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INTERACTIVE EFFECT OF NITROGEN AND PACLOBUTRAZOL ON ANNUALLY PRUNED SAMMAR BAHISHT CHAUNSA

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Abstract

There is evidence that vegetative growth is limited in many cultivars of mango grown under subtropical regions reducing their flowering tendency that ultimately results in low productivity. Prolonged use of certain growth retardants commonly used to manage vegetative and reproductive growth in the mango crop, such as Paclobutrazol (PBZ) has been associated with deleterious effects on plant growth. The present 13-years study was aimed at investigating the effects of integrated use of nitrogen and PBZ on vegetative growth, flowering pattern and fruit yield of annually pruned mango cv. Sammar Bahisht Chaunsa. Twenty five years old trees were used in the study. The experiment was laid out according to a randomized complete block design (RCBD) with nine treatments and five replications keeping two plants as the experimental unit. Different concentrations of nitrogen and Paclobutrazol (PBZ) alone and in combination were evaluated. Data were collected for consecutive 13 years based on vegetative growth and reproductive behaviour. Optimum postharvest vegetative growth, maximum flowering terminals and the highest fruit yield were obtained from the trees treated with 1 Kg of nitrogen annually. The use of PBZ, alone or in combination with nitrogen, helped boosting up fruit yield during the initial five years of investigation but later on resulted in reduced yield and gradual mortality of mango trees.

Key words: Tree canopy; Pruning; Nitrogen; Paclobutrazol; Vegetative flushes; Flowering terminal.

Introduction

The landscape of Pakistan is favourable for producing various valued fruit crops for domestic use and export as well. Among fruit crops, Mango (*Mangifera indica* L.) belongs to the Anacardiaceae family and is well adopted across the tropical and subtropical areas of the world (Chapman, 1999). Mango is crowned as “King of fruits” owing to its extraordinary characteristics, rich nutritional value and well-accepted taste and aroma (Teshome *et al*., 2023). Pakistan has been blessed with ago-climatic conditions, which favour high-quality mango production. Pakistan is currently producing 1.72 million tons (MT) of Mango from an area of 168.6 thousand hectares and holds 5th position after India, China, Thailand and Indonesia in the world (Anon., 2019). The per hectare yield of mango in Pakistan is 10.2 tons which are comparatively lesser as compared to other mango producing country such as China (11.4 t/ha), and Brazil (12.6 t/ha) (FAOSTAT, 2016). The main reason for this gap is insufficient knowledge among the growers regarding modern production practices as well as low plant density.

In Pakistan, limited work has been done regarding the nutrition management, pruning and water requirements of mango plants. The yield can be improved by the application of synthetic fertilizers (NPK) and well-rotten farmyard manure (FYM) (Singh, 1987). A trial was conducted to evaluate the effect of nitrogen fertilizer on the performance of Mango, Varying concentrations of nitrogen were applied to the young tree in a long-term trial and found 1000 g N/tree was effective for good vegetative growth and yield (Kanwar *et al*., 1987). Hasan *et al*., (2006) reported that application of 800 g N and 50 kg of FYM together with pruning at a 4-meter height produced the highest shoot length, shoot girth, number of leaves per shoot and canopy spread. Paclobutrazol (PBZ) is a growth retardant and previously various results of PBZ regarding manipulating the vegetative and reproductive performance of various mango cultivars have been reported. Kulkarni (1988) performed the initial experiments regarding the effects of PBZ on mango for reducing the shoot elongation and tree size while an enhancement of flowering in young mango trees was observed by the soil application of PBZ.

Earliness of flowering has shown variable results, as influenced by cultivars and the rate of PBZ used. Earliness varied from one-week (Tongumpai *et al*., 1991) to four and eight weeks (Kulkarni, 1988; Burondkar & Gunjate, 1993). Similarly effect of different concentrations of PBZ on increasing the yield (2.6 times more than control) has also been reported for cv. Alphonso was treated for three years with annual applications of 5 and 10 g PBZ per tree (Burondkar & Gunjate, 1993). Effects of PBZ on fruit size and quality have not been significant (Kulkarni, 1988; Burondkar & Gunjate, 1993; Kurian & Iyer, 1993b).

In Pakistan, most of the commercial mango cultivars grown are tall growing and many of the old orchards are planted at a distance of 35-40 feet (12m) with the idea that the trees may remain away from the surrounding trees for a much longer period and usually, no measure is practised to manage the tree canopy volume. After 20-25 years of plantation, the tree achieves a huge canopy with 40-50 feet in height and more spread than the allocated space and trees intermingle with each other. At this stage the decline in yield of orchards starts, availability of light for shoots, and proper application of fungicides and insecticides on the tree become impossible. Resultantly, the trees produce fruit on few terminals due to insufficient light access and the fruit exhibit poor quality. High-quality fruits and the regular crop cannot be achieved from these trees due to their huge size. Small trees can produce fruit of high quality but exhibit a low yield per tree. It is also observed that pruning in mid and late season mango cultivars not only makes the tree unproductive for a year but also makes the tree more susceptible to the winter season. So, these are the basic threats which make tree pruning and canopy management intricate.

Previously no significant work has been done in Pakistan on regulating the plant canopy of mango trees. So, the real challenges were, to prune the tree after harvest and achieve immediate vegetative growth before winter and make this postharvest vegetative growth productive. Therefore, the present experiment was undertaken to determine the yearly optimum levels of nitrogen and PBZ required for a mango tree after the post-harvest pruning to maximize total yield and yield stability and to spot the effects of prolonged use of PBZ on mango trees.

Material and Methods

This trial was conducted at Mango Research Station, Shujabad (located at 29º 52'55.818" N to 71º 21'12.318" E) Distt. Multan (Pakistan). 25-year-old mango trees cv. "Sammar Bahisht Chaunsa", planted at a distance of 12 m (40 ft) between rows and plants, was used for this trial and data were collected for thirteen consecutive years from 2008 to 2020. The height of all experimental trees was reduced to 8 meters with a canopy diameter of 11 meters. Later, annual pruning was performed immediately after harvesting to maintain the same tree size. Commencing from the year 2008, three levels of nitrogen (0, 1/2 kg, and 1 kg per tree) were applied during the first week of August and three levels of PBZ (0, 40 and 50 mL per tree) were applied by soil trenching during the first week of September every year during the trial period (2008–2020), alone and in suitable combinations, were tested to record their effects on tree vigour and their yield components. All experimental trees received uniform orchard management measures including plant protection.

First data for postharvest growth was recorded in October 2008, while the first flowering and yield data were recorded in March 2009 and July 2009 respectively. The experimental data on vegetative/reproductive growth and yield components were recorded at respective times every year during the trial period. Two levels of PBZ were tested to discourage further postharvest vegetative growth and to facilitate the vegetative flushes to induce flowering. The following treatments were tested under the experiment.

PBZ was applied at the onset of postharvest vegetative growth on the collar portion of the experimental trees. Nine inches deep trench was made around the stem for application of PBZ. AuStar (Paclobutrazol) @250 g/L manufactured by Chemical Direct Pvt. Ltd, Australia was used under the trial. 1 L of PBZ was mixed with 20 and 25 L of water separately. 1 L from each mixture was applied to experimental trees as per the treatment plan. Finally, 4-5 L of water was added to the collar portion and the trench was refilled with soil. The soil level was maintained as per field level so that the PBZ application zone may get sufficient water during irrigation.

