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Long Term Effect of Paclobutrazol Application on Fruiting, Yield and Quality of Mango cv. Alphonso

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A study was conducted for twelve years (2000 to 2011) to investigate the long term effect of paclobutrazol application on fruiting, yield and quality of mango cv. Alphonso at Agriculture Experimental Station, Navsari Agricultural University, Paria, Gujarat. The experiment was laid out in randomized block design (RBD) with eight treatments replicated three times. The treatments consisted of T_1: 4 g a. i. paclobutrazol/tree every year + Recommended Doze of Fertilizer (RDF); T_2: 4 g a.i. paclobutrazol/tree every year + 1.5 times RDF; T_3: 4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + RDF; T_4: 4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF; T_5: 4-3-2-1 g a. i. paclobutrazol/tree in four year repetitive cycles + RDF; T_6: 4-3-2-1 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF; T_7: RDF; T_8: 1.5 times RDF. The results revealed that application of treatment T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) recorded maximum fruit set per panicle at marble stage (2.05), minimum days to maturity (92.20), maximum number of fruits/tree (285.97), highest yield per tree (71.26 kg), maximum TSS (20.41 ^{o}Brix) and highest total sugars (14.85 %). All these parameters were statistically at par with treatment T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF) which recorded the Highest Cost Benefit Ratio (CBR) and hence recommended to the farmers.

Introduction

Mango (*Mangifera indica* L.) is one of the most prized tropical fruits worldwide due to its pleasant taste, aroma, attractive colour and high nutritional value (Silva *et al.*, 2012). In commercial mango plantations, it is desirable to control the vegetative growth and the canopy size to prevent or reduce alternate bearing and to facilitate cultural practices. The improvements in crop productivity in modern agricultural systems are increasingly dependant on manipulation of the physiological activities of the crop by chemical means (Subhadrabandhu *et al.*, 1999). Paclobutrazol (PBZ) is a synthetic plant growth regulator, which has been used in fruit tree crops to control vegetative growth and to induce flowering (Swietlik & Miller 1985). PBZ can be applied to mango trees as a foliar spray or as a soil drench (Tongumpai *et al.*, 1991). PBZ (especially soil drenched at higher concentrations) has been observed to reduce vegetative growth and increase flowering, percentage hermaphrodite flowers, fruit set as well as yield (Singh 2000) whereas it reduced incidence of floral malformation (Singh and Dhillon 1992). The first report about the use of paclobutrazol (PBZ) on mango (*Mangifera indica* L.) came from India where Kulkarni (1988) tested concentrations of 1.25 to 10 g a.i. per tree on 'Dashehari' and 'Banganepalli'. Davenport & Nunez-Elisea (1997) elaborated that unlike the other classes of growth retardants that are normally applied as foliar sprays, PBZ is usually applied to the soil because of its low solubility and long residual activity. The king of mangoes, Alphonso, better known as 'Hapus' in Gujarat and Maharashtra, is in great demand in domestic and international markets for its taste, pleasant fragrance and vibrant colour. It has long been one of the world's most popular fruit and is exported to various countries including Japan, Korea and Europe. However, this variety has the alternate bearing tendency and PBZ is being used indiscriminately by the farmers. There are negative connotations towards the use of PBZ, regulations for export of fruit from PBZ-treated trees to certain countries. The maximum residue limit of PBZ accepted by the Food and Agriculture Organization of the United Nations (FAO) in stone fruit is 0.05 mg/kg (Singh & Ram 2000). Hence, this experiment was designed to standardize the PBZ dozes along with enhanced fertilizer applications and to judge their effects on fruiting, yield and quality of Alphonso mango.

Materials and Methods

Studies were conducted for twelve years (2000-2011) at the Agriculture Experimental Station, Navsari Agricultural University, Paria (Elevation: 16 m amsl; Latitude: 22° 35' N; Longitude: 72° 35' E). The site is located in the western coastal region of India, which is characterized by sub tropical, hot and humid climate. The monsoonal rains commence from the second week of June and most of the precipitation is received during mid June to end of September. The seasonal rainfall ranges from 1500 -2000 mm. Minimum temperature varies from 18.0 ^{0}C to 22.0 ^{0}C, while May is the hottest month when the maximum temperature varies from 35.0 ^{0}C to 41.0 ^{0}C. Soil of the experimental plot was medium to deep with high clay content, belonging to vertisols, medium in nitrogen, high in phosphorus and sufficient in potash. Fifteen-year-old 'Alphonso' mango trees, planted at a density of 100 trees ha^{-1}, uniform in vigour and canopy spread were selected for study. All the trees were provided with standard orchard management practices including insect and pest management. The experiment was laid out in randomized block design with eight treatments *viz*. T_1: 4 g a. i. paclobutrazol/tree every year + Recommended Doze of Fertilizer (RDF); T_2: 4 g a.i. paclobutrazol/tree every year + 1.5 times RDF; T_3: 4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + RDF; T_4: 4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF; T_5: 4-3-2-1 g a. i. paclobutrazol/tree in four year repetitive cycles + RDF; T_6: 4-3-2-1 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF; T_7: RDF and T_8: 1.5 times RDF. There were three replications each with a two tree units. The quantified amount of PBZ (Cultar- 23% SC) was dissolved in 15-20 litres of water and applied around the root zone by making a ring with a radius of 1.5-2.0 m in mid-August. The control trees were treated with water. The RDF recommended for the study area was 100 kg FYM/tree and 750-160-750 g N-P-

