FLOWER FORCING TECHNOLOGY FOR OFF SEASON MANGO PRODUCTION

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I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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It is a fact that the remembrance of Allah brings peace in the heart. It is better to ponder over the verses to bring us even closer to Allah (swt).

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

An experiment was accomplished in the Roof top of Sher-e-Bangla Agricultural University during the period of July, 2018 to January, 2019 to adopt flower forcing technology for off season mango production. Four treatments *viz.* No chemical application (T_0), 1g PBZ/L water (T_1), 0.5g PBZ/L water (T_2), 0.25g PBZ/L water were studied in this experiment following completely randomized design with six replications (CRD). Data on flowering and fruit related parameter were taken and significant variation was observed with different treatments. Among them, maximum inflorescence number/plant (8.7), fruit number/inflorescence (4.5), fruit number/plant (30.8), harvested fruits/plant (8.3), fruit length (11.7 cm), single fruit weight (273.8 g) and yield/plant (2.3 kg) was found in T_2 treatment whereas maximum days required to first flowering (100.0 days), minimum inflorescence number/plant (3.2), fruit number/inflorescence (3.0), fruit number/plant (12.3) recorded in T_3 treatment and no flowering observed in control. So, it can be concluded that, significant treatment effects were observed on different parameters and T_2 treatment (0.5g PBZ/L water) gave best results. Therefore, it can also be articulated that a new flower forcing technology is developed and it will be potential for off season mango production.

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CHAPTER I

INTRODUCTION

Mango (*Mangifera indica*), belongs to the family Anacardiaceae, a tropical to sub-tropical fruit, originated in the Indian sub-continent in the prehistoric times and often mentioned as the 'King of fruits' (Purseglove, 1972). It has been reported that about 4,000 years ago the mango plant was seen in India and since then it has been growing in the Indo-Bengal region where it was first cultivated. In 2017, global production of mangoes (report includes mangosteens and guavas) was 50.6 million tones, led by India with 39% (19.5 million tons) of the world total China (4.8 million tons) and Thailand (3.8 million tons) were the next largest producers. In Bangladesh, it occupies an area of 109584 acres of land with an annual production of 1165804 metric ton (MT) (BBS, 2019). Mango grows in almost all of Bangladesh but commercial and good quality mangoes grown in the North-Western districts of the country.

Mango is a tropical perennial fruit crop but in Bangladesh mango fruiting is seasonal. In most mango producing regions of Bangladesh, the trees give fruits only once in a year. During the peak season (15 May to 15 August), prices for mango fruits at farm gate are very low because of the glut in the market. Mango is a highly perishable fruit with a shelf life of 7 to 10 days depending on the stage of maturity at harvest. Therefore, once the fruits attain maturity or ripen, they have to be harvested or left to spoil on the tree. The majority of the farmers lack cold storage facilities or postharvest technologies to extend the shelf life and the marketing period of the highly perishable fruits and therefore they are forced to sell at the prevailing prices making huge losses (HCDA, 2011). Apart from lost profits for the farmers, seasonality in mango production is a problem for the fruit processing industries. These industries receive fewer mango fruits therefore operate below capacity during the off season (September to April). This not only denies the proprietors of these factories continuous income, but also creates seasonal unemployment for the workers. On the other hand, consumers are denied the benefit of continuous supply of mango at reasonable prices because during the low season, the prices of mango fruits are high.

Seasonality in mango production is a major factor contributing to the high postharvest losses (≥50%) reported in the mango value chain. Effective strategies to address seasonality can contribute significantly to mango production loss reduction. Although the flower induction technologies have been used in different countries before such as Thailand, Philippines, Japan, India etc. Flower forcing is a scientific agricultural procedure which is used to produce flowers, fruits, vegetables out of season. But in Bangladesh it is not used before. If we can apply this technology mango production in desire month can be possible. The flower induction technologies have been used to induce off-season flowering in mango trees thereby leading to year-round fruit production. Some of the chemicals such as potassium nitrate, ethephon and paclobutrazol have been used for flower induction in off season. Efficacy of these chemicals is dependent on several factors including mango variety, dosing, time of application and stage of development among others (Galan and Fernandez, 1987). For these chemicals to be successfully promoted among the small holder farmers for the desired benefits of off-season flower induction and to ensure year-round production there is need for studies to establish the effective dosing range in the major commercial varieties of mango.

OBJECTIVES

- To adopt flower forcing technology for off season mango production
- To determine the effect of different PBZ doses on reproductive growth parameters and yield components of 'Nam dok mai' mango.

CHAPTER II
REVIEW OF LITERATURE

Mango is a juicy stone fruit and one of the most frequently consumed fruit around the world as well as in Bangladesh. There are many hundreds of named mango cultivars. According to consumer interest and worlds demand, the mango is now cultivated in most frost-free tropical and warmer subtropical climates. Some significant research work which have been done in home and abroad related to this experiment have been presented in this chapter.

2.1 Factors that contribute to biennial bearing in mangoes

Varieties with a long growth cycle show natural biennial tendency. Mangos show clearly demarcated and very distinct growth patterns during an annual growth cycle. New growth flushes emerge after harvesting and these flushes mature and remain dormant for some period before the trees flower. Again, from flowering to fruit harvesting there is a period called fruit development. After harvesting, the vegetative flushes emerge and this growth cycle continues (Usha and Shiva, 2014).

Time spans for the periods from harvesting to flushing, from flushing to flowering and from flowering to harvesting vary according to variety. Time taken from flowering to harvesting may vary from 3.5 to 5 months for a range of mango varieties, and based on these the varieties may be classified as early, mid-season and late varieties. Usually for a single variety time taken from flowering to fruit maturity is fairly constant and may slightly vary with climatic conditions experienced during fruit development (Usha and Shiva, 2014).

Thus, for late varieties it takes more than 12 months to complete a growth cycle. Then after giving a heavy crop in one-year, late varieties have less time period before next flowering to produce the flush and to accumulate reserves for the next crop. Then that crop in the second year may be poor or sometimes trees may not flower at all if the shoots are not physiologically conditioned for flowering by the time next flowering season starts (Usha and Shiva, 2014).

Even if a regular variety is grown under rain fed conditions, irregular bearing may be observed, not necessarily biennial bearing, in line with the variations in climatic conditions. The primary climatic factor affecting the irregular bearing is rainfall. If rains delay after harvesting, there will be a longer time period between harvesting and the following growth flush. Then the time period available for trees to have the rest before flowering and accumulate food reserves is shorter than that happen under a normal season. Under such conditions, poor crops will be produced in the following season (Usha and Shiva, 2014).

If mango trees under rain fed conditions face this kind of irregular bearing, then the only option available to control it is to provide irrigation facilities. In so doing the productivity of the orchards may be significantly improved.

If mango trees are established in very fertile, deep rich soils or in places with high water tables, or in locations with lot of shade, irregular bearing may be a problem. Under such conditions, it is difficult to control the vegetative growth of trees. Especially in places where growth checks cannot be achieved between flushing and flowering as a result of too much nitrogen or too much water, irregular crops may be produced. Under this kind of situation also the crop load depends on rainfall. However, heavy crops may be possible only when drought periods occur. Drought affects the availability of nitrogen and water to trees and results to growth control for successful flowering and fruiting under the drought conditions (Usha and Shiva, 2014).

To control irregular bearing under circumstances of very fertile, deep rich soils or in places with high water tables, chemical growth retardants may be quite helpful. Also, change of varieties is another possibility (Usha and Shiva, 2014).

If the variety, growing environment and planting site is alright, still the biennial or irregular bearing problem might exist due to lack of a proper tree management. If the trees are subjected to a management system based on tree phenological cycle, this irregular bearing may be controlled effectively (Davenport, 2003). Some of important management tools available for control of irregular bearing are nitrogen and irrigation (James et al., 1992). Special care should be taken to apply nitrogen and water at right time. Another key factor when managing mango flowering is proper management of vegetative growth in tree canopies to allow all the stems in a canopy to be in the same physiological stage of maturity when KNO_3 applications are made (Davenport, 2000). Synchronized growth is best accomplished by proper tip-pruning all terminal stems on trees (Davenport, 2003, 2006).

Proper tip-pruning not only produces a specifically timed uniform flush of vegetative growth throughout the canopy, but it removes factors that inhibit growth and flower formation in stems derived from the previous season's flowering and fruiting panicles (Davenport, 2000, 2009). Tip-pruning mature trees quickly results in a synchronous flush of lateral vegetative shoots if water is adequate (Davenport, 2003). If the lateral stems produced by this pruning event subsequently remain in rest for 4 or 5 months (depending on cultivar) in warm temperatures, then flowering will usually occur when shoots are initiated to grow by foliar application of potassium or ammonium nitrate (Davenport, 2006).

In addition, crop protection also affects irregular bearing. If flowers are not protected from pests like mango hoppers or from diseases like anthracnose, the crop will be very poor in that season. However, the following season crop may be little higher due to the buildup of more tree reserves essential from flowering to harvesting to control this (Usha and shiva, 2014).

In addition, the behavior could be due to plant hormones, particularly gibberellins produced in excess in the "on" years in the embryos of the young fruit. It could also be caused by depletion of carbohydrate reserves in the tree (Davenport, 2003).

2.2 Different flower forcing

Disha *et al.* (2018) reported that certain chemical sprays found very effective for the reduction of intensity and losses due to these limitations. Foliar application of KNO_3, Ethrel and urea significantly increase the flowering percentage. Applications of KNO_3 induce early flowering and reduced alternate bearing. Ethrel release ethylene gas and turn triggering the mechanism of flowering. In addition, urea spray was reported to be helpful for better retention of flowering in certain crops. It is also observed that delayed flowering in mango fail to fetch attractive price from the market. Delayed flowering also has risk due to early rainfall, which may bring fruit drop and deterioration in quality.

Maloba *et al.*, (2017) studied the efficacy of two flower induction chemicals, potassium nitrate (KNO_3) and ethephon on reproductive growth parameters and yield components were evaluated on two mango varieties: 'Apple' and 'Ngowe'. KNO_3 was applied at two concentrations (2 and 4%), and ethephon (600 and 1000 ppm) then compared to control (water). They were applied to trees which failed to flower/set fruit in 2014 season. There effect was established from reproductive growth parameters: days to flowering, number of panicles per tree, fruit set per 20 panicles, fruit fall and hormonal effect. KNO_3 (4%) and ethephon increased percentage flowering in both 'Ngowe' and 'Apple' and AEZs (Agro-Ecological Zones), significantly ($p < 0.05$) shortened time to flowering and increased fruit set. The findings show that KNO_3 and ethephon can be used to induce flowering/fruiting in mango fruits. These technologies can therefore be applied to induce off season mango production to address seasonality and reduce postharvest losses during the peak season.

Hari Prasath *et al.*, (2017) conducted a field experiment on pruning treatment in 15-year-old tamarind plantation at Harur taluk, Dharmapuri district, Tamil Nadu. The tamarind trees were imposed with three pruning intensities (15 % pruning, 30 % pruning and 50 % pruning) and control for enhancing the flowering and fruiting in Tamarind. The total nitrogen (2.25 %), total phosphorus (0.302 %), total potassium (0.207 %), chlorophyll 'b' (0.672 mg g-1) and total chlorophyll

(1.046 mg g-1) were found superior in T_2 (30 % pruning) and the lowest leaf nutrient status (Total nitrogen - 1.45 %, Total phosphorus - 0.251 %, Total Potassium - 0.140 %, Chlorophyll 'a' – 0.263 mg g-1and chlorophyll content, Chlorophyll 'b' - 0.403 mg g-1, Total chlorophyll - 0.666 mg g-1) in T4 (Control-Unpruned trees). The maximum tamarind fruit yield was exhibited in 30 per cent pruning with the fruit yield of 39 kg. And the minimum was recorded in control (14 kg.). To conclude the study, the moderate pruning in tamarind tree enhanced the nutrient status in leaf and fruit yield.