Pruning of Mango plants was conducted immediately after fruit harvest and fungicide was applied to protect from any possible infection. Plants under the experiment were pruned uniformly to maintain the homogenous canopy volume. Tree height of 8 meters and canopy diameter of 11 meters were maintained immediately after fruit harvesting every year. The fungicide paste was applied on thick branches at cut points to minimize the chances of infection. After the pruning and fungicide application, the complete dose of P_2O_5 (1kg), K_2O (1kg) in August and Nitrogen (½ kg) at flowering in March was applied as a constant dose in all the treatments including control every year. The Nitrogen was applied as Ammonium Nitrate, P_2O_5 as Single Super Phosphate and K_2O as sulphate of Potash.

Parameters studied: Efficacy of nitrogen and PBZ was evaluated based on the vegetative and reproductive performance of mango trees. Tree height and spread were measured by using a measuring tape.

Vegetative and flowering terminals: Vegetative and flowering terminals of mango trees were counted by applying the ring method and the results were expressed as a percentage (%). A wooden ring of known diameter (Approx. 1.5 meters) was used for measuring growth intensity, the ring was placed all around the plant randomly on the plant canopy at the variable height at 20 different locations and vegetative growing/ grown and other terminals were counted inside the ring. Similarly, the counted terminals were used to calculate and express the growing terminals in percentage by using the following formula and flowering terminals were counted in the last week of March each year by using the same procedure.

$$\text{Flowering terminals (\%)} = \frac{\text{Growing terminals inside the ring}}{\text{Total terminals inside the ring}} \times 100$$

Number of fruits and fruit weight: All the fruits on an individual experimental tree were harvested and counted and fruit yield was taken by exact weighing of all fruits (UWE-ESP 5). The average fruit weight was calculated accordingly.

Fruit yield (Kg): Total number of fruits per tree was recorded at the time of harvesting and the actual yield kg/tree was taken by weighing the harvested fruits. The small de-shaped splitted fruits which were not edible were excluded from the count.

Statistical Analysis

This experiment was laid out according to Randomized Complete Block Design (RCBD) with nine treatments that were replicated five times. Two trees in each replication served as an experimental unit making the total of 90 trees for this experiment. Data were analyzed by analysis of variance (ANOVA) over the year technique (Steel *et al*., 1996). Comparisons among the means were made by the LSD test ($p \leq 0.05$).

Results

Climatic conditions: The monthly maximum and minimum temperatures are given in (Table 1). The maximum temperature remained in the range of 44–47ºC recorded during the month of May-June whereas the monthly average minimum temperature fluctuated between 1 and 4ºC recorded during the month of December-January every year until the conclusion of this experiment. The climatic data were recorded to develop the correlation of different phenological stages with temperature extremes. The better flowering in 2010, 2011 & 2016 may have a slight influence on the freezing temperature observed during these years in January.

Table 1. Treatment plan.

Treatment	Detail of treatment
T_1	Nitrogen (0 kg)
T_2	Nitrogen (½ g)
T_3	Nitrogen (1 kg)
T_4	Nitrogen (0 kg+ PBZ 40ml)
T_5	Nitrogen (½ kg+ PBZ 40ml)
T_6	Nitrogen (1kg + PBZ 40ml)
T_7	Nitrogen (0 kg+ PBZ 50ml)
T_8	Nitrogen (½ kg + PBZ 50ml)
T_9	Nitrogen (1 kg + PBZ 50ml)

Postharvest growth terminals: Mango trees produce flowers on mature vegetative shoots; therefore, the trees must have sufficient vegetative growth every year to ensure regular fruiting (Fig. 1A and B). In the present investigation, data on percent growth terminals produced on the tree were recorded during October every year (Table 2). Regardless of the doses applied, significant effects of nitrogen application on the emergence of new growth flushes were observed suggesting that judicious application of nitrogen enhances postharvest vegetative growth in mango trees which ensures optimum flowering, fruit set and yield during the next season. The highest number of vegetative flushes (65.42%) were produced by the trees treated with 1 kg of nitrogen and trees treated with ½ kg of nitrogen produced 51.25% of growth flushes while zero nitrogen produced minimum vegetative flushes (43.92%) on average without PBZ application. A similar growth pattern was observed under various combinations of PBZ and nitrogen with much reduced vegetative flushes as evident from Table 2. Contrary to the nitrogen application, PBZ was found to inhibit postharvest vegetative growth in mango trees throughout the trial period (2008-2020). The annual treatment of 50 mL of PBZ per mango tree applied by soil trenching resulted in the production of the least (17.33%) vegetative flushes suggesting its well-known prohibitory effects on vegetative growth. Continuous application of 50 ml PBZ to mango trees by soil-trenching during the entire trial period (2008-2019) caused a gradual decline of vegetative growth from 31% in 2009 to 3% in 2019 which ultimately resulted in tree mortality (Table 9) after the present investigation, irrespective of the doses applied.

April flushes: During the spring season (March–April), data on the emergence of vegetative flushes were recorded on non-flowering shoots every year. Maximum April flushes (17.17%) were recorded from the trees treated with 1 Kg of nitrogen annually. It is important to mention here that occurrence of postharvest vegetative flushes and April flushes in mango trees have a rectilinear correlation, regardless of the treatments applied (Tables 2, 3). The lowest occurrence of April flushes (7.17%) was recorded from the trees treated with 40 ml of PBZ per tree without nitrogen application. The trees treated with PBZ depicted a very low occurrence of April flushes irrespective of the doses applied, indicating its strong inhibitory effects on the vegetative growth of mango trees over an extended period (Fig. 2A and B).

Flowering terminals: The data regarding flowering was collected at the end of the flowering season in March last week every year (2009-2020) by the "Ring Method". Flowering and non-flowering terminals were counted within the ring at 20 different sites randomly selected all around the tree. Applications of nitrogen to mango trees had significant ($p \leq 0.05$) effects on percent flowering terminals (Table 4). The results indicated that an annual application of 1 kg of nitrogen to mango trees increased their flowering tendency from 39% in the year 2009 to 69% in 2020. However, we observed a slight up and down in flowering terminals during the entire period (2009-2020) of investigation within all treatments (Table 3). The average of twelve years of data revealed that the highest number of flowering terminals (54.25%) was produced by the trees treated with 1 kg of nitrogen annually whereas those treated with 40 mL of PBZ annually without nitrogen produced the least number (35.25%) of flowering terminals. Application of PBZ to mango trees by soil trenching, impressively increased their flowering tendency during 2009-2014 following which we observed a notable trend of decrease in flowering tendency of mango trees, regardless of the doses applied (Fig. 3A and B).

Fruiting terminals: A continuous increasing pattern of fruiting terminals were observed in the trees treated with nitrogen annually without the use of PBZ. The application of 1Kg of nitrogen per tree per year significantly enhanced the percentage of fruiting terminals in mango trees from 19% in the year 2009 to 53% in 2020. Taking the average of 12 years of data, we found that maximum fruiting terminals (33.09%) were produced by the trees treated with 1 Kg of Nitrogen annually followed by those treated with 50 mL of PBZ applied by soil trenching combined with ½ Kg of nitrogen annually which produced 32.92% fruiting terminals. The least number of fruiting terminals (18.83%) was recorded in control. We concluded that the application of PBZ to mango trees by soil trenching, alone or in combination with nitrogen, regardless of their doses applied, resulted in an abrupt increase in fruiting terminals during the initial six years (2009-2014) of present investigation and a gradual decrease in the percentage of fruiting terminals were also recorded as evident from (Table 5). After this experiment in the year 2020, the mango trees treated with 50 mL of PBZ, alone or in combination with nitrogen produced 0% fruiting terminals. The data is almost showing similar trends as observed in post-harvest growth and flowering (Fig. 4A and B).