K/tree which was multiplied by 1.5 to calculate 1.5 times RDF (150 kg FYM/tree and 1125-240-1125 g N-P-K/tree). In order to study fruit set, Days from Full Bloom (DFFB) to maturity, twenty panicles were tagged on each direction. Total number of fruits harvested from each tree was counted and twenty randomly selected fruits were weighed and averaged to ascertain weight of fruit. Fruit quality was determined 9 days after harvesting using 30 fruit per tree. The fruit used for the quality test were ripened at room temperature. Total Soluble Solids (TSS) were measured by digital refractometer (0–85 °Brix, Hanna), total and reducing sugars were estimated by methods suggested by Ranganna (1986) and titratable acidity was estimated by 0.1N NaOH method (AOAC, 2005). All the observational data were pooled for twelve years. Cost of cultivation, net returns and Cost Benefit Ratio CBR) was also calculated to work out the economics of different treatments and to suggest the best treatment. Statistical analysis was carried out by following the standard methods given by Panse and Sukhatme (1967).

Results and Discussion

Effect of treatments on fruiting

Fruit set at marble stage was significantly influenced by different treatments (Table 1). Maximum marble sized fruits per panicle (2.40) were recorded in the treatment T_2 where paclobutrazol (4 g a. i.) was applied/tree along with 1.5 times RDF and this treatment was at par with T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF), while lowest marble sized fruits per panicle were recorded in trees which were supplied with only RDF (T_7). Fruit set is primarily determined by the transfer of viable pollen on the stigma, pollen germination, and fertilization, and in all the physiological events gibberellins play important role. During fruit set and development rapid cell division and cell expansion occur, which are primarily regulated by gibberellins. Paclobutrazol tends to reduce the level of gibberellins (vegetative promoters) and thereby stimulates flower induction in weakly inductive shoots of fruit crops (Adil *et al.,* 2011). It seems that by affecting biosynthesis of GAs, PBZ demonstrates two pronged action i.e. induction of flower and regulation of vegetative growth.

The inhibitory role of GAs in flowering of perennials at the expense of reproductive development has been reported in many fruit crops (Wilkie *et al.*, 2008). Paclobutrazol treated trees had higher food reserves enhanced the highest fruit set compared to the lowest fruit set in the untreated tree with low reserves because of excessive vegetative growth (Yeshitela *et al.,* 2004) corroborate the present result. Zora *et al.*, (2000) revealed that Cultar was the best treatment to promote flowering as well as fruit set in mango cv. Dashehari at Ludhiana, when applied in October.

Days from full bloom (DFFB) to maturity is an important harvest index in mango and different treatments exhibited significant influence in reducing this period (Table 1). In the pooled data of twelve years, least DFFB were recorded in T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) which was at par with T_1 (4 g a. i. paclobutrazol/tree every year + RDF) and seven days earlier then control i.e. T_7 (RDF). Kulkarni (1988) observed increased flowering earliness in the treated trees. In other words, the flower-inductive factor may commence earlier in the season. Induction for an early flowering (Burondkar and Gunjate, 1993) may also advance fruit maturity and hence have another commercial advantage.

Table.1 Effect of long term paclobutrazol application on fruiting, yield, quality and Cost Benefit Ratio (CBR) – pooled data for twelve years (2000-2011)