Kishore *et al*., (2015) reported that Paclobutrazol (PBZ), a triazole derivative, has been effectively used to induce and manipulate flowering, fruiting and tree vigour in several perennial fruit crops. However, its use in mango is quite common. Soil application of paclobutrazol has been efficacious in promoting flowering and increasing yield in many fruit crops. However, there are some conflicting reports on its impact on fruit quality parameters. Besides reducing gibberellins level, PBZ increases cytokinin contents, root activity and C: N ratio, whereas its influence on nutrient uptake lacks consistency. PBZ also affects microbial population and dehydrogenase activity in soil. PBZ has been characterized as an environmentally stable compound in soil and water environments with a half-life of more than a year under both aerobic and anaerobic conditions. However, its residue could not be detected above quantifiable level (0.01 ppm) in soils and fruits when applied in optimized rate. The potential of PBZ to contaminate groundwater at optimum concentrations is low however the risk of its exposure to aquatic life is high. PBZ is considered moderately hazardous for human beings with remote chance of being genotoxic and carcinogenic. In view of the above, optimized use of the PBZ to derive maximum benefit with least undesirable impact on food and environmental safety aspects is suggested**.**

Sarker and Rahim, (2013) conducted an experiment to determine the effects of KNO_3 and urea in manipulating the harvesting time and increasing yield as well as quality of nine years old mango (*Mangifera indica* L.) cv. Amrapali plants was carried out at the BAU Germplasm Centre, Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from September 2006 to July 2007. The five treatments included in the experiment were potassium nitrate at 4%, 6% and 8%; urea at 2% and 4% and the control (water spray). Foliar spraying of urea at 4% exhibited better performance in relation to terminal shoot length, number of leaves and leaf area and potassium nitrate at 4% gave superior results with respect to length and breadth of panicle and number of secondary branches per panicle compared to control. The plants sprayed with KNO_3 at 4% expressed earlier panicle appearance by 17 days as compared to delayed appearance of panicle in untreated control plants. The plants received KNO_3 at 4% produced the highest number of panicles per plant (220.67) whereas the control plants had the least number of panicles (107.67). Regardless of concentration, KNO_3 and urea manifested slightly earlier harvest (5 days) compared to control. Plants treated with KNO_3 at 4% noted the highest number of fruits per plant (136.67) compared to control (62.67). The treatment urea at 4% resulted in the biggest fruit (202.83g) and the control plants exhibited the smallest fruit (175.00g). Potassium nitrate at 4% gave maximum yield (23.14 kg/plant) as compared to minimum yield (9.12 kg/plant) in the control (water spray).

Protacio *et al.*, (2009) reported that mango shoots must have low GA content to allow total non-structural carbohydrates, primarily starch, to accumulate in the leaves and buds leading to the early formation of floral initials. Floral initials were present before KNO_3 application indicating that this chemical merely induces bud break of quiescent pre-existing floral buds and is not responsible for the transformation of vegetative buds to reproductive ones. An experiment was conducted using 13-year old 'Carabao' mango trees wherein the level of gibberellic acid (GA_3) was artificially reduced through application of 1.0 gram of paclobutrazol (PBZ) per meter canopy diameter. Levels of GA_3, total non-structural carbohydrates, and presence of floral initials in the terminal shoots were followed monthly. Three months after PBZ application, GA_3 content of shoots in PBZ- treated trees decreased by more than 79% compared to the control. At this time, 56% of the terminal shoots in PBZ-treated trees had floral initials and none in the control trees. By the fourth month, shoots with floral initials in PBZ-treated trees increased to 86% while 42% of the control trees also had floral initials just before KNO_3 was sprayed. At the same time, a peak in the 1-aminocyclopropane 1-carboxylic acid levels also coincided with the development of floral initials in PBZ-treated trees; indicating a possible involvement of the ethylene biosynthetic pathway in floral initiation in mango. The development of floral initials was accompanied by a decrease in GA_3 levels and a concomitant increase in starch levels in the apical buds, leaves and stem. Induction of flower bud break by 2% KNO_3 resulted in a flower intensity index of 4 (flowers all over the canopy) and longer inflorescences in PBZ-treated trees while control trees exhibited a flower intensity index of 2 (less than 25% of the canopy have flowers) that mango shoots must have low GA content to allow total non-structural carbohydrates, primarily starch, to accumulate in the leaves and buds leading to the early formation of floral initials. Floral initials were present before KNO_3 application indicating that this chemical merely induces bud break of quiescent pre-existing floral buds and is not responsible for the transformation of vegetative buds to reproductive ones.

GAO Li-xia *et al.*, (2009) investigated the effects of spraying different concentration of potassium dihydrogen phosphate and N6-benzyladenine on flower induction of potted seedlings of Arizona.[Method] With tissue culture seedlings of Arizona as tested materials, the bloom tests of potted seedlings of Arizona were carried out by spraying different concentration of potassium dihydrogen phosphate and N6-benzyladenine.Some biological characteristics such as the number of bud differentiation, leaf number, flower diameter, the length of flower palm were determined to study the effects of different chemical treatments on flower induction of potted seedlings of Arizona. The application of 3 mg/L potassium dihydrogen phosphate could promote potted seedlings of Arizona to flower earlier; the effect of 3 mg/L potassium dihydrogen phosphate +20 mg/L N 6-benzyladenine was the best. The flower bud differentiation was early and more, with the flowering rate of 90%,and the flowering branches were long and sturdy; when N6-benzyladenine was 40 mg/L, the growth of potted seedlings of Arizona was inhibited;N6-benzyladenine had a certain inhibition on leaf etiolation of potted seedlings of Arizona. The technologies of improving the quality of potted seedlings of Arizona and the flowering uniformity were obtained, which increased the level of large-scale cultivation of domestic potted *A. andraeanum*.

Mochizuki *et al.*, (2009) discussed the technological factors for Japanese forcing culture in details. In Japan, more than 90% of strawberry production is forcing culture. In Japanese forcing culture, flowering is induced by several artificial methods (e.g., chilling, short-day) in autumn, and plants are grown under a heated greenhouse to avoid the induction of dormancy and dwarfing, and kept in a non-dormant status to continue harvest. Normally harvest period is from late November to June. The accumulation of the technological research and development for forcing contributes to such a long-term harvest. In forcing culture, it is important to understand the status of dormancy in strawberry plants. Controlling dormancy is a key to realize the long-term successive harvest during winter to early summer. Basically, heating at a minimum of 5°C and supplemental lighting are applied to avoid the onset of the dormancy.

Poerwanto *et al*., (2008) reported that the application of paclobutrazol followed by application of a dormancy-breaking substance has forced mango, citrus and mangosteen trees to produce off-season flowers. With this technique, mango trees can be forced to flower practically at any time; while mangosteen trees flowered 3 months earlier than the control trees. However, the same treatment given to durian and rambutan trees has not shown any satisfactory results. It is possible to induce flowering in durian by the application of paclobutrazol in combination with the application of plastic mulching to prevent infiltration of rainfall into the soil. In rambutan, ringing treatments induced the trees to flower and produce fruit off-season. The ringed trees started to flower 4 months earlier than the control trees without any effect on the size and number of inflorescences, and the number of flowers per inflorescence.

Pogonyi *et al.*, (2005) examined the effect of grafting on the yield and fruit characteristics in tomato cultivar. Lemance F_1 was used as scion and Beaufort as rootstock. Earliness, total yield, fruit weight and number of each graft combination were recorded. Moreover, the main fruit components such as Brix°, carbohydrate, acid and the carbohydrate/acid ratio were analysed. We harvested more yield from the grafted plants. The increase of yield was mainly caused by higher average fruit weight. Brix° and carbohydrate content were lower in the fruits on grafted plants than on ungrafted ones but there was no significant difference in acid content.

Yeshitela *et al.*, (2005) studied the effects of leaf applications of potassium nitrate (KNO_3*)*, alone and in combination with urea at different concentrations on flowering, fruit set and fruit quality of 'Tommy Atkins' mango grown in the rift valley of Ethiopia were evaluated. The trees were characterised by erratic flowering, continuous and high intensity of vegetative growth as well as irregular bearing. Uniform trees were selected for a randomised complete block design experiment with three replications and three trees per plot. Spraying was conducted initially on the immature postharvest flushes and then repeated after the flushes had matured and had dark green leaves. Potassium nitrate concentrations especially in combination with urea (5-liter solution of 4% $KN0_3$+O.5 g urea tree- 1 and 5 liters of 4% $KN0_3$+1 g urea tree-I) produced better results for most of the flowering and yield parameters. There was a non-significant difference for the qualitative parameters between the treated and non-treated trees. The supplementation of nitrogen through the spraying of KNO_3 and urea is believed to be the reason for the observed greater flowering and yield results of the sprayed relative to the unsprayed trees.

Kun *et al.*, (2004) investigated the effects of different planting methods on growth characters and yield components of vegetable soybean Qingsu No.2 under plastic tunnel were compared, and the optimum seedling age of transplanting and the appropriate planting density for the vegetable soybean were also explored. The results showed that protected culture changed the phenophase of vegetable soybean and made its growth period short. Forcing culture could control the plant height and make the internode length short, the flowering time ahead, the pod-bearing close and the seed expansion rapid, and also make the soybean come into market ahead of time. Raising seedlings and then transplanting is an effective method for the early maturing and high yielding vegetable soybean under protected culture. The optimum seedling age for transplanting is 10～15 days, and planting density is 8000 holes/666.7m^2 and 2 plants/hole.

O'Hare, T. J. (2004) reported that root temperature has a direct effect on the length of the shoot dormancy period, with high temperatures reducing this period and the subsequent level of floral initiation. However, an extended period of dormancy in itself is not sufficient for floral initiation, with low shoot temperatures also a necessary prerequisite. Potted lychee trees (cv. Tai so) with mature vegetative flushes were grown under three day/night temperature regimes known to induce floral (18/18°C), intermediate (23/18°C) and vegetative (28/23°C) shoot structures. Heating roots respective to shoots accelerated bud-break and shoot emergence, but reduced the level of floral initiation in emergent shoots. At 18/13°C, root temperatures of 20 and 25°C decreased the period of shoot dormancy from 9 weeks to 5 and 3 weeks, respectively. A root temperature of 20°C also increased the proportion of both leafy and stunted panicles to normal leafless panicles, and reduced the number of axillary panicles accompanying each terminal panicle. A root temperature of 25°C produced only vegetative shoots. At 23/18°C, heating roots increased the proportion of vegetative shoots and partially emerged buds to leafy and stunted panicles as well as accelerating bud-break. Cooling of roots in relation to the shoot resulted in non-emergence of buds at both 28/23 and 23/18°C. Bud-break did not occur until root cooling was terminated and root temperature returned to that of the shoot. At 23/18°C, subsequent emergent shoots had a greater proportion of leafy panicles relative to control trees. At 28/23°C, all emergent shoots remained vegetative. Lychee floral initiation is influenced by both root and shoot temperature.