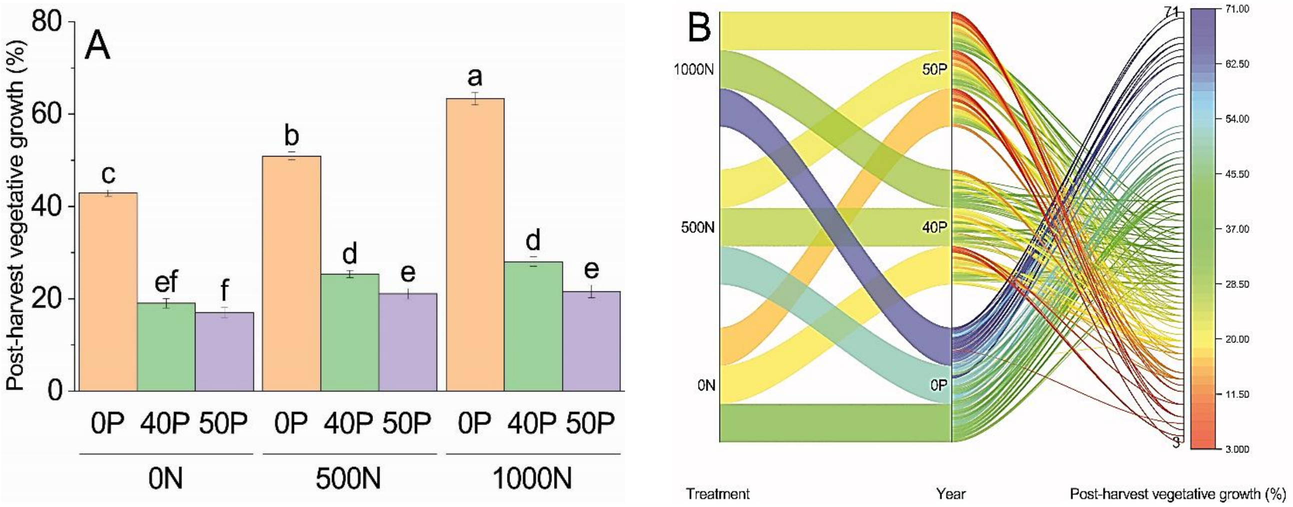

Fig. 1. Effect of variable application rates of nitrogen and PBZ on post-harvest vegetative growth of mango. Bars are means of 5 replicates and average of 12 years data ± SE. Different letters of bars are showing significant difference at $p \leq 0.05$ (A). Parallel plots are showing the data range of post-harvest vegetative growth of mango obtained during 12 years of study (B).

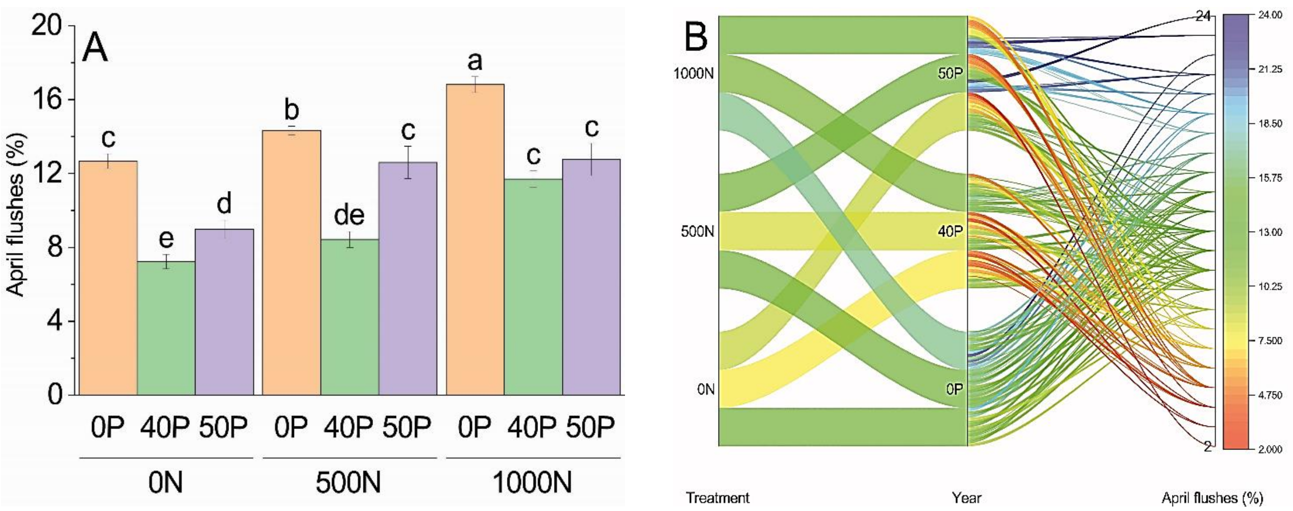

Fig. 2. Effect of variable application rates of nitrogen and PBZ on april flushes of mango. Bars are means of 5 replicates and average of 12 years data ± SE. Different letters of bars are showing significant difference at $p \leq 0.05$ (A). Parallel plots are showing the data range of april flushes of mango obtained during 12 years of study (B).

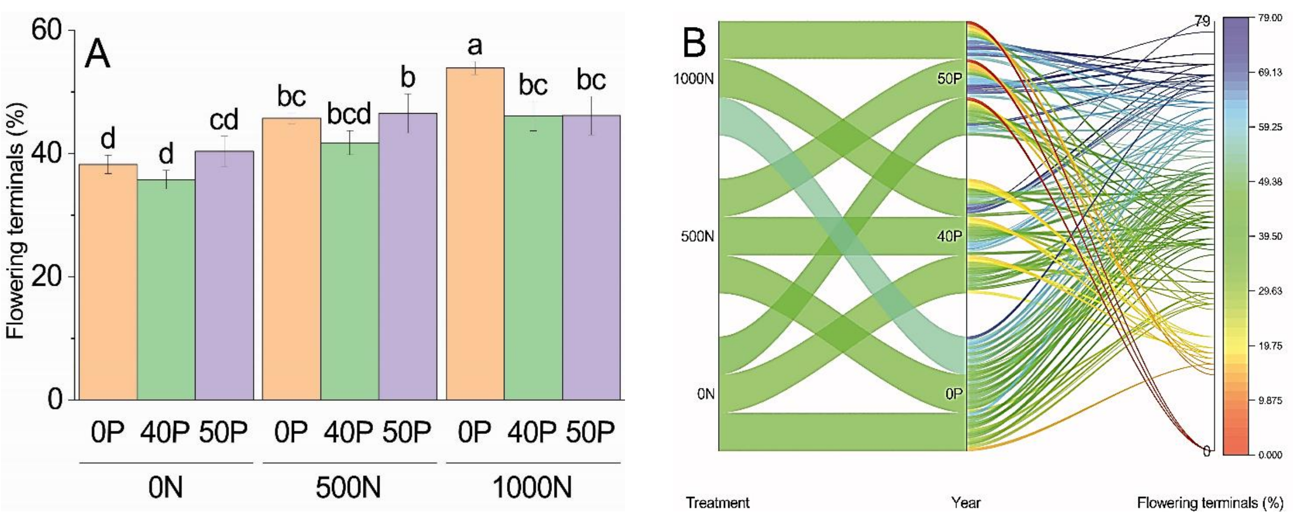

Fig. 3. Effect of variable application rates of nitrogen and PBZ on flowering terminals of mango. Bars are means of 5 replicates and average of 12 years data ± SE. Different letters of bars are showing significant difference at $p \leq 0.05$ (A). Parallel plots are showing the data range of flowering terminals of mango obtained during 12 years of study (B).

