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THE ROLE OF PRUNING, PACLOBUTRAZOL, AND KNO_3 IN OPTIMIZING MANGO PRODUCTION: A REVIEW

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ABSTRACT

Mango (*Mangifera indica* L.) is one of the most important tropical fruit crops. Pruning, potassium nitrate (KNO_3), and paclobutrazol (PBZ) are essential tools for optimizing mango orchard management. Pruning balances vegetative and reproductive growth, enhances light penetration, boosts photosynthesis, and improves yield and fruit quality. Regular pruning synchronizes flowering, controls tree size, and redirects nutrients to axillary buds, promoting floral growth. KNO_3, a nutrient-rich foliar fertilizer, accelerates flowering, improves fruit set, and enhances yield and quality by facilitating ethylene production and nutrient transport. PBZ, a growth regulator, inhibits vegetative growth by reducing gibberellin biosynthesis, promoting early and profuse flowering while increasing yield and quality in alternate-bearing cultivars. By integrating these practices, growers can achieve sustainable orchard management, improved productivity and higher profitability, underscoring their importance in modern horticulture and these techniques can further improve overall mango production.

Key words: Pruning, Paclobutrazol, KNO_3, Mango production.

Introduction:

Mango (*Mangifera indica* L.) is one of the most important tropical fruit crops, often referred to as the "King of Fruits" due to its exceptional flavor, high nutritional value, and economic significance. Successful mango cultivation requires a complex interplay of horticultural practices that directly influence growth, flowering, fruiting, and overall productivity. Among these practices, pruning and the application of growth regulators such as paclobutrazol and potassium nitrate (KNO_3) have gained significant attention for their role in optimizing tree physiology and enhancing yield.

Pruning, an age-old horticultural technique, is vital for shaping the tree, balancing vegetative and reproductive growth, and enhancing fruit quality and quantity. By strategically removing portions of the plant, pruning promotes better light penetration, canopy renewal, and nutrient allocation, thereby ensuring sustainable productivity. The practice also aids in the synchronization of vegetative flushing and improves flowering dynamics, making it a cornerstone of mango orchard management.

Growth regulator such as paclobutrazol (PBZ) and soluble fertilizer potassium nitrate (KNO_3) have revolutionized mango cultivation by addressing critical challenges like irregular flowering, vegetative vigor, and alternate bearing. Paclobutrazol, a triazole derivative, effectively inhibits gibberellin biosynthesis, leading to reduced vegetative growth and enhanced reproductive performance. Its ability to induce early flowering, improve fruit set, and increase yield has made it an indispensable tool for mango growers. Similarly, potassium nitrate plays a pivotal role in breaking bud dormancy, stimulating ethylene production, and promoting floral initiation, significantly advancing flowering and improving fruit quality.

This document explores the intricate effects of pruning, paclobutrazol, and potassium nitrate on mango cultivation, focusing on their impact on vegetative growth, flowering, fruiting, and yield. The aim of the present review is to provide detailed information on the effects of pruning, potassium nitrate (KNO_3), and paclobutrazol (PBZ) on mango cultivation.

Pruning

Pruning is the art and science of selectively cutting away portions of a plant to improve its shape, influence its growth, flowering, and fruitfulness, and enhance the quantity and quality of the produce. It is an age-old practice in fruit tree management that involves the renewal of specific plant parts to influence physiological functions, thereby promoting higher crop yields with better fruit quality. Pruning redirects sap flow from one part of the plant to another, ensuring better distribution of fruiting wood and maintaining the tree in a manageable form. The removal of crisscross branches and the thinning of weak terminal shoots regulate tree growth, establishing a balance between vegetative and reproductive functions (Madhav Rao and Shanmugavelu, 1975). In mango, pruning is particularly important in subtropical and tropical regions due to the tree's tendency to produce frequent flushes, especially in humid tropics. Annual pruning as part of a flower management program prevents trees from becoming excessively tall, reshapes medium-sized trees into smaller, more manageable forms, and rejuvenates large, unproductive trees by reducing their size and height (Davenport, 2006).