Barba, (2002) conducted an experiment where ten lychee trees var. "UPLB Red" were ringed to promote flowering. Five permanently wilted partly because of water stress. Girdling was made in Dec 2001, when the weather was still wet, on trees with immature leaves (late flush). However, unexpected dry spell occured in January 2002 when the author was out of town and the trees were not watered to avert the water stress caused by girdling. Girdling is normally made in August during active growth and rainy weather. Degree of girdling is also a factor. Although this was not meant to be an experiment, enough information could be derived to indicate the potential of girdling to promote flowering in lychee: 1) Four of the surviving trees flowered. The smallest did not. 2) The trees are about 6 years old, normally too young and too small to flower. The original "UPLB Red" mother tree which the author planted at the UPLB-CA Horticulture Orchard in 1971 flowered in 1985 after 14 years. 3) All trees of this variety at the Horticulture Orchard with immature leaves in December 2001 did not flower naturally. Only dormant trees at the Horticulture Nursery and Orchard as well as those of Dr. Leo Namuco at Pleasant Village, Los Banos and in Sta. Maria, Laguna [Philippines] flowered in January 2002. 4) Leaves of the girdled trees at IPB were immature in December 2001. 5) Unexpectedly, two flower panicles emerged at the trunk near the girdle of one tree. There is an opinion at IPB that girdling, a routine practice in Hawaii.

Kubota *et al.*, (2001) investigated the effect of photoperiod on a potted grape 'Pione'; treated for 13 weeks from the end of December under warming conditions, changing the time zone with a plant growing lamp for long days and interrupting the dark period, resulting in new tree growth and flower bud differentiation. When the length of the light was kept for 16 hours after sunset or sunrise, and 3 hours before sunset and before sunrise, the length of the new treetops, the number of subtree leaves and the number of new tree leaves were measured. In terms of area, the growth of new shoots was significantly better than that of the natural day length control group, and the difference between the long day treatment group and the control group was notable in the number of sub-tree leaves. The number of radix was about three times that of the control group, but there was almost no difference in shoot growth and flower bud differentiation within the long-day-treated section. The dark period was 2 hours after sunset 3, 6 and 9 hours. When suspending treatment was performed, both the growth of new shoots and the flower bud differentiation were superior to the control group, but there was almost no difference within the section where the dark period was suspended. It was bought. In the 24-hour photoperiod-ku, which does not give a dark period at all, than any other ward is promoted shoot growth and flower bud differentiation, Gen Hanabusa base was about four times that of the control group.

Protacio, (2000) presented a model explaining the effect of the potassium nitrate on mango flowering within the framework of developmental biology concepts. This model redirects our fascination with a flower stimulus to one where an inhibitor controls flowering. The model assumes that a tree sprayed with potassium nitrate is already competent to flower but is inhibited from doing so by gibberellic acid (GA). The inhibitory effect of GA probably arises from its ability to mobilize carbohydrates thereby preventing starch accumulation. Once GA levels fall below a threshold, starch can start to accumulate allowing the tree's competence to flower to be expressed. After enough starch has accumulated, floral initiation will ensue but remains quiescent until conditions favorable for flowering are achieved. Depending on the tree's nitrogen content and balance of growth regulators, floral development may continue or shift to a vegetative flush as the tissues are not yet determined or committed to a floral development program. Potassium nitrate probably acts by elevating nitrogen levels over a nitrogen threshold thereby synchronizing bud break from apices with existing floral initials. The signaling process is probably mediated by polyamines or ethylene. Corraboratory evidence, from local as well as international studies, are presented to support each component of the model.

Basak *et al.*, (2000) reported that Prohexadione-Ca is an inhibitor of late stages of gibberellin biosynthesis. This compound is under actual development for use as a growth retardant in different crops. Trials with prohexadione-Ca to control vegetative growth of apple, pear and (prune) plum trees were carried out over three seasons (1995–1997) in Poland. The following cultivars were used - apple: 'Lobo', 'Gloster' and 'Jonagold', pear: Conference, plum: 'Stanley', 'Dabrowice' and 'Lowicz'. The growth retardant was used at concentrations ranging from 75 to 250 mg/L of active ingredient in one or two foliar treatments. It was shown that prohexadione-Ca is suited for regulating the growth of the investigated pome and stone fruits. It caused a significant reduction of vegetative growth, however, particular species and cultivars differed with their sensitivity to the compound and needed different concentrations. In several instances increases in yield and quality could be observed.

Nartvaranat *et al.,* (2000) studied on the application methods and showed that soil drenching of paclobutrazol is more effective for the induction of flowering in mango as compared to foliar spray. The rate of paclobutrazol application depends on the size of tree canopy as well as on mango cultivars. For most cultivars, the rate of paclobutrazol applied is generally determined by multiplying the diameter of tree canopy (expressed in meter) with 1.0–1.5 g. of active ingredients of paclobutrazol. At 120 days after the application of paclobutrazol, 0.5% thiourea is sprayed to the tree for bud breaking. Using this method, inflorescences are visible within 2.5 to 4 months after the paclobutrazol application depending on cultivar. However, the success in producing off-season mango is also dependent on other factors such as climatic conditions, mango cultivars, orchard management and most importantly the experience of mango growers.

Tongumpai *et al.*, (1997) conducted an experiment to determine the effect of single and multiple foliar application of paclobutrazol at 1000 and 2000 ppm on mango tree, *Mangifera indica* L. cv. Nam Dok Mai, in June to induce off-season flowering. The treated trees initiated flowering 29 to 41 days earlier than the controls. The amount of flowering shoots of all paclobutrazol treated trees was 2 times greater than that of the control.

Tongumpai *et al.*, (1997) investigated the effect of paclobutrazol on five uniform mango trees, *Mangifera indica* L., cv. 'Khiew Sawoey'. The plants were drenched with 6g/tree paclobutrazol 16 days after leaf emergence. Terminal shoots of the treated and control trees were collected weekly for anatomical studies. Apical meristems of both control and treated trees slowly developed increasing amounts of leaf primordia and bud scales after the paclobutrazol treatment. Ninety one days after paclobutrazol application 30% of the apical buds from the paclobutrazol treatments developed floral primordia. Ninety and 100 % of the treated shoots developed floral buds at 105 and 112 days after treatment respectively. None of the terminal buds of the control trees developed into flower buds.

Tongumpai *et al.*, (1997) suggested that flower initiation induced by paclobutrazol was completed after the 90-day paclobutrazol treatment**.** Three-year-old mango trees, *Mangifera indica* L., cv. Nam Dok Mai, were treated with thiourea to induce bud break. Thiourea at 0.5 and 1% were sprayed until run-off on the leaves of mango trees when the leaves were at full expansion. Treated trees produced uniform terminal bud breaks within 14 to 16 days after treatment, while the controls broke buds after 31 days. One percent thiourea induced severe defoliation. The phenology of the new shoots produced by all treatments were similar. To determine whether thiourea overcomes dormancy of mango buds, 3-year-old mango trees, cv. Khiew Sawoey, were treated with 0.5% thiourea at the full leaf expanded state. The treated trees induced new shoot growth within 14 days. To induce flowering the trees were then drenched with 6g/tree of paclobutrazol and the trees were randomly divided into 7 groups and treated with 0.5% thiourea at either 45, 60, 75, 90, 105 or 120 days after paclobutrazol treatment. Bud break was low in the 45 to 75 days treatments, 100% vegetative in the 90 day treatment, 80% flowers in the 105 day treatment and 100% flowers in the 120 day treatment.

Ndung'u *et al.*, (1996) investigated the use of post-harvest water stress as a management practice in producing two crops of grapes annually, using three-year-old own-rooted Kyoho grapevines. The vines were established under a restricted rooting-zone culture (*ca*. 30 L/vine). Five weeks after harvesting the first crop, vines were subjected to water stress treatments by completely cutting off irrigation. Control vines received normal watering throughout the year. Though vines in all the treatments produced a second crop, the severe water stress lasting for 16 days was effective in inducing early budbreak, enhancing blooming, and increasing fruitfulness, cluster size, berry set, and berry growth, compared to continuously well-watered vines. The mild water stress of 10 days was less effective. There was an apical dominance tendency in budbreak and a growth potential gradient favoring the upper shoots during the second cycle. Fruits from the two cycles did not differ significantly in their quality. The study showed the potential of water stress as a management practice, especially in increasing the productivity of warm-regions grapevines.

Oosthuyse, (1993) discussed high density planting with a view to optimal tree spacing, canopy size maintenance, and pruning of young trees to improve growth, cropping ability and sturdiness. Mango yields world-wide are generally poor, ranging from 4 to 9ton/ha in the major producing countries. This is partly attributable to wide tree spacing, which are traditionally based on expected eventual tree size. Little consideration is generally given to canopy size maintenance once overcrowding eventually occurs. Yields for more closely spaced trees of well managed orchards in Florida and Puerto Rico, where annual or biennial hedging is employed to maintain canopy size, generally exceed 20 ton/ha. Recent studies show the marked positive effect on yield by radically increasing planting density.

Kurian *et al.,* (1993) reported the effects of soil drenching with paclobutrazol and foliar sprays of Cycocel and Alar on flowering and fruit set of nine year old mango trees. Early and profuse flowering was a striking response to paclobutrazol treatments. Cycocel and Alar slightly increased flowering in first year and reduced flowering in the following year. Treatments resulted in condensed panicles, an enhanced proportion of hermaphrodite flowers and tended to reduce pollen fertility. Fruit set was promoted by 2.5 g paclobutrazol per tree. Fruit retention was not promoted by any of the treatments, but the highest concentration of paclobutrazol (10 g per tree) had a detrimental influence both on fruit set and retention.

Lieten *et al.*, (1993) presented a brief resume of the evolution of 'out-of-season' production of strawberries in greenhouses and plastic tunnels in Netherlands and Belgium. Strawberries are traditionally cultivated in soil. In the 1970's, the nutrient film technique (NFT) was introduced. Later on, rockwool, polyurethane or polyphenol slabs were combinated with the NFT system. Also experiments were done with cultivating strawberries in vertical hydroponic systems. In the early 1980's, the bucket culture was introduced. The first trials with grow bags were done in the 1970's, but the final breakthrough came in 1987. Strawberry culture on peat bags is now widely spread in central Europe and replacing bucket culture. The general methods of the culture under plastic tunnels and greenhouses are discussed.

Lin, (1992) conducted an experiment where different measures were adopted to overcome the problems encountered in production of tropical fruit in subtropical Taiwan. Among these, strategies to reduce the vegetative growth are the key to induction of flowering and thus lead to fruit production. Methodologies for production of oriental pear, guava, carambola, mango, grapes and wax apple were illustrated. A theoretical model for forcing production based on wax apple was proposed. Beside the methodologies already in practice, an approach to alter durian production season without chemical application will be proposed.

Hsieh *et al.*, (1990) developed cultural practices for the regulation of the grape production season in Taiwan: forcing a winter crop; producing 1 crop/year (in summer or fall); producing 2 crops/year (summer and winter crops, or fall and spring crops), and producing 3 crops/year (summer, fall and winter crops). In order to force the winter crop, a mature cutting is rooted in early spring and becomes established as a new plant. After the flower buds have formed, the pruning of the semi-hardwood is carried out. For the production of the fall crop, the mature canes are pruned back in winter, leaving 2-3 buds/cane. The young shoots are then pruned again to promote flowering and fruit set. To produce 2 crops/year, mature branches are pruned to 12-14 nodes in length after the harvest of the first crop in summer or fall. Manual defoliation treatments or chemical defoliants are used to promote bud break and flowering. The second crop is harvested in winter or in the following spring. For the production of 3 crops/year, a V-shaped frame is used to induce upright growth in the grape canes for the first and second crop. The third crop is forced on the horizontal trellis. The overlapping of fruit development of 2 different crops makes it possible to harvest 3 crops in 10 months. Plant growth regulators are used to retard terminal growth**.**

Eckel *et al.*, (1990) conducted an experiment to determine suitable set size for forcing and recommended that sets of at least 86 g should be used for forcing. Sets derived from layer cuttings and softwood cuttings of cv. Northern Brewer were forced for 21 days at 15°C and then again for 29 days at 10°. Shoots were harvested after each forcing period. Both types of cutting were equally suitable, but sets weighing 86-250 g produced more than twice the shoot yield of sets weighing 24-85 g. Yields were lower in the second forcing period. The larger sets also produced larger, thicker shoots than the smaller ones. There was some evidence for the existence of a dormant period.

