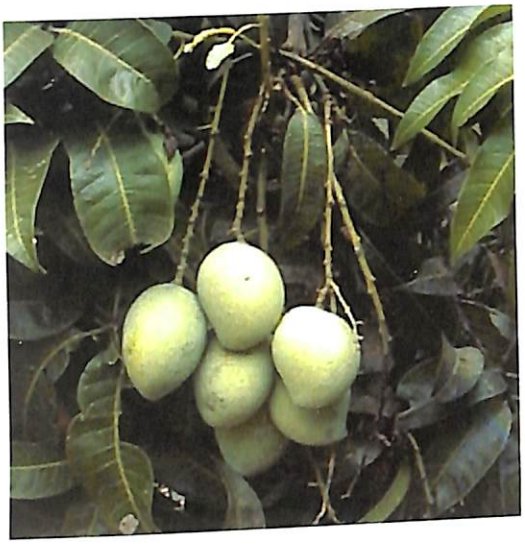
Treatment	Muvandan	Priyor
T_1	55^{b}	58^{b}
T_2	47^{c}	62^{a}
T_3	64^{a}	44^{c}
T_4	56^{b}	40^{c}
T_5	42^{cd}	39^{d}
T_6	65^{a}	41^{cd}
T_7	41^{d}	0
T_8	40^{d}	0
T_9	38^{de}	35^{e}

Table 23. Fruit characters of cv. Muvandan at harvest

Treatment	Fruit length	Fruit girth	Fruit weight
T_1	10.65^{f}	18.50^{g}	205.10^{d}
T_2	11.20^{e}	20.20^{e}	178.14^{ef}
T_3	12.23^{d}	22.13^{c}	280.55^{a}
T_4	13.03^{b}	23.06^{a}	201.68^{d}
T_5	12.58^{c}	22.67^{b}	182.05^{e}
T_6	13.26^{a}	21.46^{d}	251.85^{b}
T_7	10.66^{f}	20.07^{e}	202.68^{d}
T_8	12.17^{d}	21.40^{d}	216.25^{c}
T_9	10.56^{g}	19.16^{f}	174.17^{f}

Table 24. Fruit characters of cv. Priyor at harvest

Treatment	Fruit length	Fruit girth	Fruit weight
T_1	10.54^{e}	18.95^{e}	215.05^{d}
T_2	12.85^{b}	22.26^{bc}	218.37^{d}
T_3	14.43^{a}	22.59^{b}	253.44^{a}
T_4	12.51^{c}	23.45^{a}	245.44^{b}
T_5	10.55^{e}	21.78^{c}	236.56^{c}
T_6	11.88^{d}	21.90^{bc}	222.09^{d}
T_7	0	0	0
T_8	0	0	0
T_9	10.60^{e}	20.03^{d}	214.21^{d}



T_1

T_3

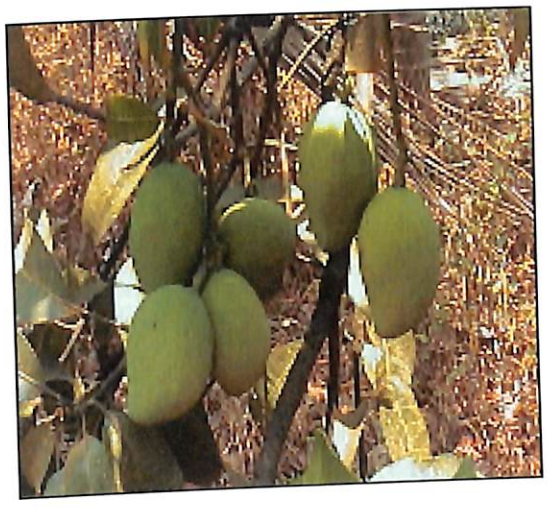
T_2

T_4

Plate 13. Fruits developing to maturity in different treatments of cv. Priyor

Plate 13 (Contd…)

T_5



T_6

T_7

T_8

T_9

whereas only 18.95 cm in T_1.The control recorded a girth of 20.03 cm. The fruit girth recorded in the other treatments were 22.26 cm in T_2, 22.59 cm in T_3, 21.78 cm in T_5 and 21.90 cm in T_6 respectively.

The fruit weight recorded at the harvest time in the cv. Priyor also showed significant positive effect of the treatments on the individual fruit weight except in T_7 and T_8. The highest fruit weight was recorded in T_3 (253.44 g)whereas, it was only 214.21 g in the control T_9.The fruits harvested in the treatment T_1 weighed on an average of 215.05 g; T_2 with 218.37 g; T_4 (245.44 g); 236.56 g in T_5 and 222.09 g in T_6 respectively.

4.7 Phenological growth stages in cv. Muvandan and cv. Priyor

The various phenological growth stages in cv. Muvandan and cv. Priyor, are furnished in the Table 25 in a concised format.

4.8 Changes in levels of carbohydrates and nitrogen in the leaves and shoots of the cvs. Muvandan and Priyor consequent to the spray treatments

Carbohydrates and nitrogen levels in the shoots and leaves were estimated at two stages i.e., prior to the first spray application and at the panicle emerged out stage in both cvs. Muvandan and Priyor (Fig. 1 to 8). A significant decrease in the level of carbohydrates in the leaves and shoots of the trees could be noted in all the treatments, whereas, the levels of nitrogen showed an increasing trend.

4.8.1 Changes in carbohydrate levels in cv. Muvandan

In the cv. Muvandan, the level of carbohydrates showed a general descending trend in leaves as well as shoots at the panicle emerged out stage except that in leaves in T_6 and T_7 (Tables. 26 and 27).

Table 25. Phenological growth stages in cv. Muvandan and cv. Priyor – An abstracted version

Sl. No.	GROWTH CHARACTERS	Muvandan	Priyor
A.	**Flush characters**	**Events ensuing**	
1	Dormant bud	Apical bud enclosed by bud scales	No apparent swelling for the dormant bud of less than 1 cm length
2	Green exposure	Bud swells and green bracts under the bud scales	Bud swells and green bracts under the bud scales
3	Large bud swell	Bud expanded and bracts about to separate	Bud expanded and bracts about to separate
4	Vegetative shoot of 3 cm	Leaf bracts are distinguishable and leaves are 1 cm long starts to emerge	Leaf bracts are distinguishable and leaves are 1 cm long starts to emerge
5	Vegetative shoot of 5 to 10 cm	Primary axes starts to extend and leaves 2-3 cm long elongates.	Primary axes starts to extend and leaves 2-3 cm long elongates.
6	Vegetative shoot of 10-20 cm	Primary axes extends.Light green colour turns to dark green.10 to 16 leaves produced per shoot.	9-16 leaves produced per shoot and turns dark green
B.	**Spray treatments and further events in the flowering shoots** **Inflorescence characters**		
7	Green dormant bud	Completely mature dark green leaves and shoots develop. The dormant brown floral bud turns light green.	Completely mature dark green leaves and shoots develop. The dormant brown floral bud turns light green.
8	Large bud swell	Bud swells and bracts are separated out	Bud swells and bracts are separated out
9	Pre inflorescence shoot	Floral -bracts turns distinguishable. Panicle axes and developing flowers are just visible	Floral- bracts turns distinguishable. Panicle axes and developing flowers are just visible
10	Inflorescence shoot of 0-5 cm	Primary and secondary axes extending and inflorescence shoot starts to grow	Primary and secondary axes extending and inflorescence shoot starts to grow
11	Inflorescence shoot of 5-10 cm	Growth results from primary and secondary axes extension	Growth results from primary and secondary axes extension
12	Inflorescence shoot of 10-20 cm	9 to 13 branches per panicle arises from the light purple tinged shoots.	13 to 31 branches per panicle arises from the light purple tinged shoots.
13	Inflorescence shoot of 20-30 cm	The axes extension ceases. Shoot turns dark purple.12 to 30 cm long and 1.4 to 2.4 cm girth.	The axes extension ceases. Shoots remain light green. 22-33 cm long and 1.4 to 2.10 cm girth of the panicle

14	0 % anthesis	Flowers are closed and floral development continues.9 to 10 branches per panicle develops	Greyish- green unopened flowers with 5 to 10 branches per panicle
15	25 -50 % anthesis	5 to 25 % mature light yellow flowers starts to open out. Panicle axes extension ceases. Floral development continues	Pinkish purple flowers opens out
Follow up spray on treated shoots			
16	75- 95 % anthesis	50 to 90 % flowers open out and development ceases of the panicle.	60 to 95 % flowers open out and development ceases of the panicle.
C. Fruit characters			
17	100 % anthesis and fruit set stage	100 % flowers open out and pinhead stage of fruits starts to set.	100 % flowers open out and pinhead stage of fruits starts to set.
18	Small to medium fruit set stage	Mustard and peanut fruit stage . Fruit drop initiates	Pinhead sized fruit drop initiates
19	Dusty panicle, fruit drop stage	Fruit size increases -Marble fruit stage and fruit drop continued.	Fruit size increases - turns dark glossy green with a prominent beak, tough skin.
20	Pre harvest fruit stage	Fruit development almost completed .	Fruit development almost completed.
21	Harvest stage	Medium ripe fruits -pale yellow skin colour with broad shoulders.	Pale glossy green skin colour changes to light yellowish green, with a pointed beak.
22	Fruit drop cessation stage	Cessation of natural drop of fruits.The panicle starts to dry.	Cessation of natural drop of fruits.The panicle starts to dry
23	Bare panicle	Panicle becomes bare, discoloured, shrivelled in appearance.	Panicle becomes bare and dry

Pre-treatment level of carbohydrates in the leaves of cv. Muvandan recorded in T_1 was 15.1 per cent which was on par with T_2, T_3, T_5 and T_8. And such values recorded for T_4, T_6, T_7 and control were 13.60, 14.00, 14.60, 12.2 respectively, whereas, the estimated values at the panicle emerged out stage showed 11.20, 12.40, 13.90, 13.30, 12.90 for T_1, T_2, T_3, T_5 and T_8 and 12.60, 15.40, 15.70 and 10.60 in T_4, T_6, T_7 and control respectively. The general descending trend in level of carbohydrates was not observed in T_6 and T_7 but an increasing trend was noted instead.

But estimation of carbohydrate content in shoots in this cultivar at the panicle emerged out stage showed a decreasing trend altogether in all the treatments. The level variations recorded were 15.60 to 12.46; 13.79 to 12.47; 12.44 to 11.21; 11.24 to 10.03; 13.24 to 11.77; 11.46 to 8.50; 11.50 to 10.53; 15.36 to 11.73 and 10.54 to 10.14 in the control respectively.

4.8.2 Changes in levels of Nitrogen in cv. Muvandan

Contrary to the trend noted in the levels of carbohydrates, the nitrogen content showed an upward trend subsequent to the different treatments. The values recorded for the treatments at panicle emerged out stage were significantly differing among the treatments and the control, in both the leaves and shoots.

Pre treatment value recorded as per cent nitrogen content in leaves of cv. Muvandan was 1.00 for T_1 which was on par with T_4, T_6, T_7 and T_9; 1.10 for T_2, T_8, T_4 and T_6. But the values noted at panicle emerged out stage were 1.32, 1.41, 1.27, 1.14, 1.32, 1.32, 1.38, 1.23 and 1.12 respectively for T_1 to T_9 (control) indicating an increase in the nitrogen level at this stage.

Such an increase in the nitrogen level was notable in the shoots of cv. Muvandan also when samples were estimated at the panicle emerged out stage. The values recorded were 0.99, 0.72, 0.87, 0.82, 0.67, 0.82, 0.68, 0.85 and 0.70 respectively for T_1 to T_9 at the

pre treatment stage whereas the corresponding values at the panicle emerged out stage were 1.32, 0.98, 1.21, 0.90, 0.78, 1.20, 0.72, 1.23 and 0.82 respectively.