Treatments	Fruit set/panicle at marble stage	Days From Full Bloom (DFFB)	Number of fruits/tree	Weight of fruit (g)	Yield (kg/tree)	Total Soluble Solids (TSS) °Brix	Total sugars (%)	Reducing sugars (%)	Fruit acidity (%)	CBR
T_1	2.05	93.47	240.17	246.84	58.91	19.91	14.59	3.93	0.200	3.92
T_2	2.40	92.20	285.97	249.55	71.26	20.41	14.85	3.96	0.202	4.74
T_3	1.97	95.33	228.67	246.59	56.60	19.75	14.61	3.91	0.203	4.10
T_4	2.29	94.43	275.47	246.04	67.89	20.16	14.78	3.93	0.198	4.88
T_5	1.74	97.03	206.13	248.32	51.18	19.78	14.56	3.95	0.195	3.81
T_6	1.80	96.80	216.83	249.45	54.27	19.82	14.60	3.95	0.200	3.91
T_7	1.54	99.80	163.77	243.94	39.95	19.33	14.25	3.93	0.202	3.56
T_8	1.61	99.47	178.15	243.56	43.39	19.43	14.07	3.92	0.198	3.73
C. D. (P=0.05)	0.12	1.72	12.28	NS	3.39	0.32	0.25	NS	NS	

Effect of treatments on yield

The treatments had significant effect on number of fruits/tree and in the pooled data treatment T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) recorded highest number of fruits (285.97) which were statistically at par with T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF), while T_7 (RDF) recorded the minimum number of fruits per tree (163.77) (Table 1).

The impact of lower vegetative growth observed for the higher PBZ concentration in soil drenching treatments contributed to the superior yield observed. Paclobutrazol was efficacious in advancing floral bud break and in increasing flowering and fruit yield (Kishore *et al.,* 2019).

The treatments did not had significant effect on weight of fruit, however heaviest fruit (285.97 g) was recorded in T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) in the pooled data analysis of twelve years (2000-2011).

The treatments had significant effect on fruit yield/tree as evident from the pooled data, where treatment T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) recorded highest yield/tree (71.26kg) which was statistically at par with T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF), while T_7 (RDF) recorded the minimum yield (39.95 kg/tree) (Table 1).

In the literature, soil application of PBZ has consistently been found to increase tree yield (Kulkarni 1988; Burondkar & Gunjate 1993; Kurian & Iyer 1992). Our results confirm the findings of Hoda *et al.,* (2001) that soil treatment is more effective than foliar spraying for increasing yield.

Effect of treatments on quality

Total soluble solids (TSS) content was significantly influenced by the application of different treatments. In the pooled data, highest TSS content (20.41 ^{o}Brix) was recorded in the treatment T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) which were statistically at par with T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF), while lowest TSS content was recorded in trees applied with RDF only (19.33 ^{o}Brix). There were significant differences in total sugar content in different treatments. In the pooled data (Table 1), highest total sugars were recorded in the treatment T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) which were statistically at par with T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF), T_3 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + RDF), T_6 (4-3-2-1 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF). Fruit quality improvements with respect to TSS, TSS to acid ratio, total sugars and reducing sugars in response to PBZ treatments can be related to assimilate partitioning of the plant. As the assimilate demand is unidirectional to the developing fruit, because of the great suppression of vegetative growth, PBZ-treated trees had higher fruit quality attributes. With the same justification, the control trees had lower TSS and sugars but higher titratable acidity. In agreement with the current experiment, Vijayalakshmi and Sirivasan (1999) and Hoda *et al.,* (2001) also reported that PBZ treatments improved fruit quality. Although different treatments had non significant influence on the quantity of reducing sugars but in the pooled data, highest reducing sugars were recorded in the treatment T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) (Table 1). Fruit titratable acidity was not affected significantly by the application of different treatments. In the pooled data, lowest acidity was recorded in the treatment T_5 (4-3-2-1 g a. i. paclobutrazol/tree in four year repetitive cycles + RDF). Burondkar *et al.,* (2013) and Singh (2000) also reported improvement in fruit quality in terms of TSS and acidity with paclobutrazol application. Based on foregoing discussion it can be concluded that treatment T_2 (4 g a.i. paclobutrazol/tree every year + 1.5 times RDF) is best in terms of fruit set, number of fruits, yield and quality characters which was at par with T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF). But T_4 (4-2-4-2 g a. i. paclobutrazol/tree in four year repetitive cycles + 1.5 times RDF) recorded highest CBR (Table 1) so it was recommended to the farmers.

Caution, however, must be given to the export regulations of some countries about fruit from trees treated with PBZ. Singh & Ram (2000) studied 'Dashehari' and 'Langra' mango and found that applications of PBZ at 2.3 g a.i. per m tree canopy had only 0.004 mg/kg fruit weight (PBZ content in the fruit), which was much lower than the international maximum value (0.05 mg/kg fruit weight). Subhadrabandhu *et al.,* (1999) also used 8 g a.i. per tree on 'Nam Dok Mai' mango and no chemical residues were detected in the mature fruits. As stated by Voon *et al.,* (1991), the extent to which mango cropping can be manipulated with PBZ varies with local climate, cultivars, and the occurrence of pests and diseases.

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