Astudillo *et al.*, (1978) investigated the effect of potassium nitrate (KNO3) on the flowering of ‘Carabao’ mango shoots. When newly emerging ‘Carabao’ mango shoots were tagged on April 1 and sprayed on one of a series of dates between August and December with potassium nitrate (KNO3) at 10-40 g/l, flowering was induced. The oldest shoots (8.5 months) required only 10 g KNO_3/l to produce the best flowering response but shoots which were younger when sprayed (4.5-7.5 months) were most responsive to 20 g/l. At all stages of maturity 40 g KNO_3/l reduced the flowering percentage, panicle length, number of flowers, primary panicle branches and sex ratio. Heavy rain and a typhoon delayed flowering. No untreated shoots flowered.

Bondad *et al.*, (1978) investigated the role of KNO_3 in induction of floral differentiation. In 7 out of 8 monthly trials, flowering of 4.75 to 12.75 months old mango (*Mangifera indica* L. 'Pahutan') shoots occurred 1 week after spraying 10 to 160 g/liter KNO_3. Induction was 33 to 100% in 7 to 14 days. The 9 months old shoots in December exhibited 100% flowering in 10 days. This was considerably better than the response of younger shoots except those in September which were sprayed twice with KNO_3 because of rain. There was a general decrease in percentage flowering of treated shoots from January to April. In contrast, natural flowering which began in February tended to increase till May. Most newly emerged buds were plump and bent to star-like 1 to 2 days later. No consistent trend was observed in bud and panicle growth and those produced by KNO_3 spraying appeared longer than natural. It was speculated that KNO_3 may play a role in induction of floral differentiation probably via the nitrate assimilatory pathway. Single spraying with 10 to 160 g/liter KNO_3 had practically no injurious effects on mango leaves but double spraying of 160 g/liter produced severe leaf scorching. Flowering of shoots at all levels and frequency of spraying KNO_3 appeared normal. Under the conditions of these experiments' single applications of up to 160 g/liter and double spraying of up to 80 g/liter were safe for 'Pahutan' mango.

CHAPTER III

MATERIALS AND METHODS

This chapter contains a brief description of location of the experimental site, Climatic condition and soil, materials used for the experiment, treatment and design of the experiment, production technology, intercultural operations, data collection procedure statistical analysis etc. which are presented as following headings:

3.1 Experimental sites

The experiment was conducted at the Rooftop Garden of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from from July, 2018 to February, 2019.

3.2 Climatic conditions

The experimental area is situated in the subtropical zone, has distinct monsoonal season, with an annual average temperature of 25 °C (77 °F) and monthly means varying between 18 °C (64 °F) in January and 29 °C (84 °F) in August. Nearly 80% of the annual average rainfall of 1,854 millimeters (73.0 in) occurs during the monsoon season which lasts from May until the end of September. Information regarding average monthly maximum and minimum temperature, rainfall, relative humidity and soil temperature as recorded by the Bangladesh Metrological Department (climate division) Agargoan, Dhaka, during the period of study.

3.3 Experimental materials

3.3.1 Planting materials

In this experiment **'Nam Dok Mai'** mango variety was used as planting material which was Thailand mango variety. It is a world famous variety and very popular in Bangladesh too. It was early mid-season variety. Nam dok mai was taken as scion and successfully grafted with local mango variety as rootstock. The plant was two years old, healthy and stout.

3.3.2 Pot preparation

Some brick chips were kept at the base. Then the soil was placed into the pot which was previously prepared with the combination of sand, cowdung and dolomite.

3.3.3 Application of manures and fertilizers

Thiourea was applied after 60 days of paclobutrazol application as foliar spray until run-off on the leaves of mango trees. One gram thiourea was dissolved in 10L water to make the solution. The chemical fertilizers like Urea, TSP, MoP were mixed with soil as basal dose as the source of nitrogen, phosphorus and potassium at BARI recommended dose.

3.4 Treatments of the experiment

The single factor experiment was conducted to study the effect of flower forcing technique for off season mango production.

3.4.1 Chemical preparation

In this experiment, there were four treatments viz. T_0 = Control (no PBZ) T_1 =1.0gPBZ/L water T_2= 0.5gPBZ/L water T_3= 0.25gPBZ/L water. The PBZ application rates were determined based on the average volume of the plant. The required quantity of PBZ was dissolved in 1 liter of water and applied to the soil according to the treatment.

Treatment	PBZ Doses/ L water
T_0	Control
T_1	1.0 g
T_2	0.5 g
T_3	0.25 g

Paclobutrazol (PBZ) is a broad-spectrum plant growth retardant that selectively controls tree vigour without markedly affecting the size of fruit. The cropping manipulations possible with PBZ ranges from off season or early season harvests to simply increased yields. It is a known antagonist of the plant hormone gibberellin.

3.5 Experimental design and layout

Experiment was laid out in completely randomized design (CRD) with six replications and thus comprised twenty four plants in the experiment. Hypothetical view of the experiment is present in (Fig. 1).

3.6 Intercultural operations

The experimental trees were managed with same cultural practices as per the standard recommendations followed by BARI with respect to manures and fertilizers, irrigation and plant protection measures etc.

3.6.1 Irrigation

Manual irrigation was practiced during the experimental period. Irrigation was done once per two days.

3.6.2 Weeding

Weeding was done when it was necessary to prevent the competition between plants and weeds for nutrient. Weeding was done with the help of khurpi and hand hoe.

3.6.3 Pruning

Pruning is one of the beneficial intercultural operation for plants especially for mango trees. It was done to remove the disease and insect infected plant parts to maintain the sound health of the plant before few weeks of Paclobutrazol application.

3.6.4 Plant protection measures

In order to prevent pest infestation such as mango fruit fly "pheromone trap" was used when the fruit reached at marble size. Soap water was used as foliar spray to control melay bug. Besides diathane M-45 was used @ 1teaspoon/4L water as foliar spray in order to prevent disease infestation.

3.6.5 Staking

Staking was done to each plants using bamboo sticks with rope to give the mechanical support to the plant.

3.7 Harvesting

Mangoes were harvested randomly when they reached at mature stage on the basis of horticultural maturity, size, color and age. It took 95-115 days from full bloom to mature stage. Throughout the harvesting period frequent picking was done. Harvested mangoes were collected and the relevant data was recorded.

3.8 Parameters

Data were collected under the following heading**:**

- Days to 80% inflorescence initiation
- Number of inflorescence/plant
- Days to first fruit formation
- Fruit number/inflorescence
- Fruit number/plant
- Harvested fruits/plant

- Fruit length (cm)
- Fruit breadth (mm)
- Single fruit weight (g)
- Yield/plant (kg)
- Brix value

3.8.1 Days to 80% inflorescence initiation

Paclobutrazol (PBZ) was applied in July 2018 as soil drench method followed by the treatments. Days to 80% inflorescence initiation was recorded after 90 days of PBZ application in October, 2018 when the shoots were at bud break.

3.8.2 Number of inflorescence/plant

The number of inflorescences per plant were recorded after 105 days of PBZ treatment when 80% inflorescence initiation was done in October, 2018. Number of inflorescences were counted per panicle according visual observation and the average value was calculated.

3.8.3 Days to first fruit formation

Days to fruiting was recorded in November, 2018 as the number of days between the spray and the stage where fruit set was done at pea size stage (when the immature fruits were at the size of a pea). The total number of fruit per plant was counted 160 days after the spray.

3.8.4 Fruit number/inflorescence

Initial number of fruits per inflorescence were counted manually when it was at pea size. After recording the data from each replication average value was calculated and expressed as average fruit number per inflorescence.

3.8.5 Fruit number/plant

The initial fruit number per plant was counted manually from each inflorescence after a certain days of fruit setting. After collecting data the average was computed and expressed as number of fruit per plant.

3.8.6 Harvested fruits/plant

Mangoes were harvested from last week of December, 2018 to mid January 2019 after 95 days of full bloom when the fruit reached into green mature stage. Final number of fruits from each plant of the treatment were counted.

3.8.7 Fruit length (cm)

Fruit length was measured by the scale in centimeter (cm) and the mean value was calculated for each treatment.

3.8.8 Fruit breadth (mm)

Diameter of the fruit was measured with the help of Digital Caliper-515 (DC-515) in millimeter (mm). Mean value was calculated for each treatment.

3.8.9 Single fruit weight (g)

Fruits were collected from each treatment and weighted with the help of an electric precision balance in gram. Total fruit weight of each treatment was obtained by addition of weight of the total fruit number and average fruit weight was obtained from division of the total fruit weight by total number of fruit. The fruits except first and last harvest were considered to take individual fruit weight.

3.8.10 Yield/plant (kg)

Fruit yield per plant was calculated in kilogram (kg) by multiplying the total number of fruit with individual fruit weight per plant.

3.8.11 Brix value

Brix reading was determined using a 'Brix Reader' hand refractometer (Model RF-30, Tokyo, Japan) and expressed as ºBrix. Juice was separately extracted from 3 fruits (from each treatment) and the TSS level determined using the refractometer. The TSS level was expressed as °brix and the data was recorded.

3.9 Statistical analysis

The collected data as per specific parameters were significantly analyzed to find out the significant variation between different treatments. The mean values were evaluated to measure the analysis of variance by the "F" (Variation ratio) test following MSTAT-C computer packaging program. How these test results have statistically significant was estimated by the least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984)

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CHAPTER IV

RESULTS AND DISCUSSION

4.1 Technology development

The plants were healthy, stout, vigorous and disease free and it was two years old. Mango plant was pruned to remove the dead, disease and insect infected plant parts before applying the treatment. After a few days the plant was treated with different PBZ doses 1.0g PBZ/ 1Lwater, 0.5g PBZ/ 1Lwater, 0.25g PBZ/ 1Lwater followed by T_1, T_2, and T_3 treatment respectively. Before apply, the chemical was diluted to 1L water to make a solution. The chemical was applied to the plant as soil drench method. A small drench was made away from the plant base beside the corner of the pot. Then the chemical was applied to the soil. After finishing the application the soil was loosen with a stick. The chemical application was done in the morning. Different intercultural operation was done followed by weeding, irrigation, pruning etc. according to the requirement. Fertilizer application was done as basal dose at the time of soil preparation. A little amount of compost was applied to maintain the soil health of the pot. As foliar spray Thiourea was applied. 1g Thiourea mixed with 10L water to make the solution. It was applied to the plant until run-off on the leaves.

Findings of the research work have been presented and discussed in this chapter. Illustration of this chapter has been focused by tables and figures to enhance their parallel and dissimilar character through discussion, comprehension and perceiving. A summary of the analysis of the variances in regard to all parameters have been arrayed in appendix. Results have been presented, discussed and possible interpretations are given under the following headings.