4.8.3 Carbohydrates to nitrogen ratio (CHO/N) in leaves and shoots of cv. Muvandan

When CHO/N ratio was worked out for the mentioned two stages, lower values were noted for both leaves and shoots at the panicle emerged out stage.

4.8.4 Changes in carbohydrate levels in cv. Priyor

In cv. Priyor also, carbohydrate level showed a significant decrease in both leaves and shoots at the panicle emerged out stage (Tables 28 and 29).

Pre –treatment level of carbohydrates in the leaves of cv. Priyor recorded in the treatments T_1 to T_9 were 14.95, 12.90, 14.89, 13.00, 14.45, 15.55, 14.77, 13.23 and 12.72 respectively whereas the corresponding values at the panicle emerged out stage were 13.45, 11.84, 12.90, 11.11, 13.65, 14.14, 11.93, 11.75 and 10.30 respectively.

In a similar pattern a fall in the levels of carbohydrates was noted at the panicle emerged out stage in the shoots of cv. Priyor. Values recorded at the pre-treatment stage for the carbohydrates in shoots for T_1 to T_9 were 12.08, 13.07, 12.41, 12.35, 11.85, 11.33, 12.50, 11.24 and 10.93 respectively where as the corresponding values for the panicle emerged out stage were 11.65, 11.56, 11.50, 8.95, 10.36, 10.50, 11.07, 10.80 and 9.29 respectively.

4.8.5 Changes in levels of Nitrogen in cv. Priyor

Pre treatment values recorded for nitrogen in the leaves of cv. Priyor for T_1 to T_9 were 1.12, 1.18, 1.00, 1.09, 0.97, 0.85, 1.04, 0.95 and 0.97 respectively whereas the

Table 26. Effect of different treatments on levels of carbohydrates, nitrogen, and carbohydrates / nitrogen ratio in leaves in cv. Muvandan

	Before treatment imposition			At Panicle emerged out stage		
Treatment	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**
T_1	15.10^{a}	1.00^{b}	15.10^{b}	11.20^{h}	1.323^{d}	8.48^{f}
T_2	15.10^{a}	1.10^{ab}	13.72^{d}	12.40^{g}	1.41^{a}	8.79^{f}
T_3	15.10^{a}	0.90^{c}	16.77^{a}	13.90^{c}	1.27^{e}	10.94^{c}
T_4	13.60^{d}	1.10^{b}	13.60^{de}	12.60^{f}	1.14^{g}	11.05^{b}
T_5	15.20^{a}	1.20^{a}	12.66^{e}	13.30^{d}	1.32^{cd}	10.07^{d}
T_6	14.00^{c}	1.10^{b}	14.00^{c}	15.40^{b}	1.32^{c}	11.66^{a}
T_7	14.60^{b}	1.00^{b}	14.60^{c}	15.70^{a}	1.38^{b}	11.37^{a}
T_8	15.20^{a}	1.10^{ab}	13.81^{d}	12.90^{e}	1.23^{f}	10.48^{c}
T_9	12.20^{e}	1.00^{b}	12.20^{e}	10.60^{i}	1.12^{h}	9.46^{e}

Table 27. Effect of different treatments on levels of carbohydrates, nitrogen, and carbohydrates / nitrogen ratio in shoots in cv. Muvandan

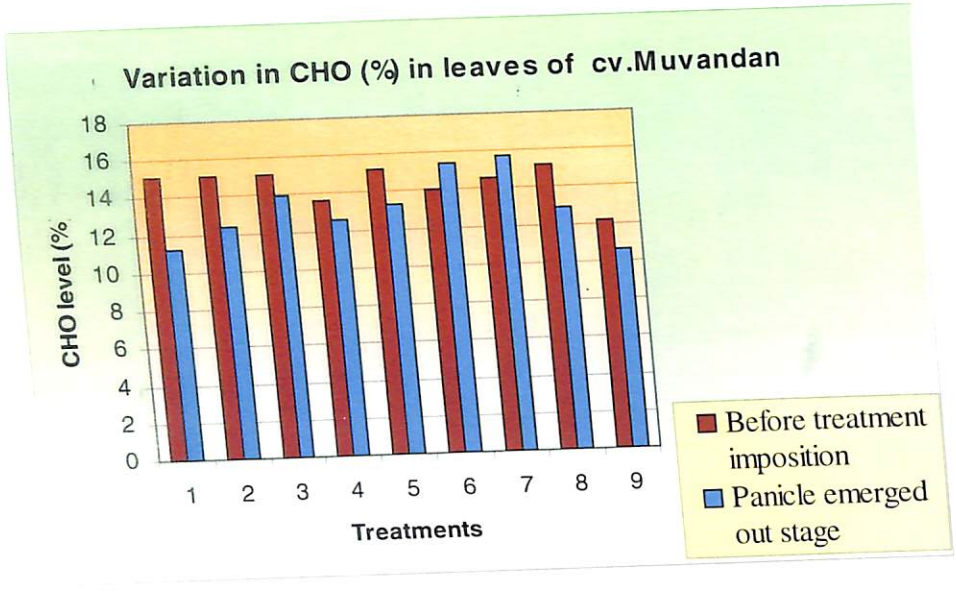
	Before treatment imposition			At Panicle emerged out stage		
Treatment	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**
T_1	15.60^{a}	0.99^{a}	15.75^{d}	12.46^{a}	1.32^{a}	9.43^{e}
T_2	13.79^{c}	0.72^{d}	19.15^{b}	12.47^{a}	0.98^{c}	12.72^{c}
T_3	12.44^{e}	0.87^{b}	14.29^{e}	11.21^{d}	1.21^{b}	9.26^{e}
T_4	11.24^{h}	0.82^{c}	13.70^{e}	10.03^{g}	0.90^{d}	11.14^{d}
T_5	13.24^{d}	0.67^{e}	19.76^{a}	11.77^{b}	0.78^{f}	15.08^{a}
T_6	11.46^{g}	0.82^{c}	13.97^{e}	8.50^{h}	1.20^{b}	7.08^{f}
T_7	11.50^{f}	0.68^{e}	16.91^{d}	10.53^{e}	0.72^{g}	14.62^{b}
T_8	15.36^{b}	0.85^{bc}	18.07^{c}	11.73^{c}	1.23^{b}	9.53^{e}
T_9	10.54^{i}	0.70^{d}	15.05^{d}	10.14^{f}	0.82^{e}	12.36^{c}

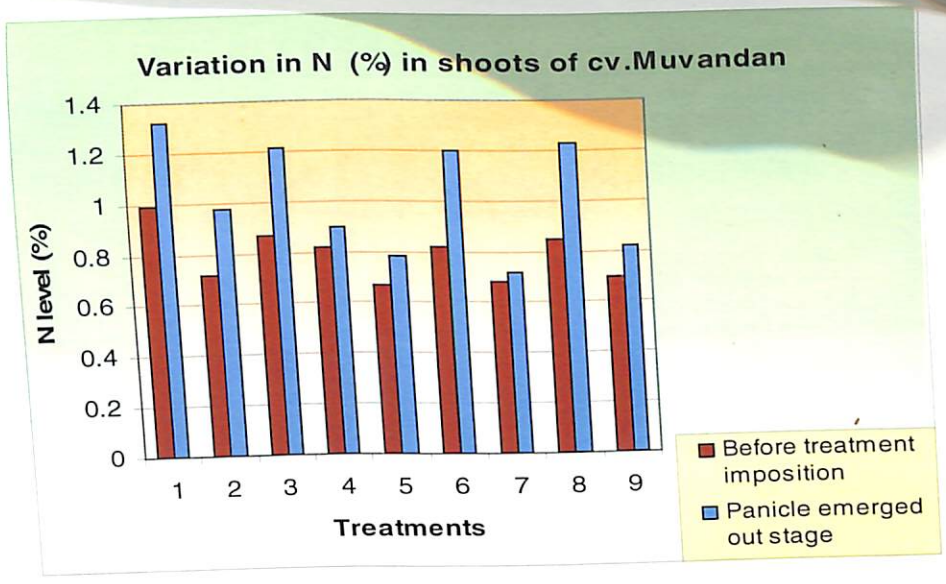
Table 28. Effect of different treatments on levels of carbohydrates, nitrogen, and carbohydrates / nitrogen ratio in leaves in cv. Priyor

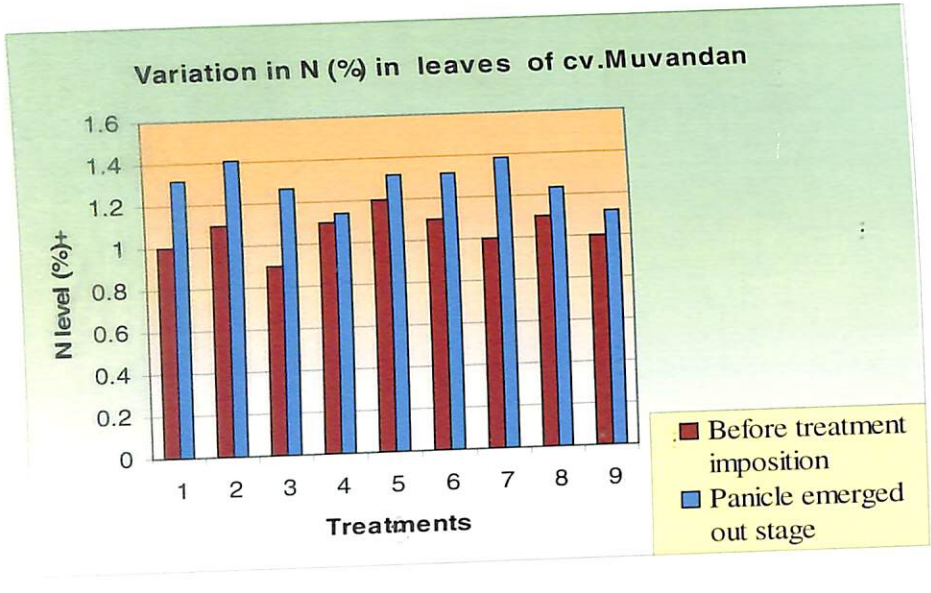
	Before treatment imposition			At Panicle emerged out stage		
Treatment	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**
T_1	14.95^{b}	1.12^{b}	13.34^{c}	13.45^{c}	1.29^{c}	10.42^{cd}
T_2	12.9^{h}	1.18^{a}	10.93^{e}	11.84^{f}	1.34^{b}	8.83^{e}
T_3	14.89^{c}	1.00^{c}	14.89^{b}	12.90^{d}	1.13^{f}	11.41^{b}
T_4	13.00^{g}	1.09^{b}	11.92^{d}	11.11^{h}	0.98^{h}	11.33^{b}
T_5	14.45^{e}	0.97^{d}	14.89^{b}	13.65^{b}	1.39^{a}	9.82^{d}
T_6	15.55^{a}	0.85^{e}	18.29^{a}	14.14^{a}	1.09^{g}	12.97^{a}
T_7	14.77^{d}	1.04^{c}	14.20^{b}	11.93^{e}	1.21^{e}	9.85^{d}
T_8	13.23^{f}	0.95^{d}	13.92^{c}	11.75^{g}	1.08^{g}	10.87^{c}
T_9	12.72^{i}	0.97^{d}	13.11^{cd}	10.30^{i}	1.26^{d}	8.17^{f}

Table 29. Effect of different treatments on levels of carbohydrates, nitrogen, and carbohydrates / nitrogen ratio in shoots in cv. Priyor

