3 Ps: Mantra for maximizing mango yield under high-density planting system

Mango is the most important fruit crop of India in terms of acreage, genetic diversity, consumers' preference and market potential. In spite of the adoption of scientific production technology, productivity of mango is still less than 7.5 t/ha, which may be due to low-density plantation, irregularity in bearing and poor orchard management[1,2]. Hence, there is ample scope to increase mango productivity by adopting a high-density planting system (HDPS), optimizing plant canopy architecture and ensuring regularity in bearing[2,3]. Under HDPS, plant density may be increased by 4–16 times compared to the conventional planting system (100 plants/ha), which provides an opportunity for increasing productivity provided canopy regulation and regularity in flowering are ensured[4,5]. Under HDPS, mango is usually planted at a spacing of 5 m × 5 m, but it bears fruits satisfactorily only up to 10–12 years which is due to vigorous vegetative growth attributed to the occurrence of multiple vegetative flushes[5]. Under such condition, canopy regulation is a vital component of production technology to enhance economic life of mango trees. In addition, flowering periodicity in commercially important cultivars is a major limitation in mango cultivation. It has been observed that the intensity of flowering even in regular varieties is affected by weather conditions, particularly at the time of flower bud differentiation. In order to harness the potential of HDPS by addressing the issue of canopy management and irregularity in flowering, studies were conducted at the Central Horticultural Experiment Station (ICAR-IIHR), Bhubaneswar, with an objective to maximize mango yield by regulating 'plant canopy architecture', by practising 'pruning' and using 'paclobutrazol', which are referred to as the 3 Ps. The experiment was conducted in mango var. Arka Neelachal Kesari (an extra early irregular variety) during 2013–2016, on 7–8-year-old and 10–12-year-old trees planted at a spacing of 3 m × 4 m and 5 m × 5m respectively.

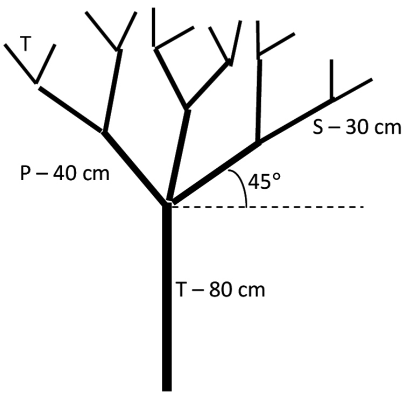

Figure 1. Canopy architecture (3P and 2S) in mango for 3 m × 4 m spacing. T, Trunk; P, Primary branch; S, Secondary branch; T, Tertiary branch.

Plant canopy architecture is a vital factor influencing light distribution, flowering, crop yield, fruit quality and pest incidence, particularly under HDPS. It also helps improve photosynthetic activity in plants, which in turn ensures higher productivity[6]. A study was conducted to optimize plant canopy architecture by regulating the number and orientation of primary (P) and secondary (S) branches. A combination of three primary branches (in different directions) and two secondary branches/primary was found to be suitable for mango planted at 3 m × 4 m spacing, whereas a combination of four primary branches (in different directions) and two secondary branches/primary was found to be optimal for 5 m × 5 m spacing. Along with the combination of primary and secondary branches, trunk height (80–90 cm), length of primary (40–50 cm) and secondary branches (30–35 cm), and angular distance of primary branches (45° from horizontal axis) were also optimized for developing an ideal canopy which acts as important framework for harnessing solar energy efficiently and ensuring high yield efficiency (Figure 1). Branches were oriented in such manner that the central portion of the plant canopy could facilitate better light penetration and distribution inside the canopy. Effect of plant architecture on yield and yield efficiency (yield per unit canopy volume) clearly indicated that the combination of four primary branches and two secondary branches/primary showed better performance in terms of yield and yield efficiency under 5 m × 5 m spacing (Figure 2).