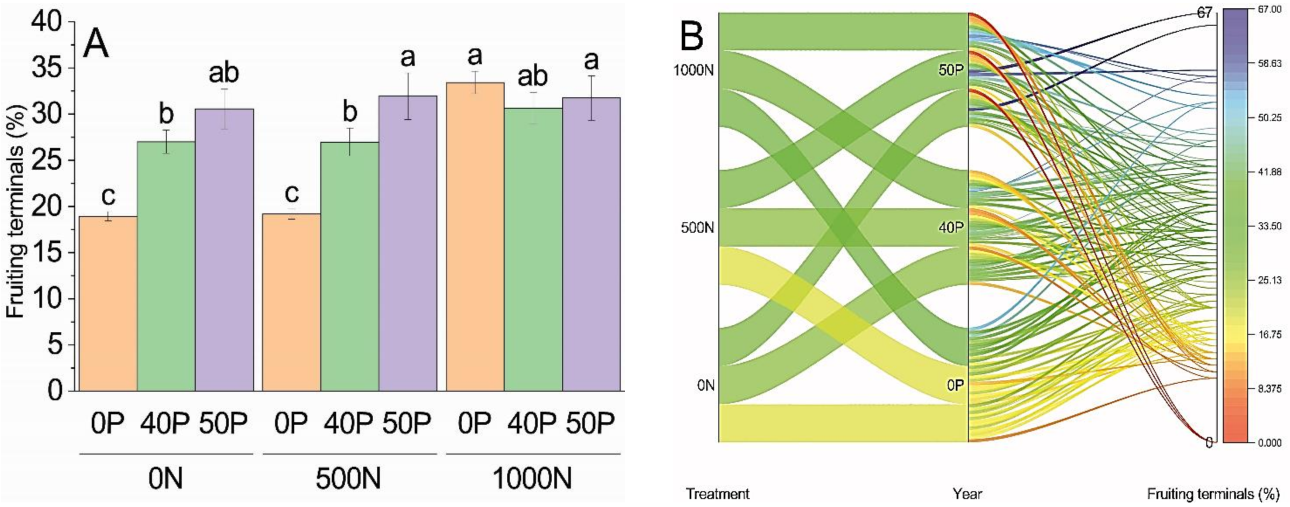

Fig. 4. Effect of variable application rates of nitrogen and PBZ on fruiting terminals of mango. Bars are means of 5 replicates and average of 12 years data ± SE. Different letters of bars are showing significant difference at $p \leq 0.05$ (A). Parallel plots are showing the data range of fruiting terminals of mango obtained during 12 years of study (B).

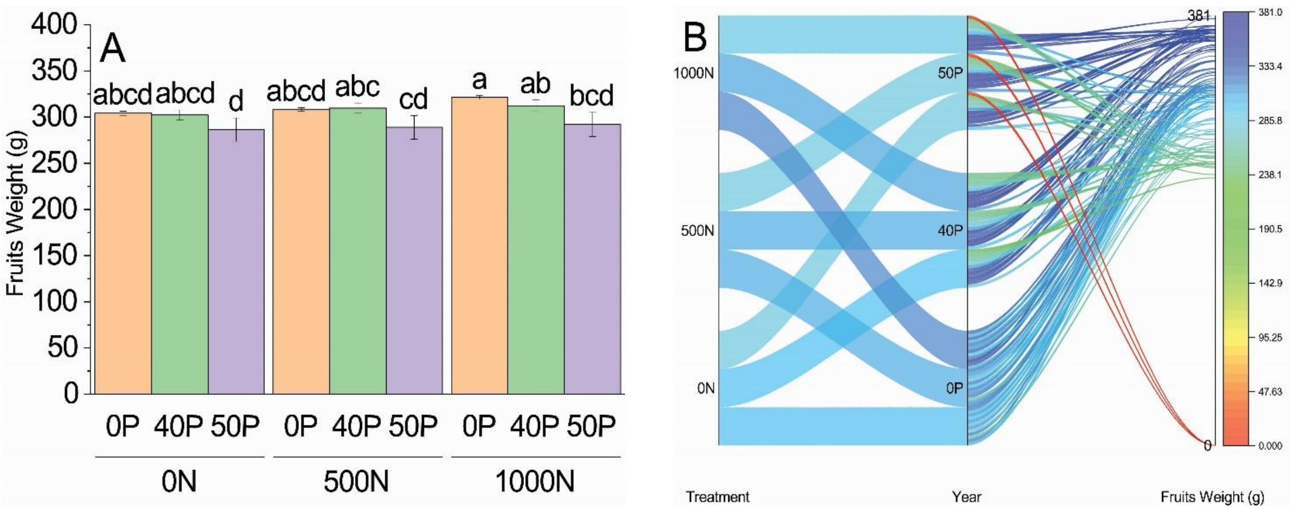

Fig. 5. Effect of variable application rates of nitrogen and PBZ on fruit weight of mango. Bars are means of 5 replicates and average of 12 years data ± SE. Different letters of bars are showing significant difference at $p \leq 0.05$ (A). Parallel plots are showing the data range of fruit weight of mango obtained during 12 years of study (B).

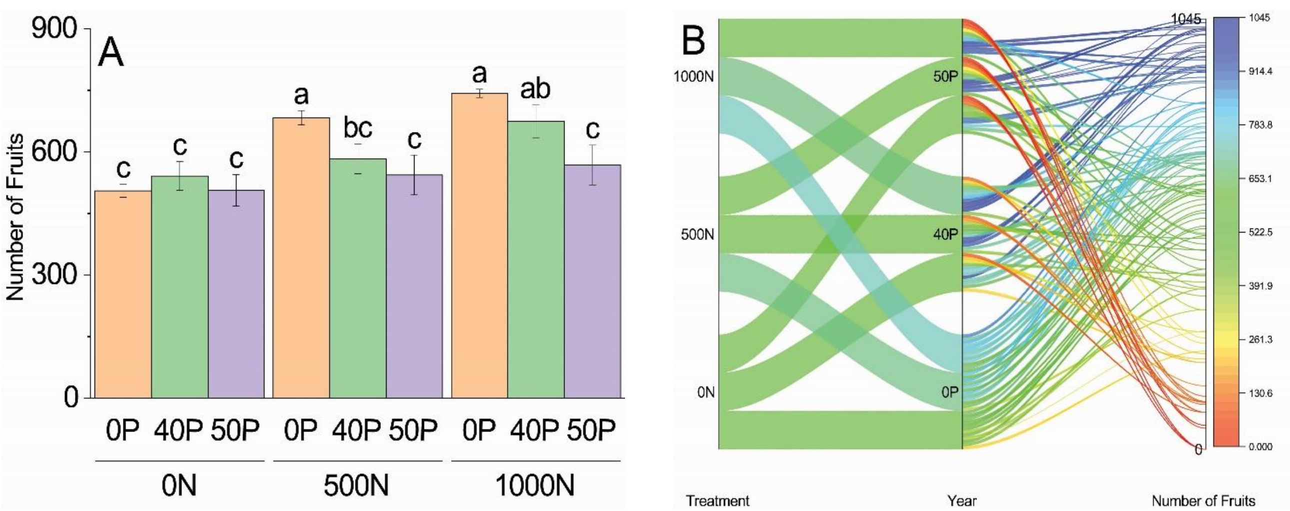

Fig. 6. Effect of variable application rates of nitrogen and PBZ on number of fruits of mango. Bars are means of 5 replicates and average of 12 years data ± SE. Different letters of bars are showing significant difference at $p \leq 0.05$ (A). Parallel plots are showing the data range of number of fruits of mango obtained during 12 years of study (B).