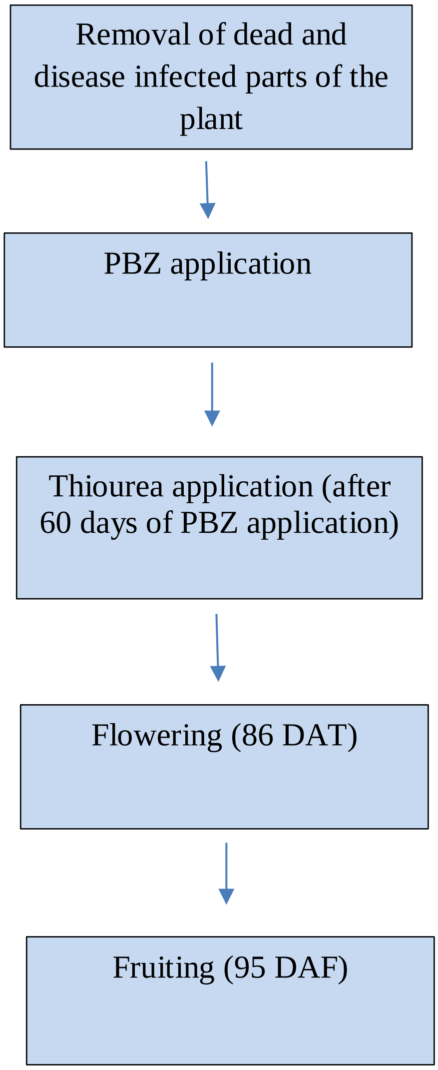


Figure 2. Diagram of mango forcing technology

4.2 Parameters

4.2.1 Days to 80% inflorescence initiation

Flowering was done in October, 2018. Significant variation was found in number of days for inflorescence development (Appendix I). Earliest flowering (86 days) was observed in T_1 treatment while delayed flowering was observed in T_3 treatment (100 days). In T_2 treatment it required (92 days) for inflorescence initiation. There was no flowering in control as it was out of season and no spray was done. Extra PBZ dose could promote flowering early but it cause heavy fruit dropping percentage and flower malformation (Tongumpai *et al.* 1991). An experiment was conducted by Tongumpai *et al.* (1997) to induce flowering by applying different PBZ doses. They found 80% flowering in 90 days after PBZ treatment which is similar to this study.

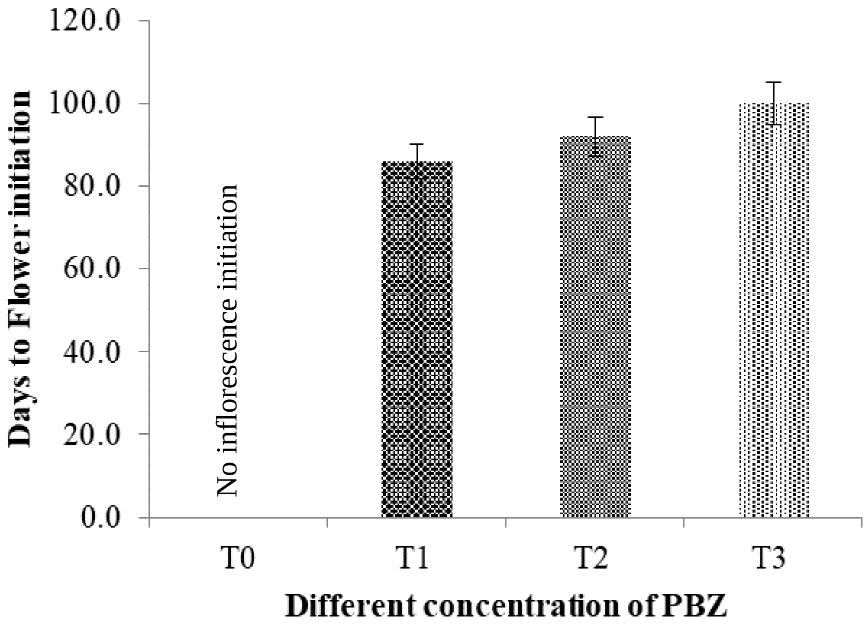


Figure 3. Effect of different PBZ doses on days to 80% inflorescence initiation (Here T_1 = PBZ dose 1.0g/L water, T_2= PBZ dose 0.5g/L water, T_3= PBZ dose 0.25g/L water)

Another findings agree with the observations in mango cv. ‘Alphonso’ (Burondkar et al. 2000) ‘Nam Dok Mai’ (Tongunpai *et al.*, 1996) and ‘Kiew Sawoey’ (Tongumpai *et al*., 1991) where paclobutrazol also promoted flowering with the breaking of the floral buds within 2.5 to 4 months after treatment. A similar promotive effect was observed in Brazilian mangoes (Sao Jose and Reboucas, 2000).

4.2.2 Number of inflorescence per plant

The variation was found in number of inflorescence per plant due to different treatments (Appendix I). The mean number of flower per plant varies from 3.2 to 8.7. There was no flowering in control as it was out of season. Higher number of inflorescence (8.7) was found in T_2 treatment whereas the lowest number of inflorescence (3.2) was found in T_3 treatment due to lower PBZ dose according to plant volume. Optimum PBZ dose according to plant canopy can increase the inflorescence number. It is evident from the results of Burondkar & Gunjate (1993) that optimum PBZ application increased the number of flowering shoots. Amarcholi *et al*. (2016) invested to know the influence of chemicals on flowering characteristics of ‘Kesar’ mango and found that foliar application of KNO_3 1% (used in flower forcing) gave maximum flowering percentage which was similar to this study. Parmar *et al.* (2014) studied that 1.5 per cent urea solution and 0.6 per cent zinc sulphate were effective for the augmentation of flowering attributes of guava.

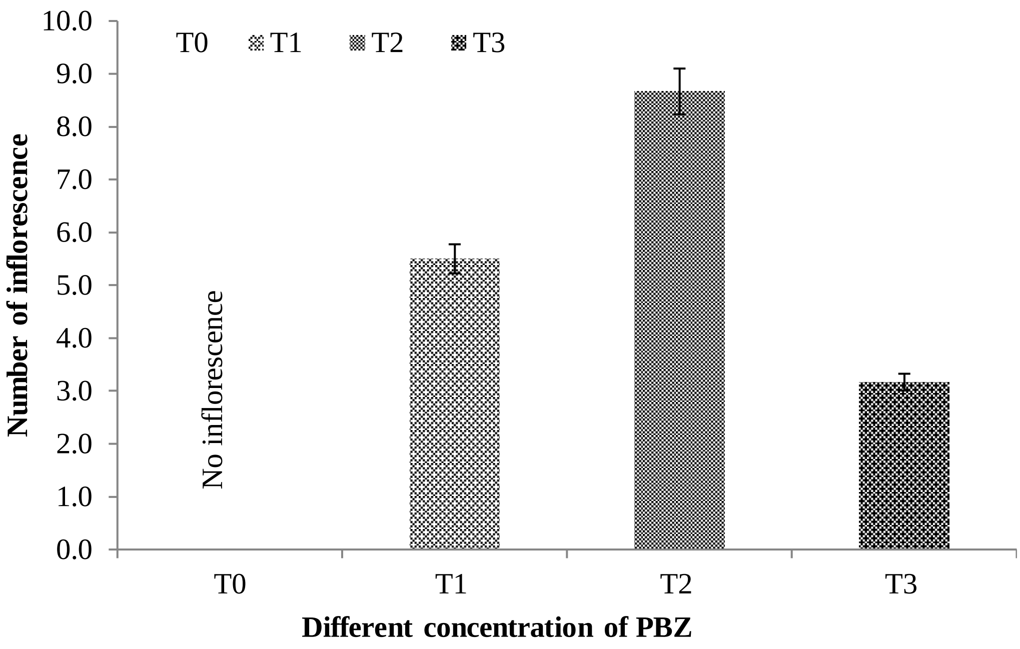


Figure 4. Effect of different PBZ doses on inflorescence number per plant (Here T_1 = PBZ dose 1.0g/L water, T_2= PBZ dose 0.5g/L water, T_3= PBZ dose 0.25g/L water)

In this study, paclobutrazol was able to induce all the young 'Nam dok mai' trees to flower completely and profusely.

4.2.3 Days to first fruit formation

First fruit formation was done in November, 2018. In this study time of fruiting varied significantly according to the treatments (Appendix I). Comparatively early fruit setting was found in T_1 (95 days) followed by T_2 (100.8 days) and T_3 (114.2 days). PBZ advances flowering time so it advances fruiting time too. Similar result was found in an experiment conducted by Kienzle *et al.* (2012) was harvest maturity detection for "Nam dok mai" mango fruit (*Mangifera indica* L.) in consideration of long supply chains. They found that it took 90-120 days to reach the horticultural maturity stage of 'Nam dok mai' mango after full bloom of inflorescence. Fruit setting was also influenced by temperature, cultivar and surrounding environmental condition.

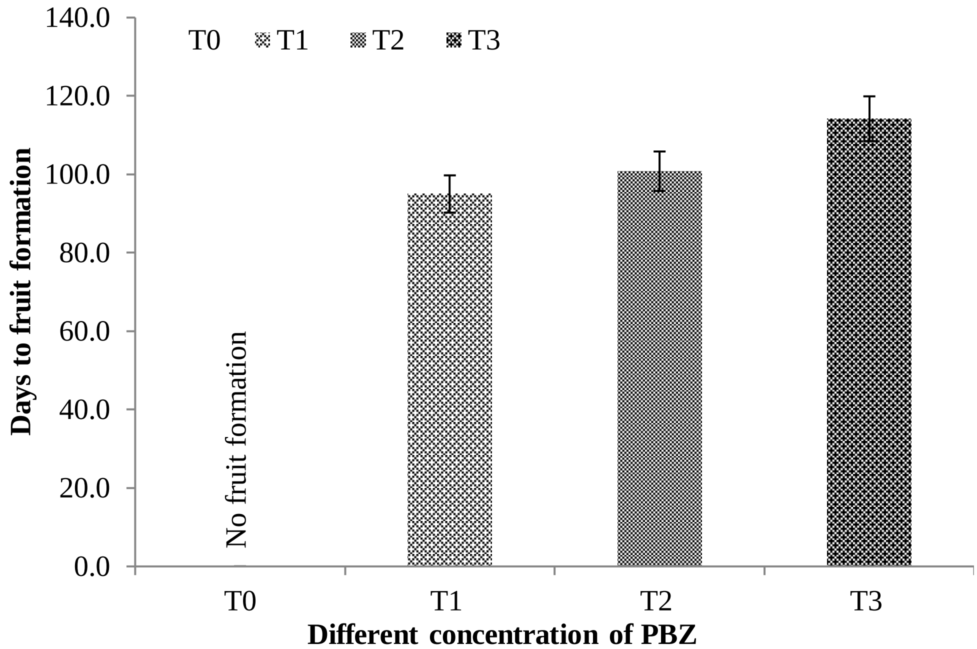


Figure 5. Effect of different PBZ doses on days to first fruit formation (Here T_1 = PBZ dose 1.0g/L water, T_2= PBZ dose 0.5g/L water, T_3= PBZ dose 0.25g/L water)

4.2.4 Fruit number per inflorescence

The variation was found significantly in initial fruit number per inflorescence due to different treatments (Appendix II). The mean number of initial fruit per inflorescence varies from 3 to 4.5. Higher number of initial fruit (4.5) was found in T_2 treatment whereas the lowest number of initial fruit per inflorescence (3.0) was found in T_3 treatment. In case of mango, fruiting is an important phenomenon. A huge number of flower formed in the plant during the season. But most of them are shed off naturally. That's why initial fruit setting is important as it is directly linked to the yield. Different intercultural operations and treatments can increase the initial fruit number. The increase in initial fruit number might be due to highest inflorescence number resulting higher fruit set percentage. So optimum PBZ dose can increase the fruit retention percentage.(Yeshitela, 2004).