	Before treatment imposition			At Panicle emerged out stage		
Treatment	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**	**Carbohydrates (%)**	**Nitrogen (%)**	**CHO / N**
T_1	12.08^{e}	0.50^{c}	24.16^{a}	11.65^{a}	1.00^{a}	11.65^{e}
T_2	13.07^{a}	0.79^{a}	16.54^{e}	11.56^{b}	0.92^{b}	12.56^{de}
T_3	12.41^{c}	0.57^{c}	21.77^{b}	11.50^{b}	0.67^{e}	17.16^{b}
T_4	12.35^{d}	0.53^{c}	23.30^{a}	8.95^{h}	0.81^{c}	11.04^{f}
T_5	11.85^{f}	0.57^{c}	20.78^{c}	10.36^{f}	0.50^{g}	20.72^{a}
T_6	11.33^{g}	0.6^{b}	18.88^{de}	10.50^{e}	0.71^{d}	14.78^{d}
T_7	12.50^{b}	0.65^{b}	19.23^{d}	11.07^{c}	0.62^{f}	17.85^{b}
T_8	11.24^{h}	0.57^{c}	19.71^{d}	10.80^{d}	1.06^{a}	10.18^{e}
T_9	10.93^{i}	0.66^{b}	16.56^{e}	9.29^{g}	0.61^{f}	15.22^{c}







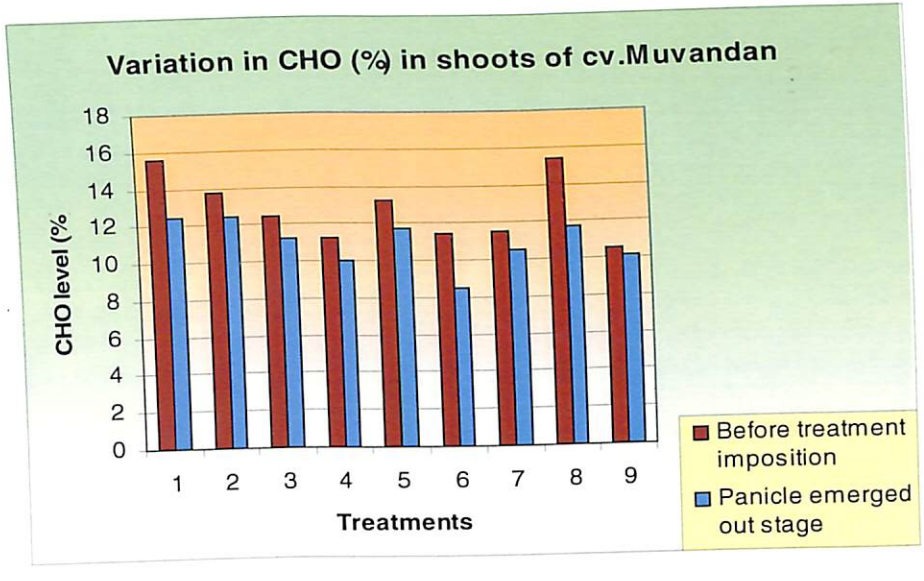
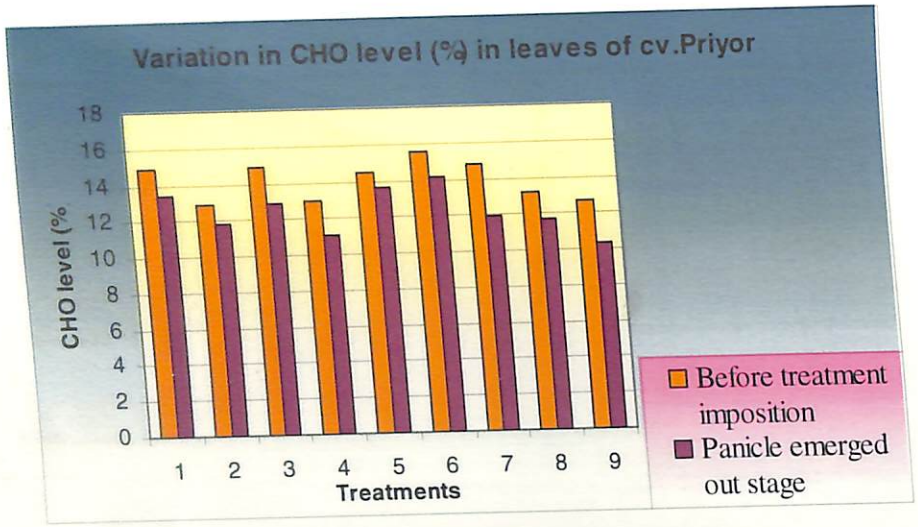
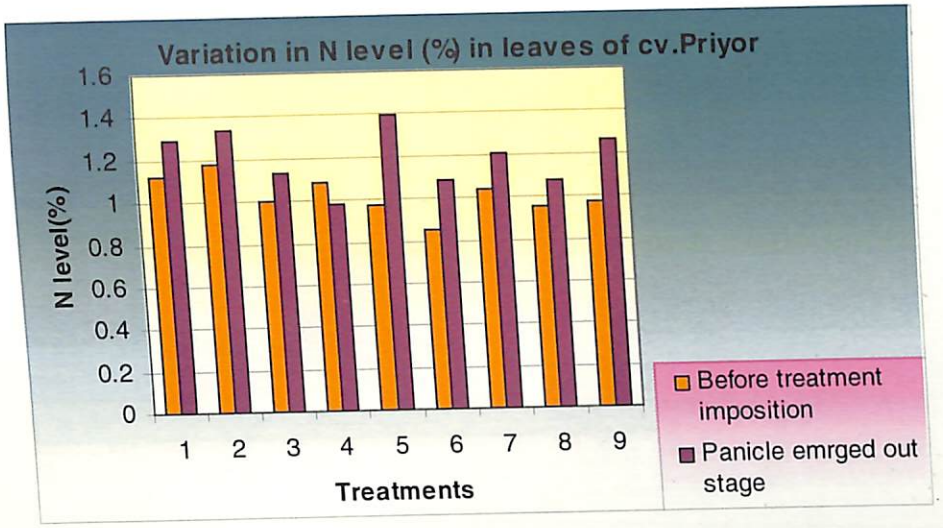
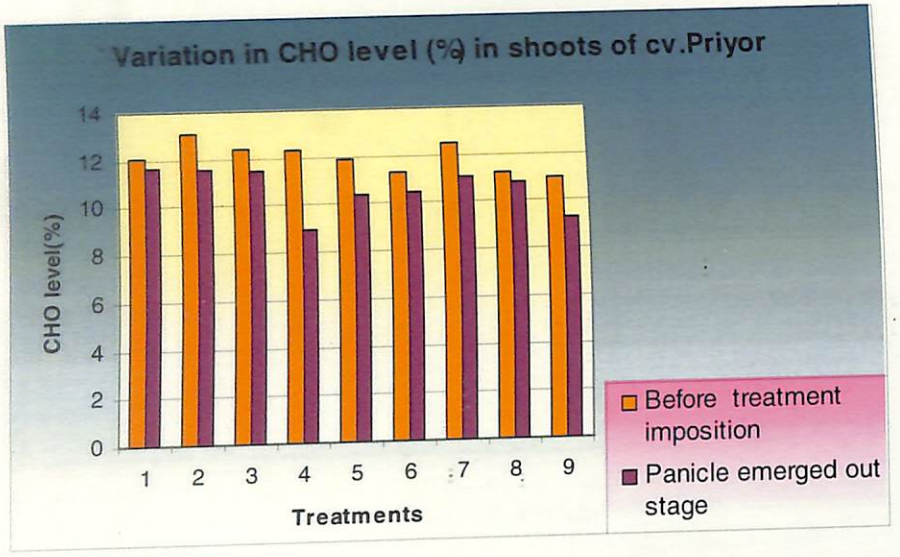


Fig. 1 to 4. Variation in carbohydrates (CHO) and nitrogen levels (%) in cv. Muvandan







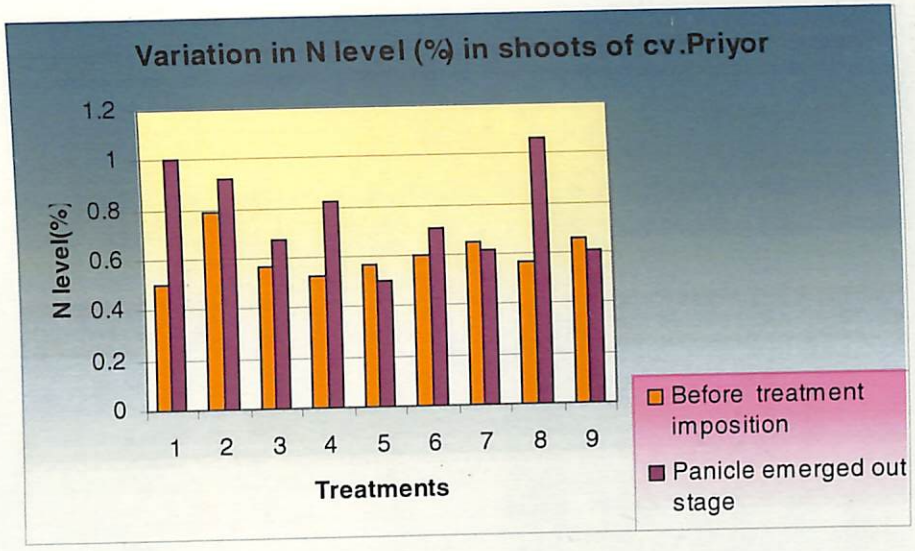


Fig 5-8. Variation in carbohydrates (CHO) and nitrogen levels (%) in cv. Priyor

corresponding values at the panicle emerged out stage were 1.29, 1.34, 1.13, 0.88, 1.39, 1.09, 1.21, 1.08 and 1.26 respectively.

A similar increase in the level of nitrogen except in $T_{5,}$ T_7 and T_9 was noted in the shoots of cv. Priyor at the panicle emerged out stage. Pre treatment values for nitrogen for T_1 to T_9 were 0.50, 0.79, 0.57, 0.53, 0.57, 0.60, 0.65, 0.57 and 0.66 respectively, whereas, the corresponding values at panicle emergence stage were 1.00, 0.92, 0.67, 0.81, 0.50, 0.71, 0.62, 1.06 and 0.61.

4.8.6 CHO/N ratio in leaves and shoots of cv. Priyor

Calculated values for CHO/N ratio at the mentioned two stages also showed a descending trend in both leaves as well as shoots of cv. Priyor.

4.9 Assessment of leaf photosynthesis, stomatal conductance and other physiological parameters at different stages of flower and fruit development

The observations on the leaf photosynthetic parameters recorded during the flower opening and fruit development stage in both the cultivars are presented in Tables 30 to 33 and Fig. 9 to 12.

4.9.1 The leaf photosynthetic rate (µ mol CO_2/m/sec)

The little conspicuous effect was noted and the photosynthetic rates were not found to be significantly affected by the different treatments imposed in the cv. Muvandan. The values recorded for most of the treatments were on par i.e., T_1, T_3, T_4, T_5, T_6, T_8 and T_9 control. The rate noted in T_7 (14.83) was significantly superior to the other treatments and control. But surprisingly the values recorded for T_2 (9.90) was lower than that of control (12.27).

The photosynthetic rate recorded during the fruit development stage showed significantly higher values with respect to some of the treatments.T_6, T_3, T_1, T_4 and T_8. T_2 and T_9 (control) were found to be on par. Highest photosynthetic rate was recorded in T_4

(14.73). Even though the values recorded for the photosynthetic rate during flower opening stage in cv. Priyor showed significant difference among the treatments, the observations are yet to be confirmed further as the value for control was significantly higher than many of the treatments.

Photosynthetic rate recorded at fruit development stage in cv. Priyor showed significant difference among some treatments than the control.T_4 recorded the highest value (14.73) whereas it was 9.26 in the control.