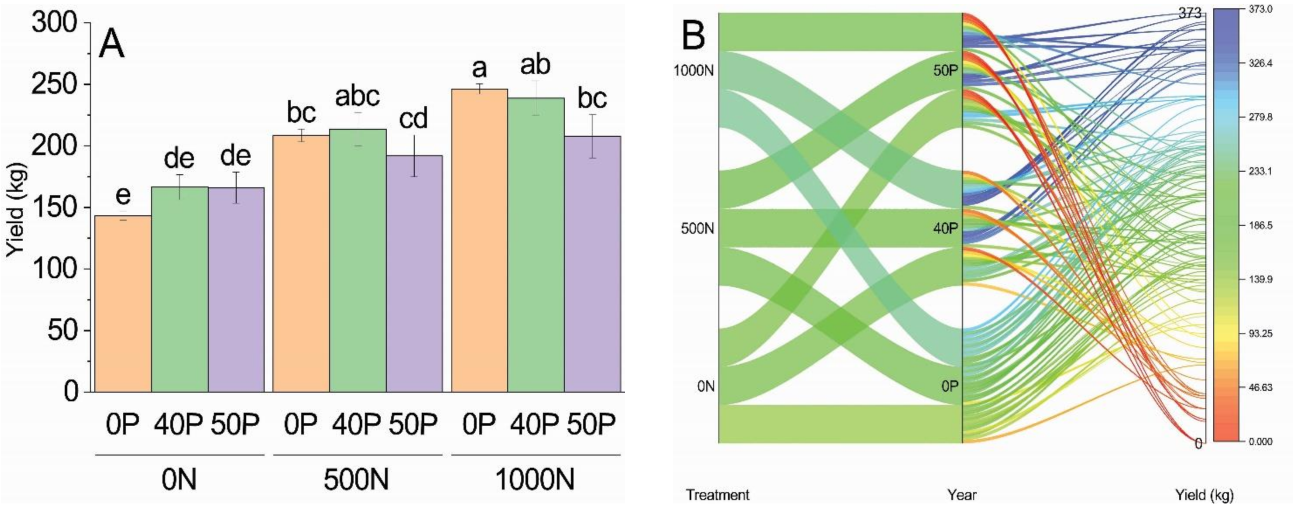

Fig. 7. Effect of variable application rates of nitrogen and PBZ on yield of mango. Bars are means of 5 replicates and average of 12 years data ± SE. Different letters of bars are showing significant difference at $p \leq 0.05$ (A). Parallel plots are showing the data range of yield of mango obtained during 12 years of study (B).

Number of fruits and fruit weight: Effect of nitrogen and PBZ on fruit numbers per tree and average fruit weight of mango fruits was calculated for successive twelve years (2009 to 2020). A significant impact of nitrogen and PBZ applications on average fruit weight was recorded (Table 6). It was found that the application of nitrogen at the rate of 1kg per tree every year enhanced the average fruit weight of mango significantly from 303 g in 2009 to 330 g in 2020. An average of 12 years showed that maximum fruit weight (321.7 g) was recorded from the trees where 1kg nitrogen was applied annually. The trees where different doses of nitrogen (0, ½kg and 1kg) nitrogen were applied depicted an increasing trend of fruit weight in almost alternate years from 2009 to 2020. It was also observed that application of PBZ alone or in combination with nitrogen enhanced the fruit weight for initial six years and after that, a continuous decline in average fruit weight was observed in the trees where 50 ml PBZ was applied in combination with 1kg Nitrogen, average fruit weight was increased from 317g in 2009 to 367g in 2014 and after that, a continuous decline was recorded and 247g average fruit weight was observed in 2019 with complete crop loss in 2020. A similar trend was also recorded regarding the total number of fruits per plant (Fig. 5A and B).

The plants where different doses of nitrogen were applied showed an increase in the total number of fruits. In 2009, 607 fruits per plant were recorded under the treatment of 1kg per plant nitrogen, which increased to 879 fruits per plant in 2020, between these years alternate bearing of mango trees was recorded (Table 7). An average of 12 years revealed that the maximum number of fruits (742.42) was recorded when 1kg nitrogen was applied while the minimum number of fruits (506.33) was recorded when 0 g nitrogen + 50 ml PBZ was applied. A sudden increase in the number of fruits per tree was observed from 2009 to 2014 in the plants where 40 ml and 50 ml PBZ were applied but after that, a decline in number of fruits was observed which led to complete crop loss of PBZ treated plants in 2020. The plants where 1kg N and 50 ml PBZ were applied depicted an enhancement in number of fruits from 521 in 2009 to 1026 in 2013, and after that, a declining trend was observed which led to 51 fruits in 2019 and 0 fruits in 2020 (Fig. 6A and B).

A significant effect ($p<0.05$) of nitrogen and PBZ on the total yield of mango was recorded for successive 12 years (Table 8). It was found that the application of nitrogen at the rate of 1kg per tree every year enhanced the total per plant yield of mango significantly from 169 kg in 2009 to 293 kg in 2020. An average of 12 years showed that maximum yield (246.33 kg) was recorded from the plants where 1kg nitrogen was applied annually. Important to mention a continuous pattern of slight alternate bearing was observed in the plants where different doses of nitrogen were applied (0, ½ and 1kg) without PBZ. Application of PBZ to the plants resulted in a sharp rise in total yield from the year 2009 to 2014 when the average yield was increased from 193kg per tree in 2009 to 373 kg per tree in 2012 where 50 ml PBZ was applied along with 1kg nitrogen. It was recorded that application of PBZ alone or in combination resulted in increased fruit yield during the initial 6 years and later fruit yield declined gradually and finally led to a minimum in 2020 (Fig. 7A and B).

A self-speaking positive interaction between April growth, postharvest growth and reproductive growth of mango plants was found. It was observed that an increase in post-harvest vegetative growth on mango plants resulted in enhanced flowering percentage and yield. After 2013 reduced postharvest vegetative growth was recorded on the plants where 40 & 50 ml PBZ was applied and subsequently flowering and fruit set was also lowest on those plants. So it was concluded that induction of postharvest vegetative growth is very important for next year's flowering and fruit set which finally determined the yield. Likewise, positive interaction between postharvest growth and fruit yield of mango was also found. It was observed that more postharvest growth on mango plants resulted in increased yield in the next year while less yield was recorded from the trees having less postharvest growth in the previous year.

Table 2. Effect of nitrogen and PBZ on Post-harvest vegetative growth (%) of mango.

Treatments		Vegetative terminals (%) (± Standard Error)											
Nitrogen (g)	Paclobutrazol (ml)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	0	31 ± 2.11	37 ± 2.21	39 ± 2.11	41 ± 2.11	44 ± 2.87	48 ± 2.76	47 ± 2.67	42 ± 1.34	48 ± 2.87	43 ± 2.35	49 ± 2.87	46 ± 2.12
500	0	42 ± 3.6	49 ± 3.33	56 ± 2.11	45 ± 4.32	48 ± 2.97	47 ± 2.97	53 ± 3.14	51 ± 3.45	66 ± 3.76	47 ± 2.87	52 ± 3.01	59 ± 2.87
1000	0	59 ± 3.10	61 ± 4.17	64 ± 2.11	67 ±.5.67	65 ± 3.46	67 ± 3.78	70 ± 3.98	66 ± 3.35	71 ± 3.87	58 ± 3.65	63 ± 3.47	70 ± 3.34
0	40	19 ± 1.11	28 ± 1.22	31 ± 2.11	28 ± 3.43	19 ± 1.35	17 ± 1.56	24 ± 2.13	18 ± 1.78	13 ± 1.14	19 ± 1.13	4 ± 0.02	9 ± 1.13
500	40	24 ± 1.19	29 ± 3.11	34 ± 2.11	26 ± 1.98	37 ± 2.24	28 ± 2.13	22 ± 2.34	31 ± 2.34	19 ± 1.67	17 ± 1.09	22 ± 1.08	20 ± 1.18
1000	40	31 ± 1.15	32 ± 3.16	35 ± 2.11	33 ± 2.34	41 ± 2.87	23 ± 1.98	33 ± 2.37	23 ± 2.65	18 ± 1.87	19 ± 1.32	24 ± 1.07	13 ± 1.02
0	50	14 ± 1.14	31 ± 2.14	29 ± 2.11	24 ± 2.12	22 ± 1.54	18 ± 1.12	13 ± 1.87	21 ± 1.87	7 ± 0.67	14 ± 1.65	9 ± 0.07	3 ± 0.02
500	50	26 ± 2.23	34 ± 2.55	36 ± 2.11	25 ± 2.32	28 ± 1.45	23 ± 2.14	19 ± 3.34	14 ± 1.09	17 ± 0.89	11 ± 1.08	12 ± 0.09	7 ± 0.43
100	50	35 ± 2.34	39 ± 2.78	33 ± 2.11	29 ± 2.10	24 ± 2.18	27 ± 2.11	16 ± 1.01	22 ± 1.81	11 ± 1.07	13 ± 1.13	7 ± 0.51	5 ± 0.11