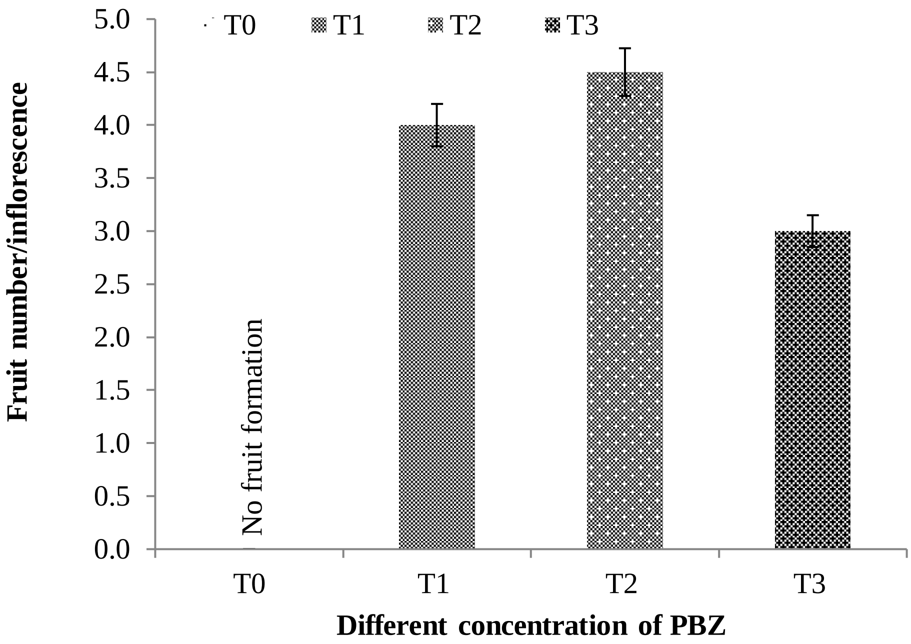


Figure 6. Effect of different PBZ doses on fruit number/inflorescence (Here T_1 = PBZ dose 1.0g/L water, T_2= PBZ dose 0.5g/L water, T_3= PBZ dose 0.25g/L water)

4.2.5 Fruit number per plant

PBZ treatments enhanced fruit set and total fruit number per plant significantly (Appendix II). Average across the application methods, the highest mean of initial fruit set per plant (30.8) was observed with the application of PBZ at a rate of 0.5 g/Lwater per plant (T_2 treatment) as compared to the other treatments T_1 (23.2) & T_3 (12.3) . There was no fruit in control due to off season.

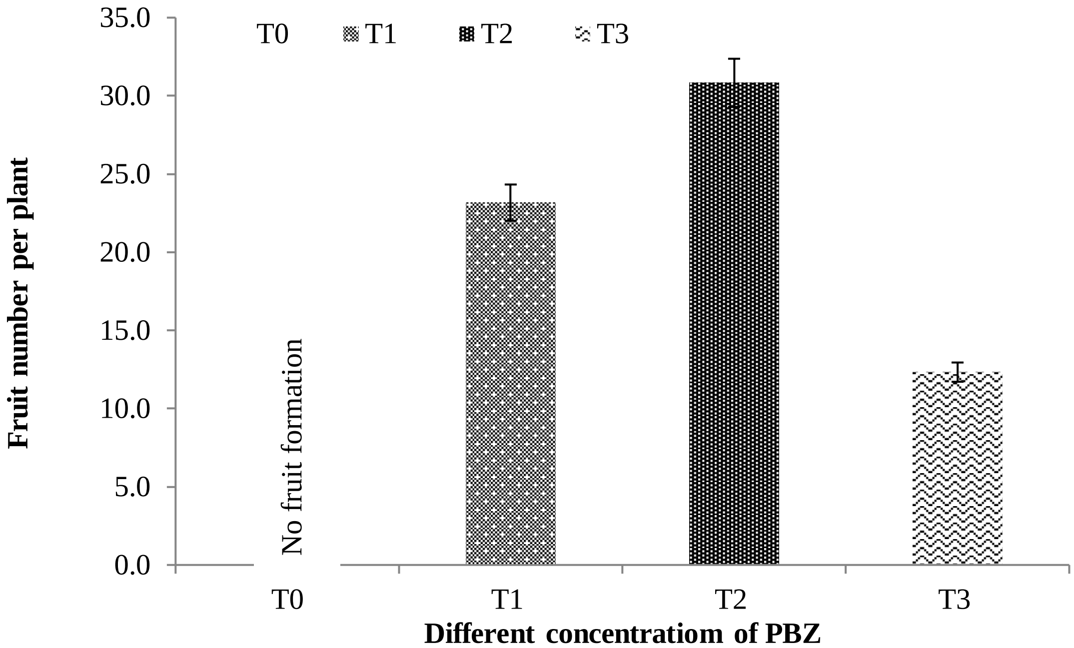


Figure 7. Effect of different PBZ doses on fruit number/plant (Here T_1 = PBZ dose 1.0g/L water, T_2= PBZ dose 0.5g/L water, T_3= PBZ dose 0.25g/L water)

Similar result was found by Feungchan *et al.* (1991) who stated that the application of PBZ gave significantly higher number of flowers and fruit production of mango plants. In Alphonso mango, relatively low rates of PBZ applied via the soil were found to increase the number of fruit retained per inflorescence (Kurian and Iyer, 1993).

4.2.6 Harvested fruits per plant

Fruits were harvested from two years old mango plant from last week of December, 2018 to mid January, 2019. The number of fruits per plant at harvest were influenced by various treatments in mango cv. Nam dok mai is presented in graph. The data indicates a significant difference between different treatments with respect to the final number of fruits per plant (Appendix III). Maximum mean number of harvested fruits per plant (8.3) were recorded in T_2 treatment (PBZ 0.5 g) followed by T_1 (6.5) and T_3 (4.0) treatments. As there was low fruit dropping percentage in T_2 (0.5g) treatment the harvest fruit number per plant was increased.

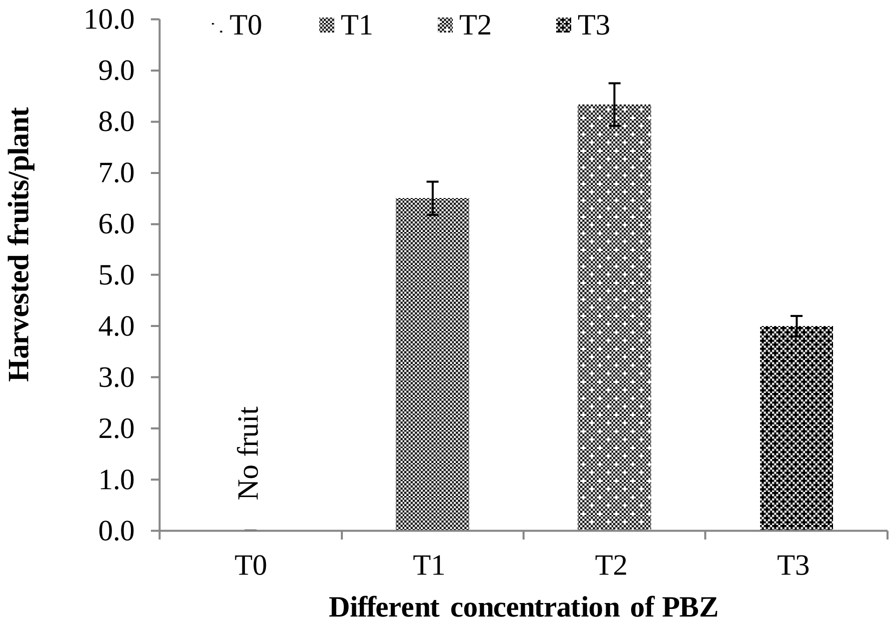


Figure 8. Effect of different PBZ doses on harvested fruits/plant (Here T_1 = PBZ dose 1.0g/ 1L water, T_2= PBZ dose 0.5g/ 1L water, T_3= PBZ dose 0.25g/1L water)

Similar results were recorded by the earlier workers Patil *et al*. (2005) in mango; Konhar and Arun (1988) in cashew; and Sharma *et al*. (2008) in apple.

4.2.8 Fruit length (cm)

After application of different PBZ doses some variation in fruit length was observed. The average fruit length was longest with T_2 (11.7 cm) followed by T_1 and T_3 with the values of (10.8 cm), (8.8 cm), respectively. The fruit length is significantly varied according to the treatment and optimum dose can increase the fruit length (Appendix III) as PBZ work as growth promoter too. Benjawan *et al.* (2006) found that PBZ has significant effect on fruit length. The result showed that at the rate of 5000 ppm gave significantly greater fruit length than the other plant which was similar to this study. But in the other set of treatment when the length of extended raceme flower was 5cm, it depressed the fruit length with the same dose which is dissimilar to this study.

4.12.9 Fruit breadth (mm)

Distinct diameter was noticed in each treatment significantly (Appendix III). With fruit dimensions, the results showed that fruit breadth was highest with T_2 (67.6 mm) followed by T_1 and T_3 with values of 64.2 mm and 63.3 mm respectively. Benjawan *et al.* (2006) was found the same result in case of mango and said that PBZ increase the fruit breadth. Gupta and Brahmachari (2004) also obtained the highest fruit size, fruit weight and yield with spraying of urea at 4% at Bihar, India corroborate the findings of current study.

4.2.7 Single fruit weight (g)

A significant variation was found in single fruit weight according to the treatment (Appendix IV). Relatively higher average individual fruit weight obtained from the application of 0.5g PBZ/Lwater 273.8g (T_2 treatment) and the trees treated with different treatments T_1 (1.0g) and T_3 (0.25g) were found lower fruit weight 258.4 g and 224.0 g respectively. Sergent *et al.* (1997) found that the application of PBZ at doses of 1.0 and 1.5g. i.a. per meter of canopy diameter increased production, allowing for regular crops in two consecutive production cycles. PBZ doses in Tommy Atkins mango had a direct effect on fruit weight, yield and new budding. Moreover, the onset of flowering was also affected by the doses of the product (Oosthuyse and Jacobs, 1997).

Table 1. Influence of different PBZ doses on Nam dok mai mango plant related to single fruit weight, fruit length and fruit breadth

Treatments	Single fruit wt. (g)	Fruit length (cm)	Fruit breadth (mm)	Yield/plant (kg)
T_1 (1.0 g PBZ/ 1L water)	258.40 ab	10.80 a	64.20 a	1.7b
T_2 (0.5 g PBZ/ 1L water)	273.80 a	11.70 a	67.60 a	2.3a
T_3 (0.25 g PBZ/ 1L water)	224.00 b	8.80 b	63.30 a	0.9c
$LSD_{0.05}$	36.90	1.80	1.30	0.1
CV (%)	8.50	10.20	8.30	4.9

In a column, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability
(Here T_1 = PBZ dose 1.0g/ 1L water, T_2= PBZ dose 0.5g/ 1L water, T_3= PBZ dose 0.25g/1L water)

4.2.10 Yield per plant (kg)

The fruit weight per plant varied significantly according to the treatment (Appendix III). Fruit set showed a direct impact on yield depending on number of fruit retained. The highest yield was obtained from the treatment T_2 (2.3 kg) and the lower yield was obtained from T_1 (1.7 kg) and T_3 (0.9 kg) treatment respectively from two years old mango plant. The impact of higher rates of PBZ in enormously suppressing vegetative growth, especially during peak fruit development stage, contributed to the superior yield observed. Similar result was found that soil application of PBZ has consistently been found to increase tree yield 2 to 4 kg from two years old plant (Kulkarni, 1988; Burondkar & Gunjate, 1993; Kurian & Iyer, 1993; Singh & Dhillon, 1992; Singh, 2000).

4.2.11 Brix value

There was no significant difference was found in brix value among the treatments (Appendix IV). Higher brix value 17.1 was found in T_2 treatment whereas lowest brix value was found in T_1 treatment (16.6). Generally 'Nam dok mai' mango is the sweetest mango in Thailand. So by the result it can be told that PBZ has no effect on brix percentage of mango. Similar result was found by Chusri *et al.* (2008). They said that the brix value and titratable acidity of the mangoes did not differ with different PBZ doses.