4.9.2 Stomatal conductance (mol H_20 /m/sec)

Stomatal conductance measured during the flower opening stage in cv. Muvandan indicated significant difference among some treatments, whereas, values of treatments T_1 and T_6 were on par with control. Stomatal conductance ranged from 0.06 to 0.19 mol H_20 /m/sec during flower opening stage in cv. Muvandan .T_8 recorded the highest value of 0.19 whereas it was 0.06 in T_4. The values recorded for stomatal conductance during the fruit development in the cv. Muvandan did not show any significant difference among the treatments. The values of stomatal conductance (mol H_20 /m/sec) during the fruit development stage was between 0.08 to 0.21.

The measurements on stomatal conductance recorded in the flowering stage in cv. Priyor also showed little significant difference among the treatments. Similar observations during the fruit development stage showed relatively superior values for some treatments. Stomatal conductance ranged from 0.08 to 0.23 mol H_20 /m/sec in cv. Priyor. The values of stomatal conductance during the fruit development stage was between 0.08 to 0.21 in both cvs. But in this case also, control T_9 (0.21) also recorded a significantly higher value than the other treatments.

4.9.3 Transpiration rate (m mol H_20 /m /sec)

The transpiration rate was measured in cv. Muvandan during the flower opening stage. The data showed no significant difference among the various treatments.

Transpiration rate ranged from 1.80 to 3.94 m mol H_20 /m /sec during flower opening stage in cv. Muvandan. The values for most of the treatments i.e., T_3 T_4, T_8 and T_9 were noted as on par. The highest value of 3.94 was observed in T_5 while the lowest of 1.80 for T_1.

During the fruit development period the value for transpiration rate in the cv. Muvandan showed slight variation in some treatments. The transpiration rate recorded during the fruit development stage was between 1.75 to 3.60 m mol H_2O /m /sec in both cvs. T_6 recorded the highest value of 3.60 and T_3 the lowest (1.75) but the values for treatments T_1, T_4, T_7 and T_8 were on par.

In cv. Priyor also transpiration rate measured during the flower opening stage did not show significant difference among the various treatments i.e., except T_3, T_5 and T9 all the other treatments were on par. Transpiration rate ranged from 1.57 to 4.31 m mol H_2O /m /sec during flower opening stage in cv. Priyor. T_9 (control) recorded the highest transpiration rate of 4.31 whereas least for T_3 i.e., 1.57. Among the treatments T_3, T_5 and T_6 recorded significant values whereas all the other treatments were on par.

4.9.4 Vapour pressure deficit (k Pa)

In cv. Muvandan the mean vapour pressure deficit during the flower opening stage, indicated significant difference among all the treatments. The values for vapour pressure deficit ranged from 1.24 to 3.25 k Pa in cv. Muvandan during flower opening stage. T_5 and T_6 were on par. The highest vapour pressure deficit value was recorded in T_4 (3.25 k Pa) whereas the lowest for T_7 (1.24 k Pa).

The measurements recorded in the fruit development stage of cv. Muvandan showed significant difference among all the treatments. The values during fruit development stage ranged between 1.20 to 2.44 k Pa in cv. Muvandan. The lowest value of 1.25 k Pa was recorded in T_1, but highest value of 2.44 k Pa for T_7.

The values for vapour pressure deficit ranged from 1.97 to 3.18 k Pa in cv. Priyor during flower opening stage**.** The vapour pressure deficit values recorded in cv. Priyor

during flower opening stage indicated that almost all the treatments on par except T_3, T_6, T_8, and t_9. The highest vapour pressure deficit 3.18 k Pa for T_8 and lowest value of 1.97 was recorded for T_3.

The measurements for this parameter in cv. Priyor during fruit development stage indicated significant variation among all the treatments. The values during fruit development stage ranged between 1.25 to 2.56 k Pa in cv. Priyor. The highest value of 2.56 was registered for T_2 while the lowest for T_1 (1.25 k Pa).

Table 30. Values of different photosynthetic and related parameters measured during the flower opening stage in cv. Muvandan

Treatment	Photosynthetic rate (µ mol CO_2 /m/sec)	Conductance to water (mol H_2O /m/sec)	Transpiration rate (mmol H_2O /m/sec)	Vapour pressure deficit (kPa)
T_1	10.52^{ab}	0.08^{bc}	1.80^{b}	2.27^{c}
T_2	9.90^{b}	0.10^{abc}	1.85^{b}	1.79d
T_3	12.99^{ab}	0.10^{abc}	2.72^{ab}	2.71^{b}
T_4	10.95^{ab}	0.06^{c}	2.21^{ab}	3.25^{a}
T_5	14.56^{ab}	0.13^{abc}	3.94^{a}	3.01^{ab}
T_6	12.23^{ab}	0.07^{bc}	2.11^{b}	2.97^{ab}
T_7	14.83^{a}	0.18^{ab}	2.14^{b}	1.24^{e}
T_8	11.42^{ab}	0.19^{a}	2.27^{ab}	1.26^{e}
T_9	12.27^{ab}	0.09^{bc}	2.30^{ab}	2.64^{bc}

Table 31. Values of different photosynthetic and related parameters measured during the fruit development stage (Marble stage) in cv. Muvandan

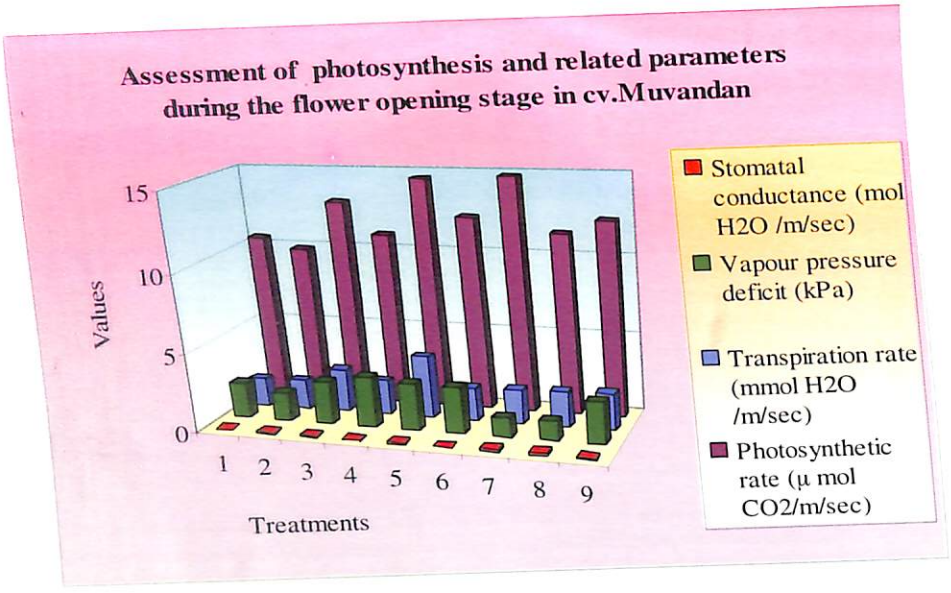
Treatment	Photosynthetic rate (µ mol CO_2 /m/sec)	Conductance to water (mol H_2O /m/sec)	Transpiration rate (mmol H_2O /m/sec)	Vapour pressure deficit (kPa)
T_1	10.73^{bc}	0.20^{a}	2.48^{b}	1.20^{e}
T_2	9.90^{c}	0.10^{a}	1.85^{c}	1.79^{bcd}
T_3	12.48^{ab}	0.08^{a}	1.75^{c}	2.12^{ab}
T_4	14.73^{a}	0.14^{a}	2.41^{b}	1.72^{bcd}
T_5	10.55^{bc}	0.21^{a}	2.97^{a}	1.45^{de}
T_6	13.58^{a}	0.19^{a}	3.60^{a}	1.89^{bc}
T_7	9.38^{c}	0.11^{a}	2.70^{b}	2.44^{a}
T_8	10.93^{bc}	0.15^{a}	2.97^{b}	2.15^{ab}
T_9	9.35^{c}	0.21^{a}	2.99^{b}	1.49^{cde}

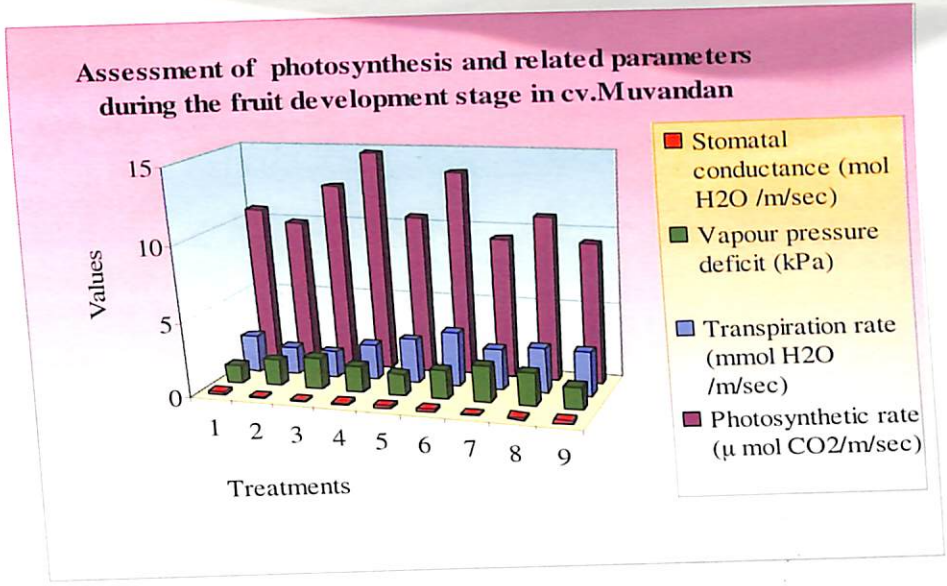
Table 32. Values of different photosynthetic and related parameters measured during the flower opening stage in cv. Priyor

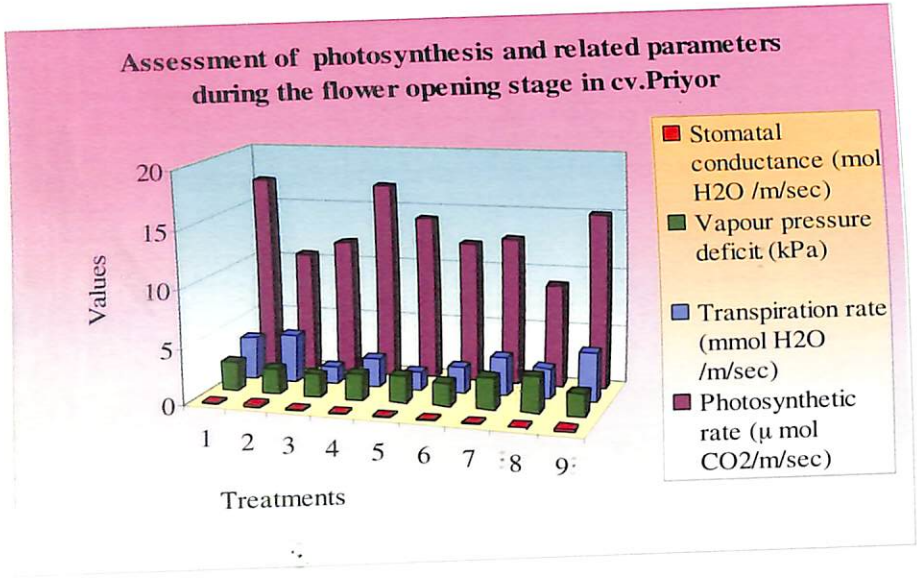
Treatment	Photosynthetic rate (µ mol CO_2 /m/sec)	Conductance to water (mol H_2O /m/sec)	Transpiration rate (mmol H_2O /m/sec)	Vapour pressure deficit (kPa)
T_1	17.24^{a}	0.16^{ab}	3.75^{ab}	2.56^{bc}
T_2	10.62^{cd}	0.19^{ab}	4.22^{ab}	2.28^{bc}
T_3	11.84^{bcd}	0.08^{b}	1.57^{b}	1.97^{c}
T_4	16.97^{ab}	0.11^{ab}	2.49^{ab}	2.33^{bc}
T_5	14.22^{abc}	0.08^{ab}	1.64^{b}	2.39^{bc}
T_6	12.11^{abcd}	0.11^{ab}	2.26^{ab}	2.00^{a}
T_7	12.73^{abcd}	0.12^{ab}	3.40^{ab}	2.81^{bc}
T_8	8.83^{d}	0.08^{ab}	2.70^{ab}	3.18^{a}
T_9	15.01^{abc}	0.23^{a}	4.31^{a}	1.99^{c}