g = Gram, ml = Milliliter

Table 3. Effects of Nitrogen and Paclobutrazol on April growth (%) of mango trees.

Treatments		April flushes (%) (± Standard Error)											
Nitrogen (g)	Paclobutrazol (ml)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0	9 ± 0.87	15 ± 1.04	11 ± -0.87	13 ± 0.73	12 ± 0.67	10 ± 0.43	15 ± 0.81	11 ± 0.21	9 ± 0.02	17 ± 0.43	11 ± 0.32	19 ± 1.15
500	0	12 ± 1.02	13 ± 1.01	13 ± 0.534	15 ± 0.53	16 ± 0.79	14 ± 0.65	11 ± 0.73	16 ± 0.34	14 ± 0.32	17 ± 0.57	15 ± 0.41	16 ± 1.12
1000	0	18 ± 1.13	20 ± 1.13	21 ± 1.13	16 ± 0.57	22 ± 1.17	19 ± 081	12 ± 0.32	15 ± 0.22	17 ± 0.43	11 ± 0.54	16 ± 1.10	18 ± 1.21
0	40	11 ± 1.07	10 ± 0,98	13 ± 0.76	9 ± 0.31	8 ± 0.21	6 ± 0.03	7 ± 0.06	4 ± 0.01	5 ± 0.01	7 ± 0.01	3 ± 0.01	5 ± 0.01
500	40	9 ± 0.87	11 ± 0,67	14 ± 0.68	11 ± 0.33	7 ± 0.02	10 ± 0.14	9 ± 0.07	6 ± 0.01	8 ± 0.01	3 ± 0.01	6 ± 0.01	4 ± 0.01
1000	40	13 ± 0.76	13 ± 0.78	15 ± 0.83	16 ± 0.44	17 ± 0.67	13 ± 0.86	11 ± 0.1	10 ± 0.01	11 ± 0.01	7 ± 0.01	9 ± 0.01	5 ± 0.01
0	50	11 ± 0.64	13 ± 0.78	16 ± 0.87	12 ± 0.37	11 ± 0.04	10 ± 0.12	6 ± 0.01	8 ± 0.01	8 ± 0.01	6 ± 0.01	5 ± 0.01	2 ± 0.01
500	50	21 ± 1.76	20 ± 0.85	19 ± 0.67	24 ± 1.17	14 ± 0.3	12 ± 0.65	11 ± 0.76	10 ± 0.01	6 ± 0.01	5 ± 0.01	5 ± 0.01	4 ± 0.01
100	50	19 ± 0.87	19 ± 0.76	21 ± 0.98	23 ± 1.16	20 ± 1.13	11 ± 0.45	8 ± 0.08	8 ± 0.01	6 ± 0.01	5 ± 0.01	5 ± 0.01	7 ± 0.01

g = Gram, ml = Milliliter

Table 4. Effect of Nitrogen and PBZ on Flowering Terminals of mango.

Treatments		Flowering terminals (%) (± Standard Error)											
Nitrogen (g)	Paclobutrazol (ml)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0	16 ± 1.34	27 ± 2.31	36 ± 2.53	29 ± 2.21	43 ± 2.87	38 ± 2.67	29 ± 2.23	47 ± 2.91	39 ± 2.65	51 ± 2.96	43 ± 2.87	61 ± 2.93
500	0	27 ± 2.12	47 ± 2.87	49 ± 2.87	44 ± 2.54	51 ± 2.87	49 ± 2.81	41 ± 2.75	51 ± 3.03	47 ± 2.76	53 ± 2.97	43 ± 271	47 ± 2.81
1000	0	39 ± 2.65	51 ± 2.91	43 ± 2.64	57 ± 2.98	50 ± 2.87	59 ± 3.13	49 ± 2.87	61 ± 3.14	52 ± 2.87	63 ± 3.23	57 ± 2.61	69 ± 3.33
0	40	19 ± 1.32	39 ± 2.87	48 ± 3.72	51 ± 2.87	42 ± 2.87	51 ± 3.01	43 ± 2.24	38 ± 2.23	31 ± 2.20	29 ± 1.81	21 ± 1.33	18 ± 1.33
500	40	38 ± 2.76	59 ± 3.03	61 ± 3.31	63 ± 3.61	51 ± 2.87	49 ± 2.91	41 ± 2.43	38 ± 2.31	33 ± 2.23	27 ± 1.81	21 ± 1.33	17 ± 1.33
1000	40	47 ± 2.87	69 ± 3.76	71 ± 3.38	67 ± 3.43	48 ± 2.81	57 ± 3.04	51 ± 3.01	47 ± 2.33	38 ± 2.27	21 ± 1.98	19 ± 1.33	18 ± 1.33
0	50	51 ± 2.91	59 ± 3.01	64 ± 3.03	69 ± 3.72	41 ± 2.85	49 ± 2.81	37 ± 2.54	42 ± 2.30	31 ± 2.28	26 ± 2.43	18 ± 1.33	0
500	50	59 ± 3.25	68 ± 3.76	71 ± 3.72	73 ± 3.81	64 ± 3.07	63 ± 3.13	59 ± 3.05	41 ± 2.31	28 ± 2.26	16 ±	15 ± 1.33	0
100	50	58 ± 3.21	69 ± 3.76	64 ± 3.67	71 ± 3.81	66 ± 3.61	52 ± 2.81	59 ± 2.85	43 ± 2.31	27 ± 2.20	17 ± 1.87	14 ± 1.33	0

g = Gram, ml = Milliliter

Table 5. Effect of Nitrogen and PBZ on Fruiting Terminals of mango.

