



## A cost-effective orchard netting against fruit sucking moth (*Eudocima materna*) in pomegranate (*Punica granatum*)

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Fruit piercing and sucking moth (FPSM), *Eudocima materna* (Clerk) belong to the family Erebidae of order Lepidoptera is an important pest of pomegranate (*Punica granatum* L.) usually found in India, is spread throughout South-east Asia up to the Pacific region. Female moths lay their eggs on Menispermaceae vines, particularly the heart-leaved moonseed, *Tinospora cordifolia*. Control of the immature stage by spraying on these larval hosts is impractical. The adult moths which emerge fly long distances, pierce and suck the fruit juice of several fruits including pomegranate. The adults have a strong barb-ended proboscis, with which they pierce the rind of fruits (even the hard rind of pomegranate) and suck the juice. The bruised area beneath the rind attracts secondary infection subsequently leading to rotting of the fruit (Atachi *et al.* 1989, Bhumannavar and Viraktamath 2001). These moths migrate from their creeper hosts and enter the pomegranate orchards in small swarms after dusk between 19:00 and 23:00 hours (Bhumannavar 2000). As the ripe fruits are attacked, insecticides cannot be recommended because of residue issues.

Pomegranate is fast catching up as a 'cash crop' in India with high nutraceutical value and export demand, therefore, effective and economic management of fruit sucking moth is of great importance. Several recommendations like baits, smoking, neem repellants, bagging, etc., have been made but most of these demand an intervention or attention on a daily basis (Jayanthi and Verghese 2009, Jayanthi *et al.* 2010) at least a month prior to harvest. Netting whole trees seemed to be effective but farmers found it drudgery to cover each and every tree as each acre has nearly 380 trees. Further, these nets have to be individually dismantled after harvest for field operations.

In view of recurring crop losses and the difficulty of managing adult FPSMs through chemical means, a

more pragmatic and field-feasible approach was required. Preliminary monitoring conducted in 2022 in fruiting pomegranate orchards revealed peak FPSM activity between September and November, with infestation levels ranging from 18–35%. These observations highlighted the need for effective non-chemical interventions. In the same region, whole netting was widely being practiced by grape growers to prevent bird and bat damages (Vergese 1998) based on studies conducted at ICAR-Indian Institute of Horticulture Research, Bengaluru, Karnataka. Pomegranate, being a high-value crop, was also considered suitable for evaluating whole-orchard netting. This approach was particularly attractive because the nets could be outsourced to professional net-erectors, who would install and dismantle them after the season. Farmers found this arrangement convenient, as it required no upfront investment in nets, and acre-based seasonal rental proved to be economically viable.

The formal field trials were conducted during the fruiting season of September to November 2023, and field trials were repeated in 2024 and 2025 in same orchards. Accordingly, four management options, viz. Azadirachtin spray (T<sub>1</sub>) @10,000 ppm at 2 mL/L, sprayed once a week on the trees from one month prior to harvest; Baiting (T<sub>2</sub>), Half-ripe banana (with peel) laced with chlorpyrifos 20 EC at 5 mL/L of water; one bait between two trees (Jayanthi *et al.* 2015, Durga *et al.* 2020), replaced weekly; Whole-orchard netting (net-house) (T<sub>3</sub>), Net-house constructed over 20 trees of the orchard using 2 cm<sup>2</sup> mesh net supported on overhead wire grid and border poles at ₹20,000/acre (covering ~380 trees); and Single-tree netting (T<sub>4</sub>), Individual trees covered with net (mesh size 2 cm<sup>2</sup>). The cost of single-tree netting for one acre (~380 trees) is approximately ₹81,700 (₹215/tree); along with an untreated control were evaluated beginning one month prior to harvest in two commercial orchards with Pomegranate variety *Bhagva*; Orchard 1 (O<sub>1</sub>) (3.6 acres) 2023: Neleri village, Devanahalli Taluk, Bengaluru Rural district, Karnataka (13.257203° N, 77.706848° E); Orchard 2 (O<sub>2</sub>) (4.5 acres) 2023: Yaluvahalli, Devanahalli Taluk, Bengaluru Rural district, Karnataka, (13.293528° N,

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77.821873° E); O<sub>1</sub> (2.8 acres) 2024: Channarayapattana, Devanahalli Taluk, Bengaluru Rural, Karnataka (13.247722° N, 77.794899° E); O<sub>2</sub> (5.6 acres) 2024: Irigenahalli, Devanahalli Taluk, Bengaluru Rural, Karnataka (13.339297° N, 77.734167° E); O<sub>1</sub> (3.5 acres) 2025: Gundlagurki, Chikaballapura, Karnataka (13.482903° N, 77.756668° E); O<sub>2</sub> (5.0 acres) 2025: Nagaraju Kadahalli, Kolar Taluk, Karnataka, (13.275759° N, 77.993357° E). Both orchards comprised approximately 380 trees/acre, with tree height ranging from 6–8 ft.