Table 33. Values of different photosynthetic and related parameters measured during the fruit development stage (Marble stage) in cv. Priyor

Treatment	Photosynthetic rate (µ mol CO_2 /m/sec)	Conductance to water (mol H_2O /m/sec)	Transpiration rate (mmol H_2O /m/sec)	Vapour pressure deficit (kPa)
T_1	12.33^{ab}	0.20^{ab}	2.48^{b}	1.25^{f}
T_2	10.56^{bcd}	0.09^{ab}	2.39^{b}	2.56^{a}
T_3	12.51^{ab}	0.08^{b}	1.75^{c}	2.12^{bc}
T_4	14.73^{a}	0.14^{ab}	2.41^{b}	1.72^{bcd}
T_5	10.56^{bcd}	0.21^{a}	3.00^{a}	1.45^{ef}
T_6	11.67^{bc}	0.19^{ab}	3.60^{a}	1.89^{cd}
T_7	9.71^{cd}	0.11^{ab}	2.69^{b}	2.45^{ab}
T_8	8.90^{d}	0.15^{ab}	2.97^{b}	2.15^{abc}
T_9	9.26^{cd}	0.21^{a}	2.99^{b}	1.49^{def}







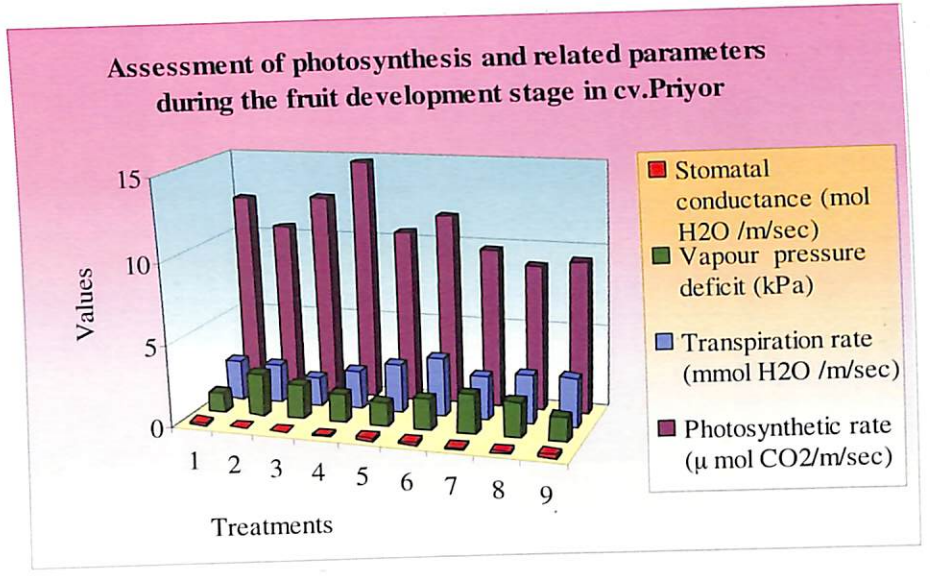


Fig. 9-12. Assessment of photosynthesis and related parameters during flower opening and fruit development stage in cvs. Muvandan and Priyor

DISCUSSION

5. DISCUSSION

The effective and efficient management of flowering and cropping time is one of the most important objectives of mango growers worldwide. Regular crop as well as out of season crop not only sustains the consumer's demand but enhances the value of the crop by lengthening the season of availability. Floral manipulation of mango is an important component for regular as well as off season cropping management.

The results from the present investigations in mango **(Flower bud forcing in humid tropic mangoes using dormancy breakers)** are discussed hereunder in the above perspective.

5.1 Assessment of vegetative phenology prior to the treatments

A basic understanding of the growth features is an essential pre- requisite before any attempts on growth and floral manipulation in a tree crop like mango. Clear alternation of periods of active growth and quiescence during shoot growth is a typical feature of the genus.

Davenport (2000) designated mango **stems** as the branch tips that are in 'rest' or remains dormant on the mango trees; and '**shoots**' as the actively growing plant tips or laterals regardless of the type of growth i.e., vegetative or reproductive. '**Flushes**' or the process of **flushing** is referred to the growth occurring in sections of the tree canopy or throughout the entire tree. It was designated as periodic short termed episodes.

History of shoots, its flushing phenology, growth increments at different intervals, morphological changes at different phenological stages of the opened out buds etc. were closely monitored during the course of present investigations along with a close observation on the changes in the environmental parameters.

The dormant buds in the shoots tagged for different treatments in the present experiments were found to open out during September 2006 on the receipt or coinciding with a rainfall during the month. An initiation of shoot growth noted with the morphological changes along with leading to the flushing of the shoots at different intensities (50 - 90%).These events were on a purely vegetative mode resulting in vegetative shoots and shoot growth continuing upto Dec.2006. Shoots (two to two and a half months old) matured and the emerged leaves turned into dark green from the limping soft light green leaves at the beginning. During the period, the apex was found to produce about 10-20 leaves (dependent on cvs.) before returning to the resting stage. The initial active growth of the emerging out buds was not evident towards the later phase of growth and the internode shortens and gets compressed towards the apex. Davenport (1992) defined these regions of the compressed internodes as **intercalations** and the entire segment of long internodes as an **intercalary unit.**

Davenport and Nunez-Elisea (1990) while elucidating the events during the vegetative and reproductive growth in mango noted that a resting bud must first initiate growth and referred **initiation** as the onset of rapid shoot development (bud break) regardless of the type of shoot evoked. They further elaborated that coinciding with shoot initiation, induction occurs based on the conditions present at the time of initiation and referred **induction** as the temporary commitment of buds to evoke particular shoot type (vegetative, floral or mixed).

5.2 Assessment of weather parameters during the vegetative phase

Assessment of weather parameters during the period showed that the optimal condition for bud break and shoot growth during September 2006 is in consequent to or resultant from the onset of rainfall from the south west monsoon during the month. It has resulted in a sudden decrease in air temperature and a rise in the soil moisture also. It is also notable that such an onset of rainfall took place after a temporary withdrawal of monsoon during the previous two weeks.

The weather data for the period shows zero rainfall recorded for an interval of 14 days preceding this. It is also worth mentioning that July –August months normally shares major part of rainfall of S-W monsoon received in Kerala. But the data for the period for the year records as blank for 2 weeks period and thereafter a resurgence in the succeeding weeks of September.

Whiley and Schaffer (1997) and Davenport and Nunez-Elisea (1997) have clearly indicated that the environmental factors play a great role in bringing about the transition of a dormant bud to vegetative or reproductive growth. Such a transition is presumed to be induced by a fall or rise in the atmospheric temperature or in combination with the moisture availability.

Generally, flowering in mango requires four to five weeks of shoot dormancy and cool night temperature trigger floral induction of the terminal buds and the absolute temperature needed for floral induction varies among the varieties.

5.3 Effect of DBC on floral induction and subsequent events

The first and foremost target of the present experiment was the flower bud forcing in the selected cvs. Muvandan and Priyor by chemical intervention, using nitrates and nitrates-micronutrient combinations and thiourea. Accordingly, the first spray was given six months after tagging the shoots (October. 2006) and the second spraying was taken up during the December 2006 (eight months after tagging).

First spraying taken up during October 2006 did not result in any induction of flowering. The notable point is that, at this period flushing and shoot growth was progressing in most of the tagged shoots. The leaves were light green (about to mature) and the trees as such in a vegetative mode. Spraying was also followed by a spell of moderate to heavy rainfall during the succeeding weeks in October. 2006. Hence, the chemical application at six months stage not only failed to evoke any floral induction on the sprayed shoots, but just retained the shoots in the vegetative phase only. It can be

attributed mainly to the prevalent conditions of the wet atmospheric situations favouring vegetative growth and secondly to the non attainment of optimal physiological maturity of the sprayed shoots at the time of spraying. These observations are in tune with the reports made by (Bueno and Valmayor, 1974) and later by (Nunez-Elisea, 1986 and Nunez-Elisea, 1988) that the mango leaves should be sufficiently mature reaching a dark green colour to obtain a reproductive shoot response and should be brittle when hand crushed.

But the treatments with DBC (nitrate combination and thiourea) did effect in induction of flowering when the spraying was undertaken during December, 2006 at the eight months stage. All the treatments except T_7 and T_8 (0.5 % and 1 % thiourea) in cv. Priyor were found to enhance flowering in both the cvs. with respect to all the quantitative floral parameters.

The treatment T_6 (Ammonium nitrate and micronutrient combination), in cv. Muvandan and T_1 and T_2 (1% and 2% KNO_3) in cv. Priyor was found to be superior among the others. The panicle emergence in T_6 (Ammonium nitrate and micronutrient combination) in cv. Muvandan occurred within a very short span of 7 days, whereas, in the control, it was 34 days. The KNO_3-micronutrient combination was equally effective in forcing the flower bud to open out panicles with in 9 days of spraying. Such an early induction of flowering was conspicuously noted in other treatments also.

Intensity of flowering recorded as the number of shoots flowered showed the highest percent of shoots flowered in T_6 in the cv. Muvandan. T_3 was also equally effective in this context. In cv. Priyor, KNO_3 treatments T_2 and T_1 were highly effective. In both the cultivars, flowering noted in the control was very much lower than the treatments except T_7 and T_8. In cv. Priyor, the treated shoots produced vegetative flushes due to some unexpected grounds. But such a change did not take place in the cv. Muvandan, where the treated shoots of thiourea turned reproductive instead.

Reports on the successful use of nitrates for stimulation of flowering in mango can be traced back to seventies itself (Barba, 1974; Bueno and Valmeyor, 1974; Astudillo and Bondad, 1978; Bondad and Linsanagan, 1979). Bondad and Linsanagan (1979) elaborated that KNO_3 could modify the flowering behaviour of mango since it makes it possible to fruit every year breaking the biennial bearing habit (alternate or regular).

Nunez-Elisea (1985) observed that KNO_3 spray produced inflorescence on 60 per cent and 76 per cent of shoots in Haden and Manila mango, respectively as compared to 32 per cent and 20 per cent in the control.

Nunez- Elisea (1988) ; Nunez-Elisea and Caldeira (1988) have noted that the nitrate anion is the active component of KNO_3 and reported further that ammonium nitrate as twice effective in inducing flowering in mango shoots.

Results from the present investigations indicating a very positive effect of nitrate sprays on induction of flowering are in conformity with these earlier reports. The response was instantaneous or rapid in certain treatments like T_6 and T_3 that the treated shoots opened out panicles within a very short time after spraying.

Fierro and Ulloa (1991) reported that KNO_3 sprays effect the date of flowering, number of panicles per tree formed in mango in some tropical regions. As per Davenport and Nunez-Elisea (1997) in low and mid latitude tropics receptive mango trees responded by initiating floral buds within two weeks after treatment, and the effective concentration varying with age of the trees and climate.