Effect of Pruning on Vegetative Growth

Pruning is a crucial horticultural practice in mango cultivation, significantly influencing vegetative growth and tree management. By breaking apical dominance, pruning stimulates the growth of sub-terminal and axillary buds, leading to synchronized and prolific re-growth, as observed by Reece *et al.,* (1946, 1949), Oosthuyse (1994), and Sasaki *et al.* (2000). Pruned branches produce more shoots compared to unpruned ones, although they may bear fewer leaves per shoot. The severity and height of pruning impact shoot girth and length, with shoots closer to the trunk displaying greater girth due to better nutrient allocation (Lal *et al*., 2000). Strategic pruning also optimizes canopy structure, enhances light penetration, and improves air circulation. Moreover, pruning methods like tipping and heading back encourage vegetative flushing, crucial for sustaining regular cropping cycles (Gross *et al*., 1997).

Pruning of shoots immediately after harvest has been practiced to encourage early vegetative growth. This practice aids in the renewal of the canopy and prepares the tree for the next flowering cycle. Additionally, higher levels of gibberellins present in the tips or growing shoots must be regulated to arrest excessive shoot extension. By arresting this growth through pruning, the shoots can achieve physiological maturity, which is critical for initiating flower bud differentiation (Pal and Ram, 1978; Pandey and Majumdar, 1988).

The angle and magnitude of pruning influence re-growth dynamics, as cuts made at a 15° or 30° angle result in faster re-growth than flat cuts (Urrutia and Elisea, 1997). Severe pruning stimulates regrowth but can reduce flowering and productivity in the following year. Overall, pruning enhances vegetative growth by activating dormant buds, increasing shoot production, and redistributing nutrients for thicker, healthier growth. When carefully managed, pruning is an effective tool for maintaining tree size, improving canopy structure, and balancing vegetative and reproductive growth, ensuring sustainable productivity in mango orchards.

Effect of Pruning on Flowering:

Pruning is a critical practice in mango cultivation that significantly influences flower initiation, panicle development, and flowering behavior. Pruning induces axillary bud flowering, even in the proximal portions of pruned shoots, with panicles flowering (Sasaki *et al.*, 2002). Light pruning significantly increased the number of panicles per branch and reduced days to panicle emergence, while moderate pruning resulted in earlier 50% flowering and maximum fruit set per panicle (Sanjay *et al.*, 2010).

Pruning in the month of July–August stimulated both terminal and axillary panicle development, while December pruning induced only axillary panicles and also resulted in longer panicles and a greater main rachis diameter, whereas November and December pruning reduced rachis size in axillary panicles Mohan Swroop*et al.,* (2001). Solkani*et al.* (2016) reported that pruning at 25 cm during the first fortnight of July led to earlier flowering and a higher percentage of flowering due to improved solar radiation availability and altered hormonal activity (IAA), which enhanced flower initiation.

Madhav Rao (1988) reported that regular flowering in pruning trees is due to, a) Every injury caused by cutting or by pruning produce ethylene which is flowering promoting substance, b) Removal of excessive shoots reduces gibberellins (antiflowering substance), c) Pruning increases abscisic acid, a growth inhibitor but a flower promoter, d) Pruning increases cytokinin, ascorbic acid and auxins which are flowers promoting substances. Further pruning operation had thus a cumulative effect of bringing about a suitable hormonal and nutritional balance favorable for flowering.

Effect of Pruning on Fruit yield

Pruning is a crucial practice in mango cultivation, significantly impacting tree productivity and fruit yield. Dense canopies reduce light penetration, leading to photosaturation of leaves and limiting the conversion of light energy into carbohydrates essential for growth and fruiting. Heavy shading within the canopy results in poor regeneration, reduced floral initiation (Dambreville *et al*., 2013), lower fruit set, and decreased yields (Sharma *et al.*, 2006). Regular and appropriate pruning enhances the overall productivity of mango trees, leading to consistent fruiting (Madhav Rao and Shanmugavelu, 1975; Madhav Rao and Khader, 1979). Pruning immediately after harvest has also shown to increase the number of fruits per tree, fruit yield (Yashitela *et al*., 2005; Singh *et al.*, 2011), and fruit weight, particularly in trees treated with paclobutrazol.