Treatments		Fruiting terminals (%) (± Standard Error)											
Nitrogen (g)	Paclobutrazol (ml)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0	10 ± 0.81	17 ± 0.81	19 ± 0.81	16 ± 0.81	21 ± 1.21	18 ± 0.81	17 ± 0.79	22 ± 1.01	18 ± 0.81	23 ± 1.11	19 ± 0.81	26 ± 1.03
500	0	14 ± 0.83	19 ± 0.87	16 ± 0.81	21 ± 1.01	18 ± 1.01	17 ± 0.77	13 ± 0.71	21 ± 1.01	16 ± 1.01	27 ± 1.79	22 ± 1.65	26 ± 1.19
1000	0	19 ± 0.87	37 ± 2.31	21 ± 1.32	36 ± 2.26	28 ± 1.28	37 ± 2.26	31 ± 2.21	26 ± 1.21	34 ± 1.33	47 ± 2.79	32 ± 2.19	53 ± 3.09
0	40	13 ± 0.81	28 ± 2.28	31 ± 2.25	33 ± 2.26	37 ± 2.26	42 ± 2.68	36 ± 2.35	32 ± 2.31	23 ± 1.23	21 ± 1.09	16 ± 0.79	11 ± 0.79
500	40	14 ± 0.81	29 ± 2.27	33 ± 2.26	41 ± 2.78	42 ± 2.26	41 ± 2.68	33 ± 2.31	28 ± 2.31	21 ± 1.21	17 ± 0.79	12 ± 0.79	10 ± 0.79
1000	40	17 ± 0.86	31 ± 2.31	39 ± 2.28	43 ± 2.78	42 ± 2.26	53 ± 3.06	44 ± 2.81	33 ± 2.31	24 ± 1.21	17 ± 0.79	14 ± 0.79	13 ± 0.79
0	50	14 ± 0.81	30 ± 2.31	37 ± 2.28	46 ± 2.81	39 ± 2.26	65 ± 3.26	43 ± 2.81	31 ± 2.31	27 ± 1.21	21 ± 1.65	13 ± 0.79	0
500	50	16 ± 0.82	33 ± 2.31	39 ± 2.28	48 ± 2.81	58 ± 2.98	67 ± 3.26	42 ± 2.81	34 ± 2.31	21 ± 1.21	13 ± 0.79	12 ± 0.79	0
100	50	15 ± 0.81	38 ± 2.33	43 ± 2.31	54 ± 3.26	57 ± 2.98	52 ± 2.98	46 ± 2.81	34 ± 2.31	21 ± 1.21	12 ± 0.79	11 ± 0.79	0

g = Gram, ml = Milliliter

Table 6. Effect of nitrogen and PBZ on fruit weight of mango.

Treatments		Fruits Weight (g) (± Standard Error)											
Nitrogen (g)	PBZ (ml)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0	305 ± 13.37	325 ± 14.23	265 ± 9.65	319 ± 13.37	278 ± 9.65	315 ± 13.37	290 ± 10.71	317 ± 13.31	298 ± 10.71	311 ± 10.71	301 ± 9.1	321 ± 13.37
500	0	318 ± 13.37	310 ± 13.31	269 ± 9.67	321 ± 13.37	310 ± 13.31	323 ± 13.37	298 ± 10.71	325 ± 13.28	289 ± 10.71	304 ± 10.71	311 ± 10.7	321 ± 13.37
1000	0	303 ± 13.37	341 ± 15.635	335 ± 14.63	319 ± 13.37	298 ± 10.41	331 ± 14.71	311 ± 13.36	321 ± 13.28	309 ± 10.71	328 ± 10.71	309 ± 10.7	330 ± 13.37
0	40	285 ± 9.67	340 ± 15.23	353 ± 15.36	340 ± 15.23	351 ± 15.56	340 ± 15.23	315 ± 13.36	280 ± 9.67	267 ± 10.71	257 ± 8.76	251 ± 8.76	237 ± 13.37
500	40	301 ± 13.37	365 ± 16.13	372 ± 16.51	334 ± 15.23	341 ± 15.23	359 ± 16.31	314 ± 13.31	288 ± 8.61	276 ± 10.71	264 ± 8.76	251 ± 8.76	249 ± 8.76
1000	40	315 ± 13.37	368 ± 16.13	360 ± 15.43	361 ± 15.43	366 ± 16.31	365 ± 16.31	305 ± 13.30	285 ± 8.61	260 ± 10.71	257 ± 8.76	250 ± 8.76	249 ± 8.76
0	50	298 ± 10.71	350 ± 15.32	363 ± 15.43	369 ± 15.43	362 ± 16.31	367 ± 16.31	319 ± 13.37	275 ± 8.67	262 ± 10.71	255 ± 8.76	240 ± 8.76	0
500	50	312 ± 13.37	361 ± 16.23	372 ± 16.41	368 ± 15.43	359 ± 16.22	358 ± 16.31	308 ± 13.31	271 ± 8.70	260 ± 10.71	251 ± 8.76	246 ± 8.76	0
100	50	317 ± 13.37	365 ± 16.73	378 ± 16.43	365 ± 15.43	368 ± 16.31	367 ± 16.31	306 ± 13.30	78 ± 5.437	259 ± 10.71	254 ± 8.76	247 ± 8.76	0

g = Gram, ml = Milliliter, PBZ= Paclobutrazol

Table 7. Effect of nitrogen and PBZ on number of fruits of mango.

Treatments		Number of Fruits (± Standard Error)											
Nitrogen (g)	PBZ (ml)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0	238 ± 9.4	437 ± 32.4	542 ± 30.5	390 ± 21.3	580 ± 33.2	390 ± 23.4	536 ± 29.4	574 ± 29.4	518 ± 23.4	651 ± 28.3	561 ± 23.4	665 ± 33.3
500	0	339 ± 13.5	643 ± 43.3	594 ± 33.2	749 ± 38.5	693 ± 37.2	825 ± 43.3	627 ± 23.3	792 ± 31.2	668 ± 27.5	828 ± 33.4	624 ± 28.3	820 ± 38.7
1000	0	607 ± 23.3	696 ± 43.3	630 ± 39.8	771 ± 39.4	712 ± 41.3	783 ± 23.2	720 ± 32.5	807 ± 38.1	750 ± 31.3	843 ± 36.5	711 ± 29.4	879 ± 32.5
0	40	219 ± 11.6	645 ± 43.5	735 ± 41.3	717 ± 39.4	964 ± 49.7	723 ± 23.3	768 ± 33.4	712 ± 29.4	426 ± 21.3	285 ± 15.4	210 ± 11.3	90 ± 8.76
500	40	406 ± 29.4	704 ± 44.5	918 ± 43.4	977 ± 51.6	954 ± 49.8	722 ± 23.2	644 ± 23.3	512 ± 29.4	484 ± 26.5	389 ± 21.3	154 ± 13.2	114 ± 11.3
1000	40	422 ± 32.4	1006 ±51.3	1022 ± 53.5	1016 ± 53.3	928 ± 48.7	840 ± 43.2	756 ± 39.5	716 ± 29.4	663 ± 29.8	372 ± 23.4	232 ± 10.3	109 ± 6.12
0	50	483 ± 36.5	693 ± 44.2	783 ± 43.2	894 ± 41.3	903 ± 44.3	630 ± 23.3	619 ± 23.3	393 ± 23.4	459 ± 29.4	129 ± 13.2	90 ± 9.41	0
500	50	498 ± 39.5	915 ± 48.3	952 ± 49.5	1036 ± 55.4	1045 ± 55.9	680 ± 23.2	613 ± 23.3	338 ± 23.4	257 ± 29.4	114 ± 12.3	58 ± 5.40	0
100	50	521 ± 41.3	926 ± 41.4	945 ± 49.5	1007 ± 54.3	1026 ± 51.4	839 ± 43.3	677 ± 23.3	437 ± 27.3	270 ± 29.4	116 ± 9.87	51 ± 5.43	0

g = Gram, ml = Milliliter, PBZ= Paclobutrazol

Table 8. Effect of nitrogen and PBZ on total yield of mango.