Goguey (1993) asserted that the responses of trees to different flower inducing treatments differ according to the cultivar, climatic conditions and geographical location.

A confusion on the timing of KNO_3 application for induction of flowering in mango could be noted in the early reports on this aspect. Some reports recommended KNO_3 application three months before the expected flowering (Fierro and Ulloa, 1991)

i.e., during the initial stage of shoot growth (flushing), while others (Bondad and Linsangan, 1979 and Perez-Barraza *et al.*, 2000) noted better results by applying KNO_3 on mature vegetative flushes. In the present experiments, the induction was evident only after spraying undertaken on matured vegetative flushes. But, the impact of the environmental factors at the time of application should not also be undermined in this context. (Point elaborated elsewhere in this chapter along with the floral phenology).

In the present studies, nitrates alone and with combination of micronutrients did show a very positive effect on early and heavy flowering in both the cvs. The nitrate-micronutrient combination had a special positive effect in the polyembryonic cv. Muvandan. These findings are confirming the observations made by Iyer (2000) on the above lines that it might be worthwhile to study the response of nitrates and nitrate-micronutrient combination under the humid tropical conditions of Kerala for the local polyembryonic cvs. to force the swollen floral buds to open out and for earlier uniform cropping.

A significant enhancement of growth and related characters of emerging out panicles was evident (manifested) in different treatments. All the treatments in both cvs., except T_7 and T_8 in cv. Priyor significantly increased the length of panicle after emergence.

Ammonium nitrate treatments (0.5 % and 1% Ammonium nitrate) were found to significantly enhance the panicle length, in cv. Muvandan. The values were 30.1cm and 28.13 cm respectively, but the control recorded only 13.1 cm. The final panicle length recorded in the other treatments in the cv. Muvandan was also found to be very much enhanced.

The girth of the inflorescence was also found to be significantly increased by the different treatments. The final girth of the inflorescence recorded in T_4 was 2.4 cm whereas it was only 1.36 cm in the control. The measurements on girth recorded in other treatments were also found to be significantly higher than the control.

Intensity of branching of the panicles was also found to be significantly influenced by the different treatments. Maximum branching was noted in T_5 which recorded a value of 25 whereas it was only 11.6 in the control in cv. Muvandan. In cv. Priyor, maximum branching was noted in T_4 (31.6) and only 14.33 in the control.

In the cv. Priyor, except in treatments involving thiourea, all the other treatments were found to enhance the panicle length significantly than the control. The maximum panicle length was noted in T_6 (32.7 cm) whereas it was 22.2 in the control. In such a similar pattern, all the treatments except T_7 and T_8 were found to significantly increase the final inflorescence girth in the cv. Priyor. The maximum girth was noted in T_2 (2.1 cm) whereas only 1.43 cm in the control.

A primary **floral stimulation effect** later turned in to a **growth stimulation rather enhancement effect**, resultant from the different treatments is clearly indicated from these observations on various floral parameters.

Yeshitela (2004) while reporting the effects of KNO_3 and other combinations in cv. Tommy Atkins recorded maximum inflorescence length using 3 per cent KNO_3. He suggested that nitrogen supplementation through KNO_3 spraying is the supposed reason for the observed greater flowering and other positive effects on different floral parameters. This is in line with the reports of Hafle *et al*. (2003) involving combination sprays of nitrates and micronutrients showing a very positive effect on different flowering parameters. In the present studies, growth of inflorescence i.e., panicle length, girth, number of branches after emergence etc. were greatly enhanced by the different treatment combinations involving nitrates and micronutrients.

Robbertse *et al*. (1988) reported that boron applied as foliar spray at the onset of flowering favoured the growth of mango pollen tube. Results from elsewhere (Robbertse *et al*., 1990, Singh, 2003; Singh and Maurya, 2004 and Dutta (2004) also indicated a positive influence of micronutrient sprays on different floral and fruit characters in mango.

According to Singh and Maurya (2004), micronutrient sprayed at three intervals – panicle emergence, two different stages of fruit development resulted in the increase in flowering, fruit set and yield in mango cv. Mallika. Maximum rachis diameter, % of bisexual flowers, highest fruit retention etc. were noted by Dutta (2004) by spraying boric acid at different concentrations in mango cv. Himsagar at the late bud swelling stage.

The present results involving the treatments of nitrates and trace elements also finds support from the report by Catchpoole and Bally (1993) who reported that foliar sprays of KNO_3 and trace elements (Potassium nitrate, boric acid, ferrous sulphate, sodium molybdate and zinc sulphate) under the tropical situations of Australia (where excess vegetative growth at the expense of flowering is noted in mango trees) resulted in an early and more uniform flowering with increased flowering %, fruit set and final yield in cvs. like Keitt, Irwin and Palmer.

An interesting observation in the present set of experiments treatments involving micronutrients-nitrate combinations in both the cvs. was the occurrence of a definite number of mixed shoots (5-10 %), out of the total flowered shoots. KNO_3 treatments in the cv. Priyor also showed mixed panicle emergence.

Previous reports by (Rojas, 1993) also showed such occurrence of mixed panicles in cv. Haden consequent to 6 per cent KNO_3 spraying. The leafiness of an inflorescence would indicate the level of induction on a tree. Leafless inflorescences are an indication of the total induction, while a leafy inflorescence indicates partial induction (Joubert *et. al.*, 1993). It is reasonable to assume that the nitrate micronutrient combination or the nitrates at certain levels resulted in forcing even the partially inducted shoots to open out inflorescences in both the cvs. in these experiments.

Van der Meulen *et al.* (1971) stated that leafy inflorescences reflect a lack of stress and excessive tree vigour usually associated with high soil nitrogen. Wolstenholme and Mullins (1982) concluded that adequately stressed trees would bear no leafy inflorescences. During the present studies, the second spraying of chemicals which

consequently resulted in the inflorescence emergence was taken up during December. 2006. The preceding month November. 2006 recorded enough rainfall throughout and hence not effected in any stress conditions on the trees sprayed. The spray treatments with nitrates would have resulted in flower opening but the supplemental nitrogen applied in the process plus the non stress conditions should have resulted in the emergence of mixed shoots in some treatments.

Treatments involving thiourea at different levels during the present set of experiments were effective in floral stimulation in cv. Muvandan but such a response was not observed in cv. Priyor.

Tongumpai *et al*. (1997) while reporting the effect of thiourea sprays on floral bud break in mango noted early flower induction in mango cv. Nam Dok Mai at 0.5 % level.

Present results in cv. Muvandan are somewhat conforming to the above findings and various other reports on this aspect from elsewhere (Junthasri *et al*., 2000; Sritontip *et al*., 2001).

A valid reason for the response of shoots in cv. Priyor to the application of thiourea- resulting in a complete vegetative flushing- could not be made from the present studies and need further confirmatory observations on the aspect.

5.4 Floral Phenology and the environmental parameters during the reproductive phase

Assessment of floral phenology consequent to the imposition of different treatments was carried out by noting the growth increments at weekly intervals after the emergence of panicles. Events taking place during the inflorescence growth at different stages were noted.

Panicle emergence was noted on the shoots consequent to the treatments made during the first week of December 2006.The mean values for maximum and minimum

temperature during this week were 31.2^{o}C and 24.5^{o}C respectively. No rainfall was recorded during that week with an atmospheric humidity of 62 per cent. The effect of sprayed treatments was evident from the subsequent week itself by observing panicle emergence in certain treatments. The values for maximum temperature recorded during the subsequent four to five weeks did not show much variation but the minimum temperature recorded during these weeks showed a fall in temperature towards the fourth and fifth weeks. The rainfall data showed zero values for subsequent five to six months, during which all the developmental processes of flowering, fruit set and development took place in both the cvs. The values for relative humidity also showed a decelerating trend, after the panicle emergence and during its further growth and development stages.

5.5 Effect of DBC on other floral and fruit characters

The number of bisexual flowers opened in the treated panicles were also found to be significantly superior in the treated shoots than the control. Maximum number of productive flowers (bisexual flowers) was found to open out in T_6 (NH_4NO_3 – micronutrient combination) in the cv. Muvandan and T_2 (2% KNO_3) in the cv. Priyor. Previous reports on micronutrient sprays also showed a significant impact on the various quantitative floral parameters and % of bisexual flowers (Dutta, 2004, Vijayalakshmi and Srinivasan, 2002 and Yeshitela, 2004).The nutritional effect of supplemental nitrogen and micronutrients in the spray materials rather than the stimulant factor might be the possible reason for this.

The observations on the initial fruit set in the various treatments also showed a very positive effect. All the treatments recorded a high initial fruit set than the control.

Oosthuyse (1997) while reporting the effect of KNO_3 sprays in cvs. Tommy Atkins, Kent, Heidi and Sensation under the S. African conditions found an increase in the fruit retention as well as the final yield. Similar reports were made by Dutta (2004), Singh and Maurya (2004) and Yeshitela (2004). Results obtained from the present investigations are in tune with these findings.

Assessment of growth parameters during the fruit development showed that the treatments did not exert much influence on the fruit length, but the effect on fruit girth was significantly superior than the control in both the cvs. These observations are in conformity with the reports made elsewhere (Ataide and Jose, 2000; Yeshitela, 2004; Singh and Maurya, 2004; Dutta, 2004 and Oosthuyse, 2005).

All the treatments except T_7 and T_8 in cv. Priyor significantly affected the final fruit retention at harvest. In cv. Muvandan, the highest fruit yield was recorded in T_6 in which 65 fruits were harvested from the tagged 90 shoots, whereas, it was only 38 fruits in the control. In cv. Priyor, the highest fruit yield was recorded in T_2 in which 62 fruits were harvested from the tagged 90 shoots, whereas it was only 35 fruits in the control.

The fruit weight recorded at harvest stage in both the cvs. showed significant positive effect of different treatments over the control. KNO_3-micronutrient combination (T_3) recorded the maximum weight of individual fruit in the *cv.* Muvandan closely followed by T_6. The values recorded for all other treatments were also significantly higher than the control. In the cv. Priyor also, mean weight of fruits at harvest were significantly higher for the treatments than the control. In this case also, KNO_3-micronutrient combination (T_3) recorded the maximum yield, closely followed by NH_4NO_3 (T_4). These results are clearly conforming to the earlier reports on this aspects (Barba, 1974; Astudillo and Bondad, 1978; Bondad and Linsangan, 1979; Robbertse and Wolstenholme, 1992 and Catchpoole and Bally, 1993).

Increased fruit retention noted in the treatments of the present experiments should be also linked with the general growth enhancement of panicle especially with the inflorescence girth. The nutritional effect of the nitrates, micronutrients etc. should be the deciding factor reducing the formation of abnormal abscission zones at the panicle base leading to the premature fall of fruits.

Mckenzie (1994) while reporting the nutrient application to mango stated that aerial application of nutrients to mango is ineffective in increasing the leaf nutrient

status-probably due to the low absorptive capacity of the leaves; but noted that nutrient application in the presence of inflorescences to be effective in increasing the nutrient status affecting the floral characters positively. Oosthuyse (1996) reported that KNO_3 spray application to Tommy Atkins mango trees whilst the inflorescences were in full bloom was found to increase the fruit retention and higher yield.

In the present investigations, a follow up spray was provided in all the treatments, when the inflorescences were opening and when it started blooming. It is reasonable to assume that it would have made a '**floral nutrition**' effect and resulted in the positive influence on growth and other floral characters of opening flowers.

5.6 Carbohydrate-Nitrogen relationship during flower bud forcing

Flowering and fruit development are exhaustive processes draining out a large amount of carbohydrates (CHO) from the trees. Fruiting requires 40 –50 times more food reserves compared to development of vegetative parts (Shivasankara and Mathai, 2000).