Singh (2017) observed that the combination of pruning and paclobutrazol treatment was more effective in achieving regular bearing and higher yields in mango cv. Dashehari compared to either practice alone. Pruning during critical periods, such as July-August, has been found to significantly enhance flowering and fruiting, as reported in mango cv. Kesar by Solkani*et al.* (2016). Thus, systematic pruning improves light distribution, promotes canopy renewal, and enhances mango yield and fruit quality.

Effect of pruning on malformation incidence

Mango malformation is one of the most severe challenges in mango cultivation, significantly impacting yield and quality. Research has consistently demonstrated that pruning is an effective cultural practice for reducing floral malformation and promoting healthier growth in mango trees.

Pruning intensities, irrespective of mango cultivars, have shown a significant effect on reducing the incidence of malformation. Sirohi *et al.* (2006) reported that pruned trees exhibited fewer malformed panicles compared to unpruned ones, highlighting the role of pruning in mitigating malformation. Similarly, Muhammad *et al.* (2011) found that early removal of malformed panicles, combined with pruning, promoted healthy vegetative growth and the emergence of normal inflorescences. However, during the ‘on’ year, malformation incidence increased due to the time lag between pruning and flowering onset, as well as increased canopy volume, necessitating timely pruning interventions.

Singh *et al.* (2010) studied pruning effects on malformation in mango cultivars Amrapali, Mallika, and Dashehari. They observed that moderate pruning drastically reduced malformed panicles (9.40–11.21%) compared to controls (41.39–51.23%). This underscores the effectiveness of pruning in reducing malformation across various cultivars. Swaroop *et al.* (2001) conducted a study on 21-year-old mango cv. Dashehari and recommended pruning during July, August, and December in ‘on’ year trees. They observed that shoot pruning during these months completely controlled malformation (7.18–8.29%) compared to controls.

Lopez-Esmeralda *et al.* (2005) also highlighted the importance of pruning in managing malformation, reporting that pruning affected branches after harvest at specific distances (80 and 30 cm from the affected zone) significantly reduced bud deformation. This method was recommended as part of an integrated malformation management strategy. Furthermore, Sharma and Singh (2006) demonstrated that pruning severity, canopy height, and their interaction significantly influenced malformation incidence. Severe pruning resulted in the lowest malformation incidence (36.20%), while unpruned plants had the highest incidence (44.20%). Additionally, malformation incidence was lower in panicles located at the tree top (37.20%) compared to those in the lower canopy.

Paclobutrazol: Paclobutrazol (PBZ), a triazole derivative, has been widely used to regulate flowering, fruiting, and tree vigor in perennial fruit crops. Soil applications of PBZ effectively promote flowering and increase yield in various fruits. By inhibiting gibberellin biosynthesis at the kaurene stage, PBZ reduces vegetative growth, inducing early and profuse flowering, and enhancing fruit yield and quality, particularly in alternate-bearing cultivars. Additionally, PBZ increases cytokinin content, root activity, and C:N ratio, although its impact on nutrient uptake varies. As a versatile plant growth retardant, PBZ restricts vegetative growth and induces flowering in fruits like apple, pear, peach, citrus, and mango. Its physiological modifications and cellular metabolite changes lead to reduced tree vigor and optimized flowering responses.