Treatments		Yield (kg) (± Standard Error)											
Nitrogen (g)	PBZ (ml)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0	68 ± 4.32	125 ± 8.76	155 ± 6.43	113 ± 8.43	160 ± 8.76	149 ± 7.16	137 ± 8.61	157 ± 8.26	142 ± 9.17	177 ± 9.61	155 ± 10.76	182 ± 10.76
500	0	103 ± 6.54	195 ± 10.26	180 ± 8.54	227 ± 11.32	210 ± 9.62	194 ± 9.63	190 ± 9.63	240 ± 10.61	217 ± 12.61	257 ± 13.76	231 ± 13.76	255 ± 15.76
1000	0	169 ± 8.54	232 ± 13.43	210 ± 12.61	257 ± 14.43	250 ± 10.61	267 ± 14.36	240± 12.21	269 ± 12.49	251 ± 13.76	281 ± 14.16	237 ± 13.76	293 ± 14.16
0	40	73 ± 5.32	215 ± 13.76	245 ± 13.76	239 ± 14.33	241 ± 10.61	256 ± 13.37	210± 10.31	178 ± 10.76	142 ± 9.61	95 ± 6.51	70 ± 6.11	30 ± 2.16
500	40	145 ± 8.76	320 ± 14.62	328 ± 17.62	349 ± 17.62	341 ± 15.64	258 ± 12.43	230± 11.32	183 ± 10.81	173 ± 10.76	139 ± 8.51	55 ± 4.13	41 ± 3.23
1000	40	151 ± 9.67	359 ± 15.26	365 ± 19.62	363 ± 17.62	330 ± 14.63	300 ± 16.52	270± 12.49	256 ± 13.37	213 ± 12.61	133 ± 8.51	83 ± 3.31	39 ± 2.86
0	50	161 ± 9.69	231 ± 12.12	261 ± 13.43	298 ± 15.43	301 ± 16.12	210 ± 10.43	173± 10.76	131 ± 9.31	153 ± 9.61	43 ± 2.11	30 ± 2.01	0
500	50	178 ± 10.76	327 ± 16.69	340 ± 15.31	370 ± 19.71	350 ± 18.63	243 ± 13.23	219 ± 10.43	121 ± 6.21	92 ± 5.11	41 ± 2.11	21 ± 1.18	0
100	50	193 ± 10.26	343 ± 17.62	358 ± 17.62	373 ± 19.62	340 ± 18.63	311 ± 15.76	251 ± 12.43	162 ± 9.37	100 ± 5.71	43 ± 2.11	19 ± 1.16	0

g = Gram, ml = Milliliter, PBZ= Paclobutrazol

Table 9. Effect of nitrogen and PBZ on plant morality.

Treatments		Plant Mortality												
Nitrogen (g)	PBZ (ml)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	0	0	0	0	0	0	0	1	0	0	0	0	1
500	40	0	0	0	0	0	0	0	0	0	0	0	1	1
1000	40	0	0	0	0	0	0	0	0	0	1	0	1	2
0	50	0	0	0	0	0	0	0	1	0	1	0	2	4
500	50	0	0	0	0	0	0	0	1	0	0	0	1	2
100	50	0	0	0	0	0	0	0	0	0	1	0	1	2

g = Gram, ml = Milliliter, PBZ= Paclobutrazol

Discussion

The potential increase in the fruit yield of the mango crop has been a major concern for commercial orchardists. In the past, a variety of management strategies had been adopted to manipulate the flowering pattern of mango trees to their vegetative growth, however, a little effort had been made to investigate the effect of postharvest vegetative growth on fruit yield. In the present investigation, mango trees were pruned immediately after harvesting fruit. The results revealed that the application of nitrogen improved the quantity of vegetative flushes which stimulated in higher flowering count in mango trees (Table 4). Patil *et al*., (2010) reported that postharvest foliar application of different nutrients was an effective strategy to induce vegetative growth and coming year's flowering in mango. Burondkar & Gunjage (1991) found that early postharvest vegetative growth resulted in increased flowering and fruit set, whereas delayed induction of vegetative growth resulted in reduced flowering and yield in mango crop (Burondkar & Gunjage, 1991). After the year 2012, the PBZ started affecting the vegetative phase negatively, consequently reducing the crop yield. Postharvest vegetative growth had been a key for next year's flowering and fruiting quality.

Application of PBZ at the rate of 50 ml/ tree enhanced the fruit yield from 178 kg/tree in the year 2009 to 327 kg/tree in the consecutive year 2010 (Table 8). The increasing trend of fruit yield continued until the year 2012 when the fruit yield peaked (i.e. 373 kg/tree). These results were in line with the findings of Burondkar & Gunjate, (1993) who obtained 2.6 times higher fruit yield as compared to control by the application of PBZ on the mango tree.

Paclobutrazol (PBZ) at the rate of 40ml and 50ml/plant is useful in the initial 5 years as it increased the flowering terminals by inducing postharvest growth and April growth. After 5 years spray of PBZ reduced the vegetative growth and consequently its yield quality. PBZ proved useful to the vegetative shoots to flowering and at the same time also to reduce the vegetative growth which is the principal area for flowering and fruiting phases.

During the initial phase of this investigation (2009–2013), mango trees treated with PBZ showed a higher tendency of flowering compared to control (Table 4). Being a well-known inhibitor of gibberellin, PBZ has extensively been reported to reduce vegetative growth in many fruit crops, as it increases the florigenic promoter/vegetative promoter ratio and stimulates flowering shoots in weakly inductive shoots of fruit crops (Adil *et al*., 2011). As shown in the present study, reduced postharvest vegetative growth resulted in the reduction of flowering tendency in mango trees irrespective of the treatments. When used over a long period, the application of PBZ caused undesirable stunted growth which gradually resulted in low yield and tree mortality (Table 9). Wongsrisakulkaew *et al*., (2022) observed that flowering was associated with reduced vegetative growth in mango trees which is often induced by lower activity of PBZ.

To understand the mechanistic phenomenon of post-harvest vegetative growth and flowering in mango trees in response to PBZ application, the present study was conducted for thirteen consecutive years (2008–2020). During the initial five years (2009–2013) of investigation, we observed an increasing trend in fruit yield which peaked (373 kg per tree) in the year 2013. However, a continuous and somewhat gradual decline in fruit yield was observed during the final 7-year phase (2014–2020) of this study. During this phase, the trees treated with PBZ showed stunted growth and gradual inhibition of flowering and fruit set. Twelve trees were also found dead (complete mortality) during the experimentation period 2016-2020. The trees treated with 40 mL of PBZ showed similar results in vegetative growth, flowering, fruit setting and fruit yield but to a lesser extent compared to those treated with 50 mL of PBZ during the last seven years of the present investigation. It was noticed that continuous application of PBZ reduced the fruiting capacity of mango trees regardless of the dose whereas the trees provided with nitrogen only produced a regular and optimum yield of mango. It is established that paclobutrazol inhibits gibberellin bio-synthesis which is required for cell elongation and extension of internodes in plants. When treated with PBZ, they produce compressed panicles which do not dry out well thereby leading to reduced yield. Davenport (1993) concluded that the application of PBZ may cause a severe reduction in yield.

The stunted growth of mango trees which resulted in lower flowering tendency and fruit yield during the final 7-year phase of the present investigation may be attributed to the application of PBZ during the entire period of study. Hadlow & Allan (1989) observed a similar (stunted) pattern of growth of scions in citrus sp. when treated with PBZ. The growth retardant reduced the hydraulic conductivity of peach roots and altered their nutrient uptake (Reiger & Scalabrelli, 1990). It causes morphological alteration in young roots of citrus and peach by increasing thickness and decreasing their length. Such alterations may influence their capacity to uptaking water and nutrients from the soil (Desta & Amare. 2021; Du *et al*., 2022) Williamson *et al*., 1986).

Conclusion

It was concluded from the study that postharvest vegetative growth is the basic production area required for flowering and fruiting. An annual application of 1 Kg nitrogen per plant immediately after tree harvesting is enough to achieve the required vegetative growth. The use of paclobutrazol helps boost the fruit yield for a few years however its prolonged use deteriorates the tree health, reduces fruit yield and may cause mortality of mango trees gradually. The use of PBZ needs further studies especially in doses, plant size and low temperature before delivering the final recommendations for the industry.

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