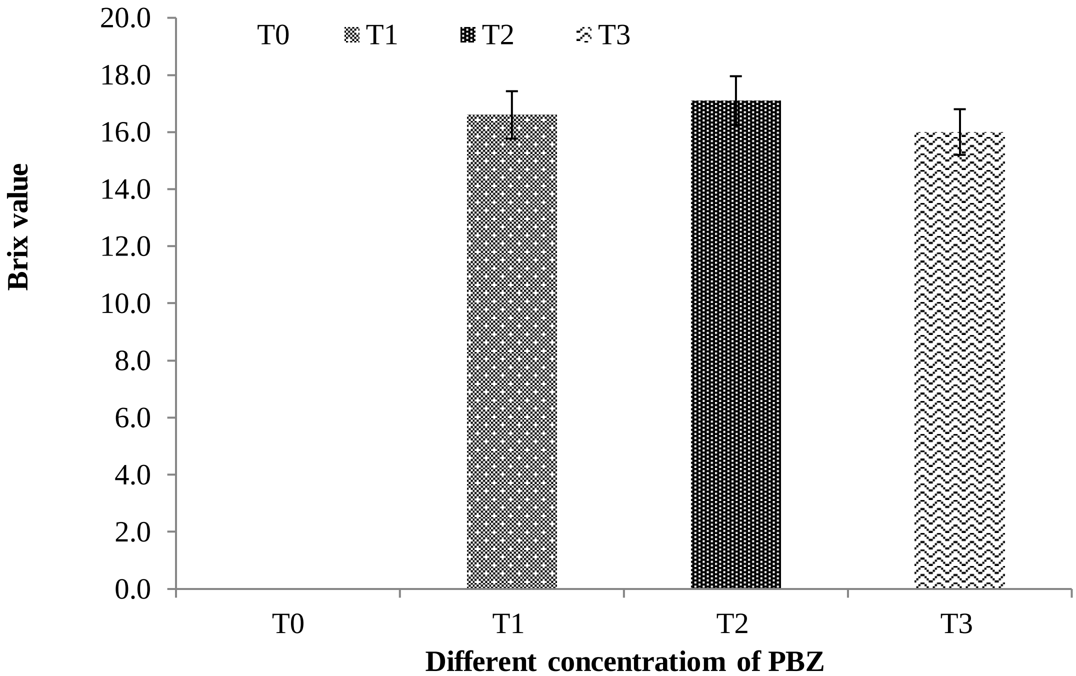


Figure 9. Effect of different PBZ dose on brix value (Here T_1 = PBZ dose 1.0g/L water, T_2= PBZ dose 0.5g/ L water, T_3= PBZ dose 0.25g/ L water)

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

In order to adopt flower forcing technology for off season mango production an experiment was conducted during the period of July, 2018 to January, 2019 at rooftop garden, Sher-e-Bangla Agricultural University. For this different PBZ doses (1.0 g PBZ/L water, 0.5 g PBZ/L water, 0.25 g PBZ/L water) were applied to the plant according to the treatments T_1, T_2, T_3 respectively. There was no flowering in control (T_0 treatment) as it was in off season.

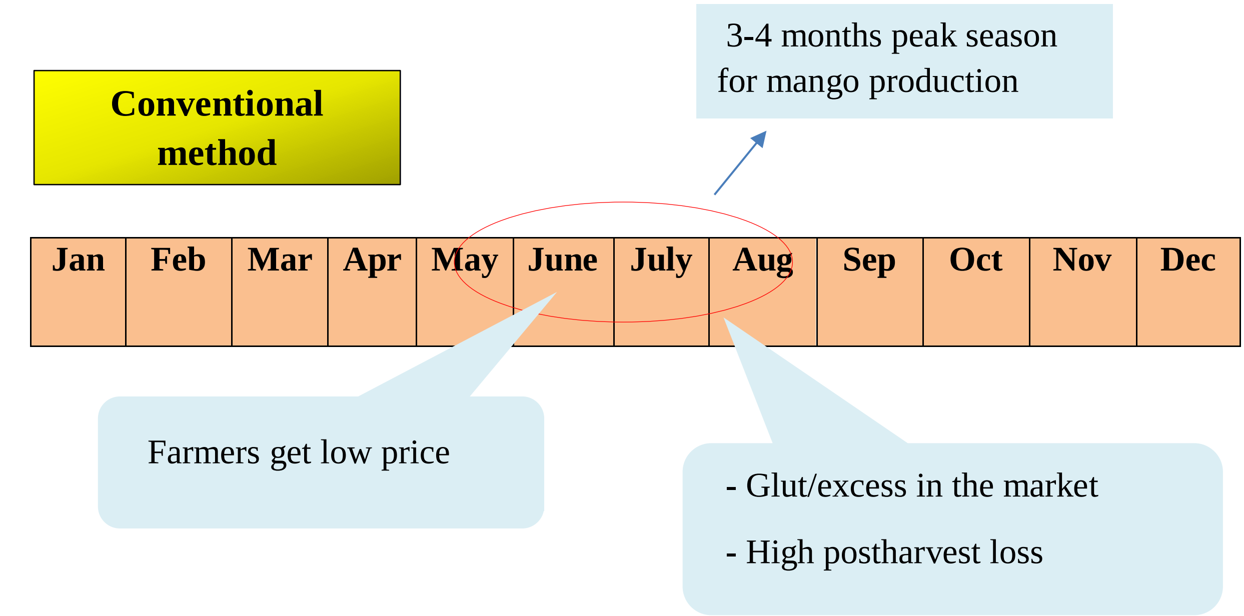
Collected data were statistically analyzed to evaluate the performance of different treatments. The findings of this experiment are summarized in this chapter.

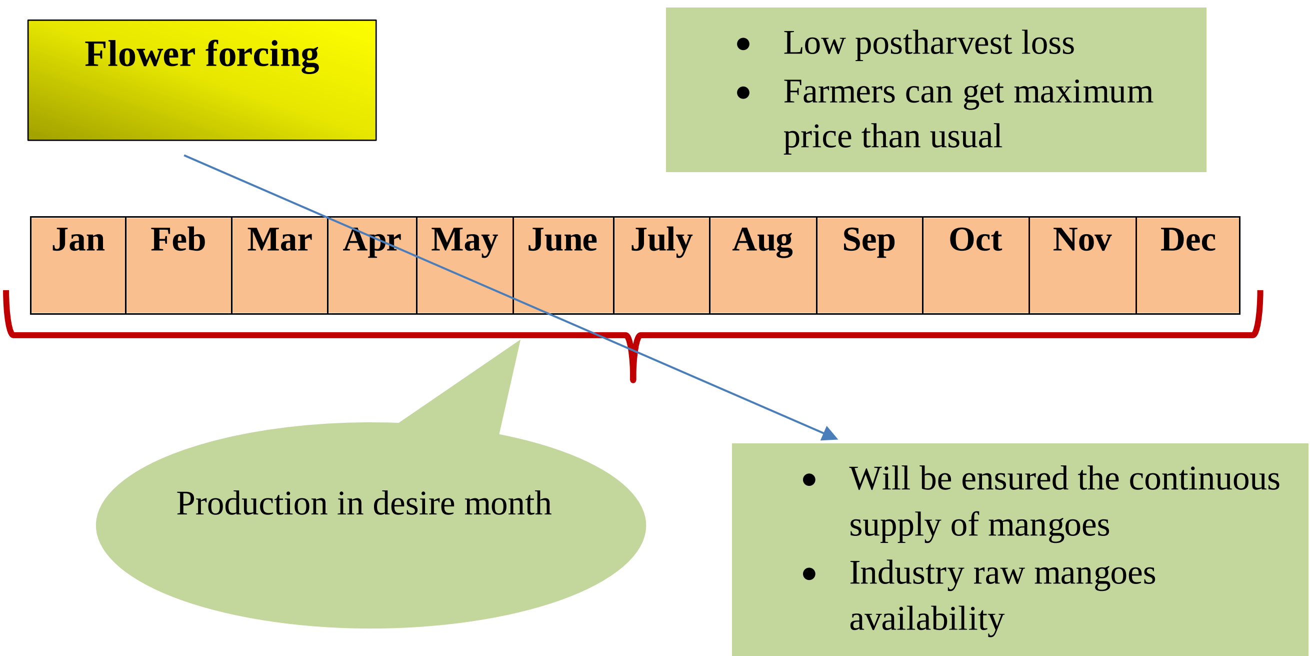
Different PBZ doses which were applied in two years old mango plant in July, 2018 showed significant variation according to different parameters. Significant dissimilarity was found in number of days for inflorescence development. In October, 2018 earliest inflorescence initiation (86 days) was observed in T_1 treatment while late inflorescence initiation was observed in T_3 treatment (100 days). In T_2 treatment it was required (92 days) for flower initiation. The mean number of inflorescence per plant varies from 3.2 to 8.7. Higher number of inflorescence (8.7) was found in T_2 treatment whereas the lowest number of inflorescence (3.2) was found in T_3 treatment. Time of fruit formation varied according to the treatments. In November, 2018 comparatively early fruit setting was found in T_1 (95 days) treatments and late fruit setting was found in T_3 (114.2 days) treatment. In T_2 treatment it required 100.8 days for fruit setting which was optimum according to plant canopy diameter. The number of fruit per inflorescence varies from 3 to 4.5. Higher number of initial fruit (4.5) was found in T_2 treatment whereas the lowest number of initial fruit per inflorescence (3.0) was found in T_3 treatment. The highest initial fruit set per plant (30.8) was observed with the application of PBZ at a rate of 0.5 g per tree (T_2 treatment) as compared to the other treatments. The lowest fruit set per plant was observed in T_3 (12.3) treatment. Maximum number of harvested fruits per plant (8.3) were recorded in T_2 treatment whereas the lowest fruit set per plant was observed in T_3 (4.0) treatment. The number of single fruit weight varies from 224.0 g to 273.8 g. relatively higher individual fruit weight obtained from T_2 treatment (273.8 g) and the lower individual fruit weight was obtained from T_3 treatment 224.0 g. The highest yield was obtained from the treatment T_2 (2.3 kg) and the lower yield was obtained from T_1 (1.7 kg) and T_3 (0.9 kg) treatment respectively. The average fruit length was longest with T_2 (11.7 cm) followed by T_1 and T_3 with the values of (10.8 cm), (8.8 cm), respectively. With fruit dimensions, the results showed that fruit breadth was highest with T_2 (67.6 mm) followed by T_1 and T_3 with values of 64.2 mm and 63.3 mm, respectively. The highest brix value (17.1) was observed in T_2 treatment. The minimum value (16.5) was recorded by T_1 treatment.

5.2 Conclusion

From this research it can be concluded that in conventional method (T_0 = control) there was no flowering while in flower forcing method flowering ocurred in all plants treated with PBZ. We got mango in December and January while the peak season for mango in our country is mid May to mid August. So we get a technology for off season mango production. According to result among all treatments T_2 treatment (0.5g PBZ/L water) shows the best result in flowering, fruit retention percentage, fruit length, fruit breadth, single fruit weight, number of harvested fruits and yield/plant. So this dose can be suggested for mango plant of two years old.

To sum up flower forcing is possible for off season mango production and it will be more profitable cultivation method than conventional method as forcing can be done any time of the year to induce flowering and PBZ application with 0.5g/L water will be potential dose for off season mango production.