Effect of paclobutrazol on vegetative growth

Paclobutrazol (PBZ) has been extensively studied for its beneficial effects in regulating vegetative growth and inducing flowering in various fruit crops, including mango, apple, and grape. PBZ functions primarily by inhibiting gibberellin (GA) biosynthesis, a hormone that promotes vegetative growth, thereby redirecting assimilates toward reproductive development. It enhances the total phenolic content in terminal buds and modifies the phloem-to-xylem ratio in the stem, which is crucial for restricting vegetative growth and promoting flowering. This alteration in assimilate partitioning and nutrient supply patterns supports new growth while controlling excessive vegetative vigor. Studies have demonstrated that PBZ effectively reduces plant height, canopy spread, and overall tree volume while leading to the development of shorter, more compact plants with smaller leaves and reduced internode lengths. For instance, Yamashita *et al*. (1997) highlighted the role of GA as a flowering inhibitor, with PBZ counteracting this effect to induce flowering in mango trees. Similar results were reported by Kulkarni (1988) in the Banganpalli, Dashehari, and Peddarasam mango cultivars, as well as by Salazar-Garcia and Vazquez-Valdivia (1997) in Tommy Atkins mango. Additionally, Khader (1991) observed that PBZ application resulted in reduced vegetative growth in Dashehari mango, and Kotur (2012) noted a significant decrease in the number of flushes, leaf area, twig length, and dry matter production. Similarly, Sarvade*et al.* (2024) observed reduced shoot length, internodal length, and earlier panicle emergence, along with an increase in the number and length of panicles, further validating the chemical's multifaceted benefits in mango production. These findings underscore PBZ's effectiveness in managing canopy size, controlling excessive vegetative growth, and promoting flowering, making it a valuable tool in the horticultural management of fruit crops.

Effect of paclobutrazol on flowering

Paclobutrazol (PBZ) has been widely recognized for its critical role in inducing and advancing flowering in mango trees, including both young non-bearing and mature bearing trees. Soil drenching with PBZ has been shown to induce precocious flowering in young trees and advance flowering in bearing trees (Kulkarni, 1988). PBZ significantly reduces the days required for panicle emergence, with higher concentrations proving more effective than lower ones. This effect is closely linked to carbohydrate reserves, which play a pivotal role in flower bud differentiation by creating favorable conditions for synthesizing substances essential for this process. A high C:N ratio, attributed to increased carbohydrate availability, has been identified as a crucial factor in regulating flowering, as observed in studies by Gohel*et al.* (2021) in Kesar mango and Sarker and Rahim (2012), where PBZ-induced flowering occurred 85 days after treatment. PBZ enhances starch reserves, total carbohydrates, and the C:N ratio in shoots, collectively promoting flower bud differentiation (Jogdande and Choudhari, 2001). The induction of early flowering has also been associated with an increase in shoot C:N ratio and leaf water potential due to a rise in ABA and cytokinins and a decline in gibberellins in buds. Additionally, an apparent increase in sugar levels during the floral induction period has been reported, with consistently higher production of total sugars and reducing sugars peaking at bud burst in apical buds of PBZ-treated trees (Palanichamy*et al.*, 2012; Jyothi *et al.*, 2000; Upreti *et al.*, 2014; Murti &Upreti, 2003). These physiological and biochemical changes highlight the effectiveness of PBZ in regulating flowering and improving reproductive performance in mango trees.

Early PBZ application significantly advances flowering and harvest by two and a half to three months, offering high economic returns from early-harvested crops. This early flowering is particularly beneficial in tropical and coastal regions, where temperatures remain conducive to fruit development during the off-season. Flowering in mango is preceded by flower bud differentiation, which is closely linked to the physiological maturity of shoots (Muhammad *et al*., 1999). PBZ-treated trees exhibit earlier bud break, with apical bud breaking observed 18-22 days earlier than in untreated trees and a significantly higher percentage of floral shoots (Chusri *et al*. 2008). For instance, over 96% of PBZ-treated 'Irwin' mango trees produced floral shoots compared to only 35% of control trees. Additionally, PBZ-treated trees showed increased flowering intensity, including shorter panicles, higher sex ratios, and enhanced cauliflory and axillary flowering (Singh, 2000). PBZ treatment also anticipated flower initiation and fruit harvest, enabling off-season production, which ensures higher profitability and premium market prices. The ability of PBZ to induce early flowering and extend the harvesting season highlights its practical application for improving mango cultivation in tropical and coastal regions.