In order to assess the physiological implications consequent to different DBC treatments, the changes in CHO and nitrogen levels in the leaves and shoots and the variation in photosynthetic attributes at different phenological stages were closely monitored during the course of studies.

The data showed a decrease in levels of CHO in both leaves and shoots in both the cvs. consequent to treatments whereas the levels of nitrogen recorded an increasing trend. Such a decrease in the levels of CHO in both leaves and shoots at a significantly higher rate may be invariably due to its consumption for the flowering and related processes. Moreover, all the emerged out panicles in the treatments showed a significant high growth rate from the initial stages itself draining out more energy reserves for the process. A rise in the level of total nitrogen was noted on the sprayed shoots during the panicle development stage.

Flowering related changes in CHO and nitrogen levels of mango leaves and shoots have been explained and reported by many-a-worker previously (Sen, 1946; Singh, 1960; Chacko, 1986; Sen *et al.*, 1965; Ravishankar and Rao, 1982; Nunez-Elisea, 1988; Patil *et. al.*, 1989 and Robbertse and Wolstenholme, 1992).

Singh (1960) opined that in all mango varieties, the highest starch reserves ,total CHO and CHO / N ratio in shoots favoured flower bud initiation and development. Sen *et al.* (1965) reported a significantly high CHO to nitrogen ratio in mango during flower bud initiation and differentiation period. Chacko (1986) reported an increase in the total nitrogen content in the stems and leaves of mango trees during flowering while Ravishankar and Rao (1982) reported a depletion in CHO levels during the panicle development stage. Robbertse and Wolstenholme (1992) observed that the starch level will start accumulating upto flowering in mango trees and showing a decline thereafter essentially diverted for flowering, fruit set and growth.

Kramer and Kozlowski (1960) while elucidating the physiological role of nitrogen compounds asserted its importance in tree crops. They are mainly concentrated in the leaves, meristematic regions and other areas of living cells which carry on the complex processes associated with growth.

Urban *et al*. (2004) while studying the effect of flowering and early fruit growth on leaf photosynthesis in mango observed lower levels of leaf nitrogen close to developing inflorescences than in vegetative leaves. Such differences in nitrogen concentration have been attributed to the proximity of strong sinks such as developing inflorescences or fruits. They also suggested that demand for nitrogen increases with fruit set. In the present experiments the level of nitrogen in the leaves and shoots at the panicle emerged out stage was higher than that in the vegetative shoots at the pre-treatment stage. Though it is in contradiction to the reports made by Urban *et al*. (2004) as quoted above, the present results can be well substantiated on the grounds that an inevitable nitrogen supplementation has resulted from the application of nitrates and other sources of nitrogen during the course of experiments. It has also possibly provided an added impetus

to the growth rate of various floral parameters viz., panicle length, girth, branching intensity of inflorescence etc. It is also reasonable to assume that the sink effects of developing inflorescences on leaf / shoot nitrogen has been well compensated by this supplemental nitrogen. Leaf nitrogen content was more in leaves than in shoots in both cultivars, irrespective of the treatments.

Protacio (2000) while elucidating the model for KNO_3 induced flowering in mango suggested that the action of KNO_3 is manifested by elevating the nitrogen levels over and above the threshold level which inturn cause synchronizing of the budbreak from shoot apices with existing floral initials. He opined that in a mature mango tree, KNO_3 spray acts as an agent that initiates flowering from tissues already competent to flower. But the exact developmental stage, which KNO_3 affects, still remains as a puzzle and the intricacies to be explored further.

The mode of action of potassium nitrate sprays on induction of flowering in mango is currently interpreted as linked to the enzymatic pathways leading to the formation of ethylene, the flowering hormone (ikisan, 2007). A sharp increase in the nitrate reductase activity has been reported in the potassium nitrate sprayed leaves and the further conversion of nitrates in the pathway is supposed to be as; nitrate → nitrite → ammonia. Ammonia is subsequently utilized in the nitrogen metabolism leading to the formation of amino acid methionine and finally to ethylene. Ethylene formed in such a way should be expected to play the key role on the nitrate induced flowering in mango.

Nevertheless these interpretations as related to the ethylene metabolism needs further in depth physiological studies to arrive at more concrete conclusions.

5.7 Assessment of photosynthetic parameters during flower bud forcing

Assessment of photosynthetic parameters during the course of investigations is yet to be conclusive in the sense that some inconsistency was notable with the recorded

values. Nevertheless, the results are interpreted and discussed here under to the extent possible.

The measurements on leaf photosynthetic rates at the flower opening stage in both did not show much significant variations among the treatments and the control. But the values recorded for the cv. Priyor during the initial stage of fruit development i.e., marble stage, showed a significant difference among the treatments than the control.

The photosynthetic rate recorded maximum values during the flower opening period in T_7 whereas T_4 and T_6 recorded highest values at fruit development stage in cv. Muvandan. In the cv. Priyor also, values for photosynthetic rate recorded during the flower opening stage did not show any significant treatment effect. But the measurements during the fruit development period in this cultivar did show a significant difference among the treatments than the control.

Chartzoulakis *et al*. (2002) reported higher photosynthetic rate in the cv. Hass avocado compared to those of cv. Fuerte. The difference was attributed to the anatomical arrangement of cells in the leaves. Cultivar Hass exhibited a higher percentage of intercellular spaces in the leaves than the cv. Fuerte.

Capellini and Dettori (1992) emphasized that the genotypic differences may influence the stomata and chlorophyll content of leaves resulting in differences in assimilation rates. Similar reports were made by Adato *et al.* (1995) and Human and Synman (1998) etc.

The variations in the photosynthetic rates observed between the two cvs. in the present investigations can be substantiated on the above lines only. Though the anatomical aspects of leaves and impact on the conductance gas exchange were not under the perview of present studies, it can be expected some leaf anatomical features unique to each of these cultivars since the cv. Muvandan is typically polyembryonic and the other one, a monoembryonic type.

Inspite of all these, the recorded values for photosynthetic rate and other attributes in cv. Priyor would throw some light on the variation in the rate of photosynthesis during flower opening and fruit development stages. Photosynthesis was noted to be at lower rate in the leaves during the fruit development stage than the flower opening stage.

The effect of fruiting on leaf nitrogen content and photosynthesis has been described for several fruit species including apple (Thiebus-Kaesberg and Lenz, 1994), olive (Proietti, 2000), peach (Rufat and DeJong, 2001) and mango (Urban *et al*., 2003). Decrease in net photosynthetic assimilation has been reported during the floral period in sweet cherry (Roper *et al*., 1988) and mango (Shivasankara and Mathai, 2000). Urban *et al*. (2004) concluded that the low photosynthetic rate of leaves close to inflorescence be probably due to the decrease in electron flow in photosystem II. But such a critical substantiation of the results /observations available from the present set of experiments is not attempted now since it needs further confirmatory estimation and standardisation.

Epilogue

It is a noteworthy conclusion from the present set of investigations that nitrate sprays (alone and with micronutrient combination) significantly effected in induction of flowering and enhancing the different floral characters in the humid tropic situations of central Kerala. Early reports on nitrate induced flowering in mango show that such treatments are effective in tropical areas where distinct wet and dry seasons prevail. The response of chemical bud forcing using nitrates is reported to be diminishing at latitudes higher than 22^{o} N or S of Equator (Mosqueda-Vazquez, 1981). The reports also note that trees planted in wet or dry subtropical climate located at 25^{o} N or S do not respond to nitrate treatments (Davenport *et al*., 1995). The positive results obtained with nitrates in the present investigations under the humid tropic Kerala situation may perhaps be due to the uniqueness in the geographic location of the state lying 8-13^{o} N of the equator having about six months rainfall from both the monsoons and typically a humid tropic situation prevails. It is a situation different from the N. Indian mango belts and even from other

parts of S. India**.** Hence, the inconsistent results reported with the nitrate treatments in mango from elsewhere (N. Indian situation or other S. Indian states) cannot be generalized as a whole and may not serve as yardstick for trying the chemicals under the situations of Kerala.

Nevertheless, the results from these investigations need further confirmatory field trials (specifically involving more indigenous mango cvs. of south-west coast) for working out standardized farmer level recommendations.

SUMMARY

6. SUMMARY

The project entitled 'Flower bud forcing in humid tropic mangoes using dormancy breakers' was taken up at Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara with the object of studying the effect of nitrogenous compounds on stimulation of flowering in the mango cvs. Muvandan and Priyor, under the humid tropical conditions of Kerala.

The results obtained are summarized as follows:

1. The phenological growth stages while flushing and shoot growth were closely monitored and changes noted as linked to variations in environmental parameters especially rainfall and temperature.

2. Flushing and shoot growth was noted in the trees selected from Sept. 2006 onwards in varying intensities, coinciding with /subsequent to a receipt of rainfall and moisture availability.

3. Application of Dormancy breaking chemicals (DBC) during October 2006. i.e., after six months of tagging the shoots did not effect in any flower induction. The shoots remained vegetative transitting through the processes of flushing and further growth.

4. Nevertheless, the treatments during the first week of December 2006 (at eight months stage) did effect the floral bud break and panicle emergence significantly. Flushing and further shoot growth was almost complete at this stage, leaves become mature, dark green and stiffy.

5. Panicle emergence was noted as rapid as seven days in T_6 (Ammonium nitrate – micronutrient combination) in cv. Muvandan and nine days in T_2 (2% Potassium nitrate) in cv. Priyor. But, comparative values for control were 34 days and 24 days respectively in these cultivars.

6. DBC application did induce more number of panicles to emerge out thereby significantly affecting the flowering intensity. The exception for this was the treatments with thiourea (T_7 and T_8) in cv. Priyor where floral stimulants was absent but resulted in further flushing and vegetative growth.

7. The effective treatments was also found to enhance in opening out more number of bisexual flowers (productive flowers) and hence positively influencing the sex ratio.

8. The various phenological events during the growth and development of emerged out inflorescence (panicles) were closely observed.

9. Application of DBC was found to significantly influence the growth of the inflorescence (panicle). The growth parameters like length of the panicle, girth at the basal portion, intensity of branching etc. were all greatly enhanced by various treatments. Longest panicles with maximum girth was noted in T_4 (0.5% Ammonium nitrate) in cv. Muvandan and T_6 (Ammonium nitrate–micronutrient combination) in cv. Priyor. Maximum branching intensity was noted in T_5 (1% Ammonium nitrate in cv. Muvandan and T_4 (0.5% Ammonium nitrate) in cv. Priyor.

10. Treatment-combination of micronutrients with KNO_3 as well as NH_4NO_3 effected in emerging out mixed panicles (5-10%) along with purely generative panicles in both the cultivars.

11. All the effective treatments significantly enhanced the fruit growth and development i.e., fruit length, girth, initial number of fruits set per inflorescence and the final number of fruits carried to maturity. The maximum fruit length was recorded in potassium nitrate combination with micronutrients in cv. Muvandan and 2 per cent potassium nitrate in cv. Priyor. The maximum fruit girth was observed in the treatment involving 1 per cent thiourea of the cv. Muvandan and 0.5 per cent ammonium nitrate in cv. Priyor. The initial fruit set and the final fruit yield were

highest in T_6 (Ammonium nitrate micronutrient combination) in cv. Muvandan and T_2 (2 % potassium nitrate) in cv. Priyor.

12. The fruit characters fruit length, girth and weight were found enhanced by different treatments. In cv. Muvandan, fruit length and weight was highest in T_6 and in cv. Priyor, in T_3 respectively. Fruit girth was maximum in 0.5 per cent ammonium nitrate. In cv. Priyor, maximum fruit length and weight was observed in potassium nitrate combination with micronutrients. The highest fruit girth was recorded in 0.5 per cent ammonium nitrate.