Conventional method
3-4 months peak season for mango production
Jan Feb Mar Apr May June July Aug Sep Oct Nov Dec
Farmers get low price
- Glut/excess in the market
- High postharvest loss


Flower forcing
Low postharvest loss
Farmers can get maximum price than usual
Jan Feb Mar Apr May June July Aug Sep Oct Nov Dec
Production in desire month
Will be ensured the continuous supply of mangoes
Industry raw mangoes availability

5.3 Suggestion

- Further research can be done on different popular varieties in Bnagladesh such as aam rupali, lengra, khirshapat, himsagor, harivanga etc.
- Scopes for future mango industry can be developed in Bangladesh.
- Higher dose of PBZ influence flower malformation and high fruit drop percentage.
- Ultimately, there is need to develop management strategies that force development responsive shoots at any period of the year. This strategy will encompass not only the flower induction chemicals but also cultural practices that enhance the trees response to the treatments.

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Appendices

Appendix I. Analysis of variance (mean square) of the data for days to flowering, inflorescence number/plant, days to first fruiting of mango

Source of variation	Degrees of freedom	Days to 80% inflorescence initiation	Inflorescence number/plant	Days to first fruit formation
Replication	5	24.40	7.422	18.67
Treatment	2	296.00**	45.722**	579.17**
Error	10	13.60	0.256	19.63

** = Significant at 1% level of probability

Appendix II. Analysis of variance (mean square) of the data for initial fruit number/inflorescence, initial fruit number/plant, fruit dropping percentage/plant of mango

Source of variation	Degrees of freedom	Fruit number/inflorescence	Fruit number/plant
Replication	5	4.367	73.822
Treatment	2	3.500**	518.389**
Error	10	0.167	1.389

** = Significant at 1% level of probability

Appendix III. Analysis of variance (mean square) of the data for harvest fruit/plant, fruit length (cm), fruit breadth (mm) of mango

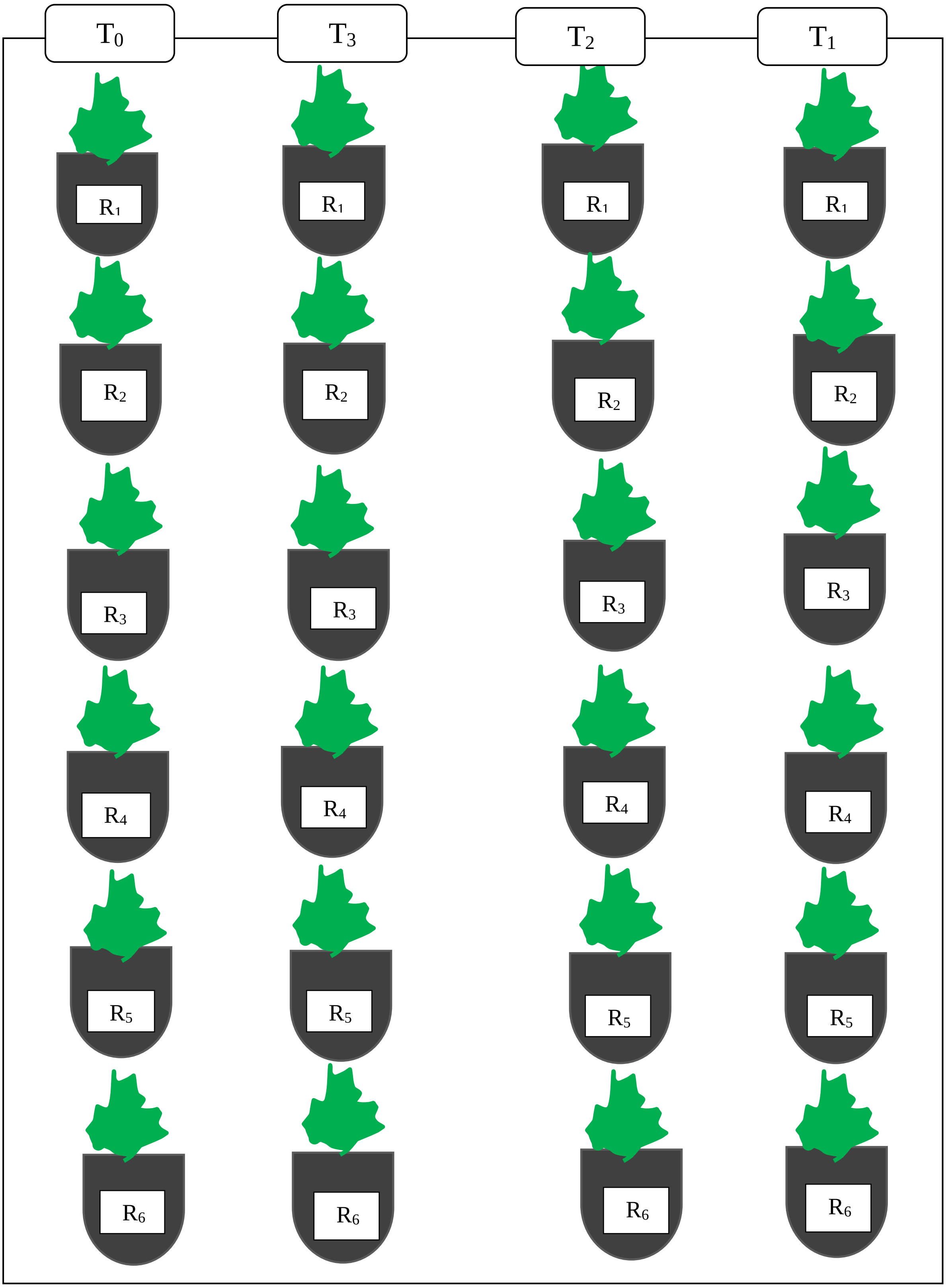
Source of variation	Degrees of freedom	Harvested fruits/plant	Fruit length (cm)	Fruit breadth (mm)
Replication	5	16.856	1.641	29.641
Treatment	2	28.389**	12.974**	31.904NS
Error	10	0.456	1.118	29.391

** = Significant at 1% level of probability

Appendix IV. Analysis of variance (mean square) of the data for individual fruit wt. (g), weight/plant (kg), organoleptic evaluation of mango

Source of variation	Degrees of freedom	Single fruit weight (g)	Yield/plant(kg)	Brix value
Replication	5	467.6	0.006	0.086
Treatment	2	3905.5**	2.863**	1.236**
Error	10	458.6	0.006	0.114

** = Significant at 1% level of probability

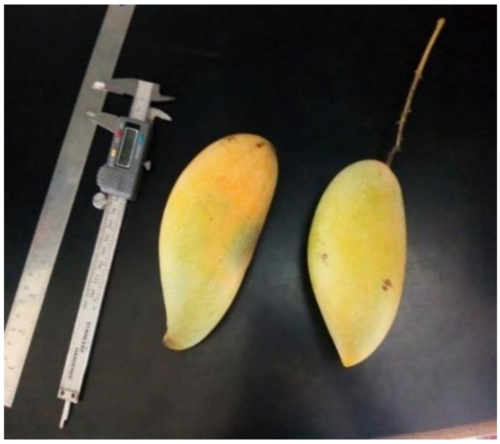


T_0 = control, T_1 = 1.0g PBZ/ 1Lwater, T_2 = 0.5g PBZ/1L water, T_3 = 0.5g PBZ/ 1L water

Figure 1. Layout of the experiment

Plate 1. Different chemicals and their application methodology a. Paclobutrazol **b.** Measuring the chemical by using Electronic Precision Balance in gram **c.** Making the solution **d.** Pouring the solution in the pot **e.** Thiourea **f.** Foliar application of thiourea

a b



c d

e f

Plate 2. Pictorial view of different plant protection measures and instruments used in data collection a. Staking with bamboo stick **b.** Pheromone trap **c**. Measuring the weight of fruit by electronic balance **d.** Measuring the length of mango with scale **e.** Measuring the breadth by slide calipers **f.** Measuring brix percentage

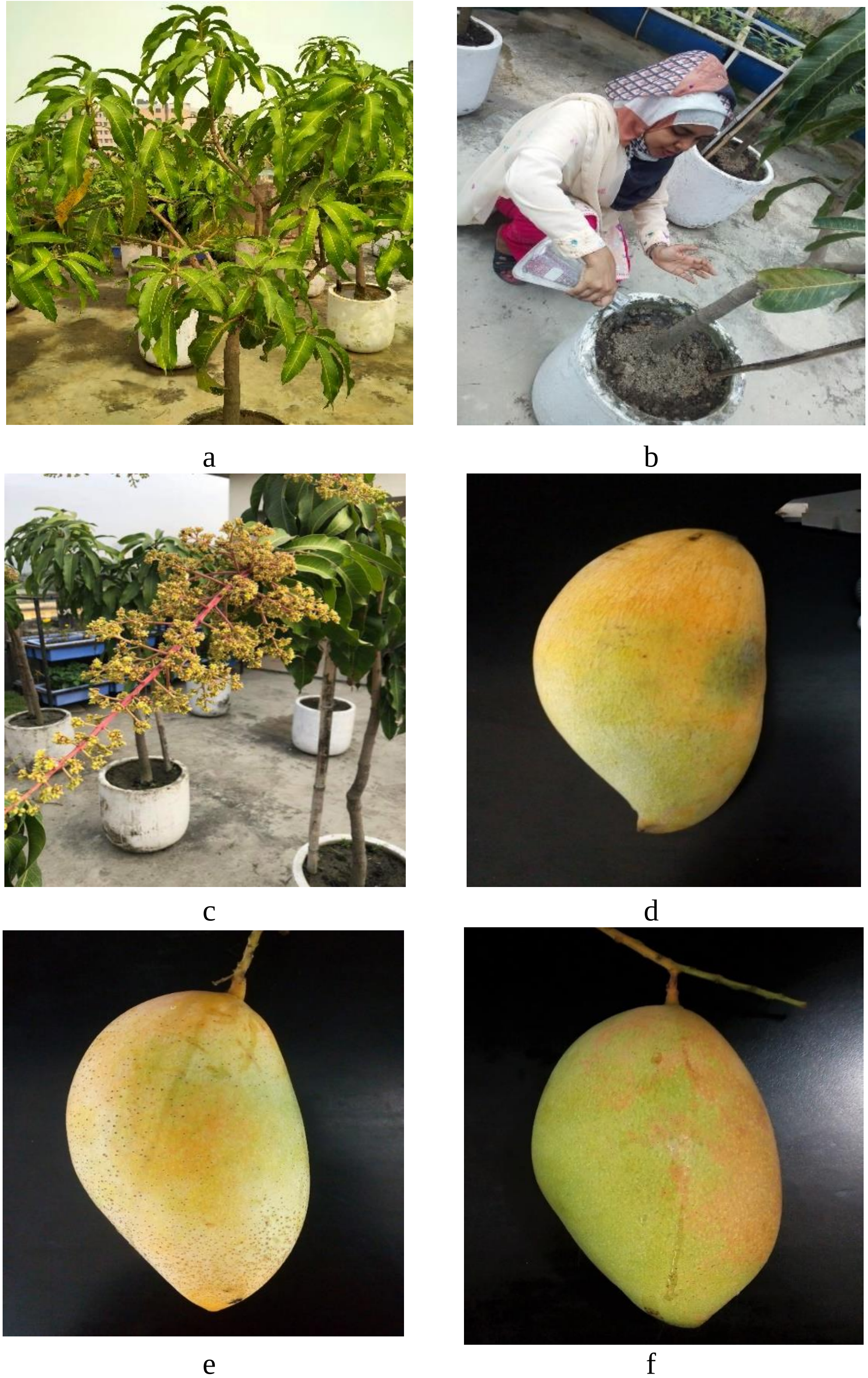


Plate 3. Pictorial presentation of production technology and mangoes of different treatments a. Mango plant before treatment **b.** PBZ application **c.** Inflorescence initiation **d.** Mango from T_1 treatment **e**. Mango from T_2 treatment **f.** Mango from T_3 treatment