Effect of paclobutrazol on fruiting & yield

Paclobutrazol (PBZ) has been shown to significantly enhance fruiting and yield in mango trees across multiple studies. The increase in fruit yield is primarily attributed to alterations in the source-sink relationship, where PBZ reallocates carbohydrate reserves from vegetative growth to developing fruits (Sonawane*et al*., 2016). Kulkarni reported a significant increase in mango yield per tree with soil application of PBZ at 10 g a.i./tree, while Shinde *et al.* (2000) observed that all doses of PBZ, regardless of application timing, significantly increased fruit set per panicle compared to control. Bagel *et al.* recorded the highest yield per tree (68.12 kg), yield per hectare (106.25 q/ha), and a 29.85% yield increase over control in 10-year-old Langra mango trees treated with Cultar at 5 g/ha combined with 20 ppm NAA. Similarly, Singh and Singh (2006) found that soil application of PBZ at 5 g/tree was most effective in improving fruit set and retention during off-years, with maximum yields of 70.50 and 68.70

kg per tree recorded at 5 and 10 g/tree, respectively.

The improvement in fruit set per panicle can be attributed to the retardation of vegetative growth by PBZ, which redirects resources toward reproductive development. In studies on mango cultivars Chausa, Dashehari, and Langra, soil drenching with PBZ at 2, 4, 6, and 8 g/tree yielded significant results. Maximum fruit set per panicle, fruit number, and yield per tree were observed with 4 g/tree in Dashehari and 6 g/tree in Chausa and Langra (Singh and Singh, 2003). These findings highlight the effectiveness of PBZ in improving fruit set, retention, and overall yield, making it a valuable tool for mango orchard management to enhance productivity and profitability.

Potassium nitrate (KNO_3)

Potassium nitrate (KNO_3) plays a crucial role in improving flowering, fruiting, and overall yield in mango cultivation. Its ability to break bud dormancy, enhance ethylene production, and stimulate floral initiation makes it a valuable tool for promoting early and uniform flowering. Research demonstrates that KNO_3 application significantly improves flowering characteristics, including increased panicle emergence, enhanced percentage of hermaphrodite flowers, and improved fruit set. Additionally, its role in optimizing source-sink relationships contributes to larger fruit size, higher fruit retention, and reduced fruit drop, ultimately leading to increased yields. Given its consistent performance across various studies, potassium nitrate is an effective and reliable foliar spray for enhancing productivity and profitability in mango cultivation.

Potassium is a vital nutrient for plant growth, development, and stress tolerance, playing a crucial role in various biochemical and physiological processes. In horticultural crops, potassium supplementation enhances fruit yield, size, quality, and shelf life, as evidenced by studies (Geraldson, 1985; Lester *et al.*, 2007). This essential nutrient facilitates phosphorylation, photoassimilate transport, enzyme activation, turgor maintenance, transpiration, and photosynthesis (Usherwood, 1985; Pettigrew, 2008). Specifically, potassium nitrate (KNO_3), a specialized fertilizer containing 13% nitrogen and 45% potassium, promotes nitrate reduction and ethylene production. Research has shown that KNO_3 application accelerates flowering and harvesting, increases yields, and reduces alternate bearing (Sergent*et al.*, 2000), with optimal results in flowering and fruiting (Khattab *et al.*, 2006).