Pruning has become an integral part for sustaining mango production under HDPS in order to regulate tree size and reduce pest load[7]. It has been observed that under higher planting densities, the intensity of productive shoots is significantly reduced if plants are left unpruned. Such a situation warrants canopy regulation to keep the orchard productive. Under the planting density of 3 m × 4 m, the height and spread of plants were restricted to 2 m, while plant height and spread of 3.5 m were regulated under 5 m × 5 m spacing. The optimized canopy height and spread were regulated by annual pruning carried out during June–July (after fruit harvest). The canopy of plants was reduced every year by 60–80 cm in order to regulate the canopy under different densities (Figure 3). During pruning operation the central branches, if any, were also removed (open centre) to facilitate better penetration of sunlight inside the canopy. It was observed that in unpruned trees, light interception was as high as 80–90%, which resulted in poor light penetration distribution inside the canopy and low intensity of productive shoots. On the other hand, light interception reduced to 50–55% and the intensity of productive shoots increased substantially when pruning operation was imposed. It was also observed that canopy regulation through pruning significantly increased fruit size and reduced the incidence of insect pests (hopper, mealy bug, etc.) and diseases (powdery mildew, anthracnose, etc.).

Crop periodicity is markedly evident in most of the commercially important mango cultivars. The 'on' year of mango is characterized by the prominence of reproductive shoots, whereas the 'off' year is marked by the dominance of vegetative shoots. Hormones, particularly gibberellins, play an important role in promoting vegetative phase in the place of reproductive phase[8]. Paclobutrazol (PBZ), a gibberellin inhibitor, has exhibited its efficacy in inducing flowering in mango in different regions of the country[9]. However its efficacy varies with agro-climatic conditions. PBZ was applied in soils at different rates (0.25–1.0 g a.i./m canopy spread) in mid-September through collar drench method. Findings clearly indicated that application of PBZ @ 0.25 g a.i./m canopy spread was effective

Table 1. Benefit–cost analysis under high-density planting system in mango

Particulars	HDPS without the 3 Ps (5 m × 5 m)	HDPS with the 3 Ps (5 m × 5 m)	HDPS without the 3 Ps (3 m × 4 m)	HDPS with the 3 Ps (3 m × 4 m)
Variable cost (Rs/ha)	103,500.00	141,750.00	112,500.00	171,500.00
Fixed cost (Rs/ha)	7500.00	7500.00	7500.00	7500.00
Total cost (Rs/ha)	111,000.00	149,250.00	120,000.00	179,000.00
Yield (t/ha)	7.12	10.28	7.31	13.51
Return (Rs/ha)	213,600.00	350,980.00	247,000.00	4,668,500.00
Benefit–cost ratio	1.92	2.35	2.05	2.59

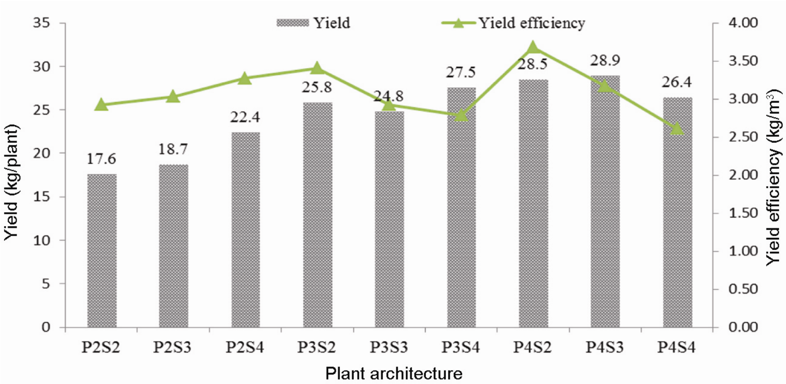

Figure 2. Effect of plant architecture on yield and yield efficiency.

Figure 3. Canopy regulation through pruning under (***a***) 3 m × 4 m and (***b***) 5 m × 5m planting densities.

Figure 4. Paclobutrazol (PBZ) influencing (***a***) flowering and (***b***) yield in mango.

in enhancing flowering intensity (70–80%) and yield (40–45%) in mango var. Arka Neelachal Kesari (Figure 4 *a* and *b*) without affecting plant growth and without leaving any residue in mature fruits. Moreover at this optimized rate of application, soil residue was also substantially low, which reached non-detectable levels within 6–7 months of application. On the basis of efficacy, PBZ was considered as an important component to maximize mango yield by ensuring higher flowering intensity and regulating plant growth.

The results clearly indicated that the 3 Ps made significant contribution in enhancing yield and fruit quality (Table 1). It was observed that in spite of high cost of cultivation, the benefit–cost ratio was substantially high (>2.3) under HDPS managed with 3 Ps, due to substantial increase in fruit yield. It is evident from the findings that the 3 Ps are vital interventions in regulating plant growth, ensuring crop regularity and sustaining fruit production in mango.

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