13. A decrease in the levels of carbohydrates was noted in both the shoots and leaves during the panicle development and flower opening stage, whereas level of nitrogen showed an upward trend.

14. Treatments did not show much significant variation with respect to leaf photosynthetic rates at the flower opening stage in both the cvs. On the contrary, the measurements showed significant difference among the treatments and the control in cv. Priyor, during the fruit development stage. These estimation need further confirmatory observations.

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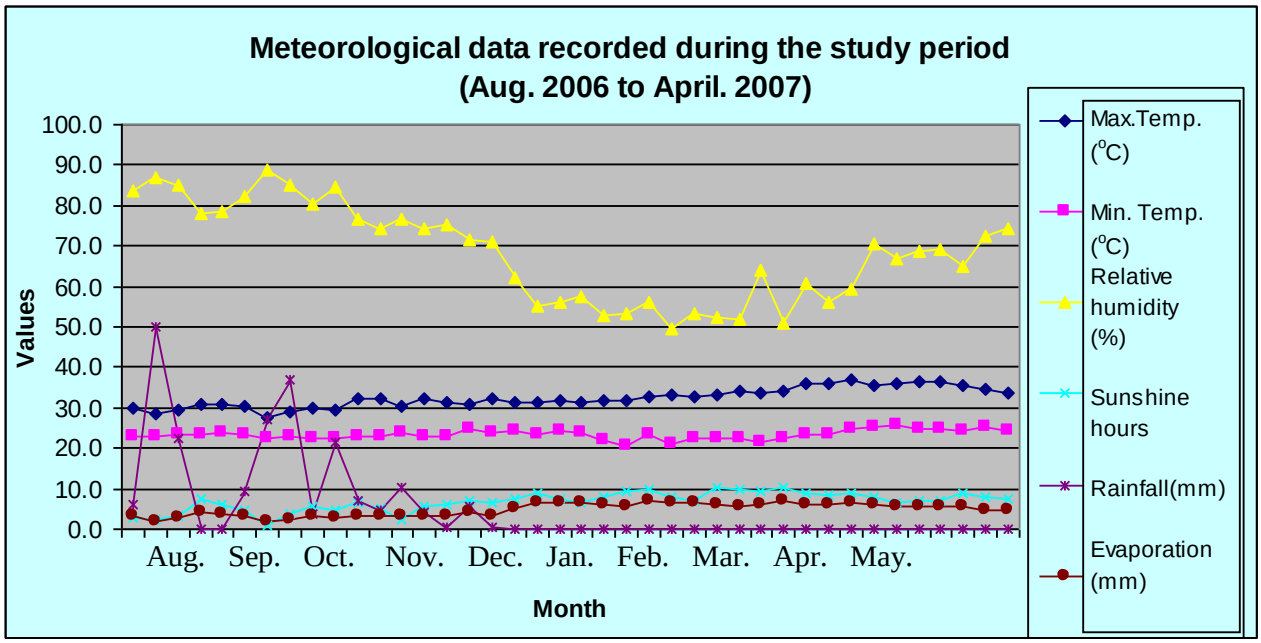
*Originals not seen

Appendix.1. Meteorological data during the study period (Aug. 2006 to May 2007)

Month	Date	Temperaure (°C)		Relative humidity (%)	Sun shine (hrs)	Rainfall (mm)	Evaporation (mm)
		MAX	MIN				
Aug.2006	**07/08/06**	**30.1**	**22.9**	**83**	**3.0**	**6.0**	**3.4**
	14/08/06	**28.3**	**22.7**	**87**	**2.5**	**50.2**	**2.1**
	21/08/06	**29.5**	**23.1**	**85**	**3.4**	**22.4**	**2.7**
	28/08/06	**31.0**	**23.6**	**78**	**7.3**	**0.0**	**4.3**
Sept.	**04/09/06**	**30.9**	**23.7**	**78**	**6.0**	**0.0**	**3.9**
	11/09/06	**30.6**	**23.5**	**82**	**4.5**	**9.3**	**3.3**
	18/09/06	**27.8**	**22.5**	**89**	**1.1**	**27.3**	**1.7**
	25/09/06	**29.1**	**22.7**	**85**	**3.7**	**36.9**	**2.2**
Oct.	**02/10/06**	**30.0**	**22.6**	**81**	**5.7**	**3.9**	**3.2**
	09/10/06	**29.3**	**22.5**	**85**	**4.6**	**21.3**	**2.7**
	16/10/06	**32.0**	**23.1**	**77**	**6.7**	**7.2**	**3.4**
	23/10/06	**32.4**	**22.7**	**74**	**5.3**	**4.7**	**3.1**
	30/10/06	**30.6**	**23.6**	**76**	**2.5**	**10.3**	**3.0**
Nov.	**06/11/06**	**32.4**	**23.0**	**74**	**5.7**	**4.4**	**3.1**
	13/11/06	**31.1**	**22.9**	**75**	**6.1**	**0.5**	**3.5**
	20/11/06	**31.1**	**24.7**	**72**	**6.8**	**5.7**	**4.2**
	27/11/06	**32.3**	**23.9**	**71**	**6.8**	**0.7**	**3.5**
Dec.	**04/12/06**	**31.2**	**24.5**	**62**	**7.4**	**0.0**	**5.2**
	11/12/06	**31.5**	**23.6**	**55**	**9.0**	**0.0**	**6.5**
	18/12/06	**31.6**	**24.1**	**56**	**7.7**	**0.0**	**6.7**
	25/12/06	**31.3**	**24.0**	**57**	**6.8**	**0.0**	**6.6**
Jan.2007	**01/01/07**	**31.7**	**21.9**	**53**	**7.8**	**0.0**	**5.8**
	08/01/07	**31.7**	**20.5**	**53**	**9.3**	**0.0**	**5.7**
	15/01/07	**32.5**	**23.5**	**56**	**9.6**	**0.0**	**6.8**
	22/01/07	**33.2**	**21.0**	**50**	**8.1**	**0.0**	**6.4**
	29/01/07	**32.6**	**22.7**	**53**	**7.2**	**0.0**	**6.7**
Feb.	**05/02/07**	**33.2**	**22.4**	**52**	**10.2**	**0.0**	**6.1**
	12/02/07	**34.1**	**22.5**	**52**	**9.7**	**0.0**	**5.7**
	19/02/07	**33.7**	**21.4**	**64**	**9.3**	**0.0**	**5.9**
	26/02/07	**34.1**	**22.5**	**51**	**10.3**	**0.0**	**7.2**
Mar.	**05/03/07**	**35.8**	**23.5**	**61**	**9.1**	**0.0**	**6.2**
	12/03/07	**36.1**	**23.5**	**56**	**8.5**	**0.0**	**5.8**
	19/03/07	**37.1**	**24.5**	**59**	**8.7**	**0.0**	**6.5**
	26/03/07	**35.6**	**25.1**	**70**	**7.8**	**0.0**	**6.1**
Apr.2007	**2/4/2007**	**36.2**	**25.8**	**67**	**6.6**	**0.0**	**5.7**
	9/4/2007	**36.6**	**24.7**	**69**	**7.1**	**0.0**	**5.5**
	16/4/07	**36.5**	**24.6**	**69**	**6.9**	**0.0**	**5.6**
	23/4/07	**35.3**	**24.2**	**65**	**9.1**	**0.0**	**5.6**
	30/4/07	**34.6**	**25.2**	**73**	**7.8**	**0.0**	**4.9**
May-07	**7/5/2007**	**33.7**	**24.5**	**75**	**7.3**	**0.0**	**4.7**

Appendix - II


Meteorological data recorded during the study period
(Aug. 2006 to April. 2007)
Values
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May.
Month
Max.Temp. (°C)
Min. Temp. (°C)
Relative humidity (%)
Sunshine hours
Rainfall(mm)
Evaporation (mm)

FLOWER BUD FORCING IN HUMID TROPIC MANGOES USING DORMANCY BREAKERS

By

HIMA K.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

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2007

ABSTRACT

The project on **'Flower bud forcing in humid tropic mangoes using dormancy breakers'** was taken up at Department of Pomology and Floriculture, College of Horticulture during March 2006 to April 2007.

The objective of the experiment was to study the effect of nitrogen compounds, viz., nitrates and their combinations with micronutrients and thiourea on stimulation of flowering in mango cultivars Muvandan and Priyor under the humid tropic situations of Kerala.

The treatments involved KNO_3 at 1.00 per cent and 2.00 per cent levels, NH_4NO_3 at 0.50 per cent and 1.00 per cent, their combination with micronutrients and thiourea at 0.50 per cent and 1.00 per cent levels.

The treatments were imposed as foliar sprays at three stages. First spray was given during the first week of Oct.2006 (6 months after tagging); second during first week of Dec.2006 and a follow up spray after the commencement of panicle emergence and flower opening.

History of the shoots prior to the treatment imposition, phenological growth stages etc. were closely monitored right from the tagging; simultaneously noting the variation in the climatic parameters. The trees showed flushing and vegetative shoot growth subsequent to the receipt of a rainfall during September 2006. A temporary withdrawal of rainfall and subsequent resurgence coincided with / probably triggered the events leading to flushing and shoot growth as noted above.

Application of DBC during the first week of September 2006 did not evoke any floral stimulation on the applied shoots, but maintained a vegetative state; but it did result in floral stimulation manifested at various levels when the treatments were imposed during December 2006. The leaves had become dark green and turned stiff by this stage.

It was noted in all the treatments other than the thiourea application on cv. Priyor. An early emergence of panicles was conspicuously noted in all the the effective treatments. It was as rapid as seven days in NH_4NO_3, micronutrient combination in cv. Muvandan and nine days in KNO_3-micronutrient combination. KNO_3 treatments in cv. Priyor also resulted in early flowering than the control. Intensity of flowering /number of shoots emerging out inflorescences was also significantly promoted by the various effective DBC treatments.

Ammonium nitrate –micronutrient combination and 2 per cent KNO_3 were superior in this aspect. The treatments were superior not only in enabling the opening of more number of productive flowers (bisexual flowers) on the panicles, but effecting in a high initial fruit set also.

'Floral stimulation effect' of various DBC treatments of nitrogenous compounds, micronutrient combination and thiourea translated further as a 'floral nutrition effect' later. Probable extra nutrition result out from the follow up sprays during Dec. 2006 on the panicles at various levels of flower opening may be yet another supplementary factor. All the effective treatments greatly enhanced the growth of the panicles by increasing the various growth parameters, viz., length of the panicle, girth of the panicle at the base and the branching intensity.

Treatments did enhance the girth of the developing fruits; but the effect on fruit length was not conspicuous. Similarly, final retention of fruits at harvest stage was also significantly superior than the control; accordingly increasing the yield and production efficiency as a whole. NH_4NO_3- micronutrient combination effected the highest yield in cv. Muvandan and 2 per cent KNO_3 in cv. Priyor.

In all the effective treatments, level of carbohydrates was found decreasing in shoots and leaves during the panicle development stages whereas the level of nitrogen showed an upward trend. A probable shifting of energy sources to the sites of accelerated growth and development of emerged out inflorescences is indicated with a dilution effect

in adjacent leaves and shoots. Accumulated nitrogen including the supplemental content resulted from the applied nitrogen sources might be the basic material for further structural development.

Measurements on photosynthesis and related attributes showed significant variation among the treatments and control at the fruit development stage in cv.Priyor. But, estimation in cv. Muvandan was not consistent and hence the aspect needs further confirmation.

Present investigations clearly indicate the potential of nitrogenous compounds (specifically nitrates and micronutrient combination) as DBC to stimulate flowering and fruiting in humid tropic mangoes. Further standardization on timing of application, maturity of shoots etc. and whole tree trials in farmers field involving more indigenous and other cv. of mangoes of south-west coast comprise the future line of work in this aspect.