Effect of Potassium nitrate on flowering

Potassium nitrate (KNO_3) has been widely recognized for its role in breaking bud dormancy and promoting flowering in mango and other fruit crops. Trewavas (1983) noted that KNO_3 effectively breaks dormancy in buds, particularly flower buds, by providing nitrate, which directly influences flowering. Adequate nitrogen reserves are essential for flowering and subsequent fruit formation. Valmayor (1962) found that spraying KNO_3 increases internal ethylene concentrations in shoots and ethylene-forming enzyme (EFE) activity in leaves, which promotes floral initiation. Protacio (2000) hypothesized that as gibberellin levels decrease below a threshold, starch accumulation begins, enabling floral initiation. Buds, however, remain dormant until conditions become favorable for flowering, and KNO_3 may activate these quiescent buds to initiate flowering. Application of 3.0 per cent KNO_3 has advanced the flowering by 28 days and harvest date by one month compared to control in mango cv. Haden (Ferrari and Sergent, 1996).

Muhammad *et al.* (2007) demonstrated that spraying KNO_3 at 3% during the last week of January induced early panicle emergence, increased panicle length (38.77 cm), enhanced the percentage of hermaphrodite flowers (34.39%), and improved fruit set (14.06%) in mango. Furthermore, Beevers and Hageman (1969) and Filner *et al.* (1969) highlighted that KNO_3 induces nitrate reductase activity, a key enzyme in the nitrate assimilation pathway for amino acid synthesis. Methionine, a precursor of ethylene, has also been reported to promote flowering in mango (Maity*et al.*, 1972). Davenport and Nunez-Elisea (1997) emphasized that the flowering-stimulating effect of KNO_3 in mango is mediated by increased endogenous ethylene levels. Additionally, potassium nitrate acts as a universal rest-breaking agent in deciduous fruit trees, hastening flower emergence from differentiated but dormant buds (Erez and Lavee, 1974). Studies by Astudillo and Bondad (1978) further demonstrated that KNO_3 effectively induces flowering in 'Carabao' mango. Collectively, these findings establish KNO_3 as a valuable tool for enhancing flowering in mango trees by breaking bud dormancy, stimulating ethylene production, and promoting floral initiation.

Effect of Potassium nitrate on fruiting and yield

Potassium nitrate (KNO_3) has been shown to significantly improve fruiting and yield in mango by enhancing photosynthate accumulation and optimizing flowering and fruit development processes and through improved fruit retention, fruit set, and reduced fruit drop. Hansen (1970) attributed the increase in fruit size to the higher accumulation of photosynthates in response to potassium application, as fruits act as metabolic sinks supplied by the photosynthetic activity of leaves. This increased source-sink efficiency, driven by potassium fertilization, likely contributes to larger fruit size and enhanced fruit yield. Yeshitela *et al*. (2005) observed higher fruit yields in mango trees sprayed with KNO_3, further supporting its role in improving productivity.

KNO_3 application also positively impacts flowering characteristics. Dalal*et al*. (2005) and Muhammad *et al.* (2007) demonstrated that foliar sprays of KNO_3 during critical flowering stages, such as flower bud differentiation and full bloom, significantly increased flowers per panicle, flowering percentage, fruit set, and overall yields. For instance, a 1% KNO_3 spray applied twice during these stages resulted in maximum flowering percentage (26.12%) and fruit set percentage (0.21%) in 'Kesar' mango. Additionally, a 2% KNO? concentration was consistently effective in enhancing fruit set and yield across studies.

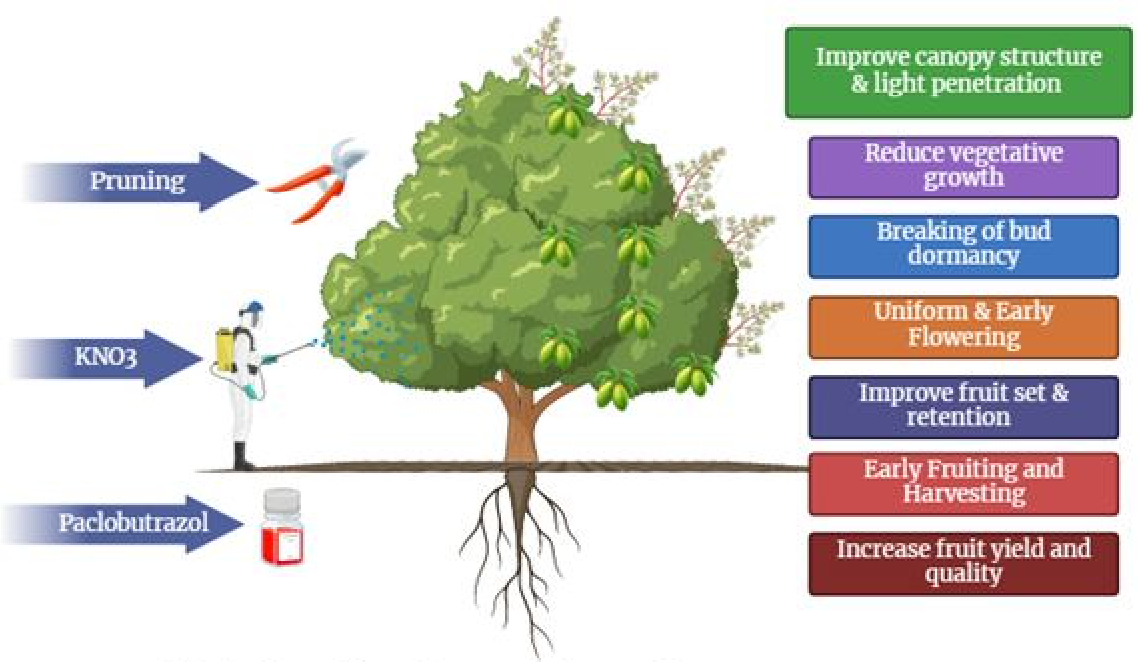
The application of KNO_3 has also been linked to improvements in reproductive parameters, such as the number of hermaphrodite flowers, which enhance pollination efficiency and fruit set. Collectively, these findings highlight the effectiveness of KNO_3 as a critical foliar spray for enhancing flowering, fruiting, and overall yield in mango cultivation.

Gupta and Brahmachari (2004) reported that foliar application of KNO_3 at varying concentrations (2%, 4%, and 6%) increased fruit retention, with the highest retention observed at 4% KNO_3. Additionally, Bibi *et al.* (2019) demonstrated that a combined foliar application of KNO_3 (1%) and Boric acid (0.2%) in mango cv. Summer BahishtChaunsa led to the highest fruit sets per panicle and the least fruit drop compared to the control, highlighting the synergistic effect of potassium and boron.

Conclusion

In conclusion, pruning, potassium nitrate (KNO_3), and paclobutrazol are essential management practices for optimizing mango production.

- **Pruning** is a vital horticultural practice in mango cultivation, influencing vegetative growth, flowering, fruit yield, and malformation management. It enhances tree productivity by improving canopy structure, light penetration, and nutrient distribution. Proper pruning, particularly during critical periods, promotes regular flowering, increased fruit yield, and reduced malformation incidence, making it an essential tool for improving mango quality and consistency in production.
- **Potassium nitrate** (KNO_3)is a vital foliar spray that enhances flowering, fruiting, and yield in mango cultivation. It breaks bud dormancy, promotes ethylene production, and improves fruit set, retention, and size. Research confirms its effectiveness in increasing productivity, reducing fruit drop, and optimizing source-sink relationships.
- **Paclobutrazol(PBZ)** is an effective plant growth regulator that inhibits gibberellin biosynthesis, reducing vegetative growth while promoting early and profuse flowering in mango trees. It enhances carbohydrate accumulation, increases the C:N ratio, and improves



Beneficial effect of Pruning, Paclobutrazol & KNO_3 on Mango Tree flowering intensity, leading to higher fruit set and yield. By optimizing resource allocation and extending the harvesting period, PBZ significantly enhances productivity and profitability in mango cultivation.

Together, these practices significantly enhance mango productivity and orchard sustainability when applied with precision, considering timing, intensity, and environmental factors. Integrating these techniques can further improve overall mango production.

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