Each treatment plot consisted of 20 trees, with each tree treated as an individual replication from which random sampling could be carried out. An isolation distance was maintained by leaving three intervening rows of untreated trees between treatments to prevent any cross-interference.

At harvest, the number of fruits damaged by FPSM/tree was recorded. From each sampled tree, 20 fruits were examined, the total number of fruits/tree was recorded, and percent damage was calculated. This standardised sampling procedure ensured consistency with the dataset (Table 1). Kruskal-Wallis one-way ANOVA was used to compare treatments; Critical difference (CD) values were calculated; significance threshold was set at  $p < 0.05$ .

Benefit-cost ratio (BCR) was estimated using average yield saved/tree, farm-gate price (₹150/kg), and netting cost (₹20,000/acre). Assumptions and sensitivity analyses were provided. Fruit damage was assessed once at harvest. Treatment effects were analysed using a one-way ANOVA.

Across all three years (2023–2025) and in both orchards, treatment effects were highly significant ( $p < 0.001$ ). Across both orchards, whole-orchard netting and single-tree netting consistently recorded zero damaged fruits, demonstrating complete exclusion of FPSM. These treatments remained statistically superior to all other interventions in all the three years. Banana baiting using half-ripe bananas laced with chlorpyrifos 20 EC (5 mL/L) emerged as the second-best treatment, with mean damage ranging from 2.7–3.5 fruits/tree across orchards and years. In 2023, damage levels were 3.0 (O<sub>1</sub>) and 3.5 (O<sub>2</sub>); in 2024, 3.5 (O<sub>1</sub>) and 4.0 (O<sub>2</sub>); and in 2025, 3.5 (O<sub>1</sub>) and 3.5 (O<sub>2</sub>). These values were significantly inferior to whole-orchard netting, and a similar trend was observed when compared with the azadirachtin treatment in all the years.

Azadirachtin 10,000 ppm (2 mL/L, applied weekly) (T<sub>1</sub>) provided only moderate suppression, with mean damage ranging from 7.5–9.0 fruits/tree, making it significantly less effective than both netting and baiting, though still superior to the untreated control. Damage was consistently higher in O<sub>2</sub>, probably reflecting slightly greater pest pressure at that site.

Control plots recorded the highest damage in all years, ranging from 16.5–19.0 fruits/tree, confirming severe FPSM pressure in both locations. Treatment efficacy was stable across all the years, with whole-orchard netting demonstrating the highest protection, comparable to single-tree netting, followed by banana baiting, then Azadirachtin spray, and lastly the control.

Table 1 Effect of treatment interventions on percent FPSM damage in pomegranate fruits in two orchards (2023–2025)

| Treatment<br>n=200 fruits/<br>treatment | O <sub>1</sub><br>(2023) | O <sub>2</sub><br>(2023) | O <sub>1</sub><br>(2024) | O <sub>2</sub><br>(2024) | O <sub>1</sub><br>(2025) | O <sub>2</sub><br>(2025) |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| T <sub>1</sub>                          | 7.5                      | 8.0                      | 8.5                      | 9.0                      | 8.0                      | 8.5                      |
| T <sub>2</sub>                          | 3.0                      | 3.5                      | 3.5                      | 4.0                      | 3.5                      | 3.5                      |
| T <sub>3</sub>                          | 0.0                      | 0.0                      | 0.0                      | 0.0                      | 0.0                      | 0.0                      |
| T <sub>4</sub>                          | 0.0                      | 0.0                      | 0.0                      | 0.0                      | 0.0                      | 0.0                      |
| T <sub>5</sub>                          | 16.5                     | 18.0                     | 18.0                     | 19.0                     | 17.0                     | 18.0                     |
| CD ( $p < 0.001$ )                      | 0.34                     | 0.40                     | 0.34                     | 0.42                     | 0.88                     | 0.40                     |

Refer to Methodology for treatment details.

The three-year evaluation across two orchards clearly demonstrated that the FPSM is a persistent and economically damaging pest in the pomegranate-growing regions of Southern Karnataka, particularly during the September–November period. Although it is commonly presumed that FPSM damage is higher on border trees, this pattern was not observed in pomegranate orchards during the study. Damage was uniformly distributed across the orchard, with all trees equally susceptible. This is likely because pomegranate trees are maintained at a uniform, low canopy height, and wider spacing typical of pomegranate orchards, which allow moths easy access to every tree rather than restricting activity to the periphery.

Among the interventions tested, whole-orchard netting and single-tree netting provided complete protection across all years and locations. Although single-tree netting is effective, it is labour-intensive and impractical for large orchards, whereas whole-orchard netting offers seamless, low-labour protection once installed. To operationalise this approach, a net-house architecture adapted from grape pandal system was developed using overhead wire grids and 2 cm<sup>2</sup> mesh, costing approximately ₹20,000/acre for ~380 trees, an investment that proved highly economical relative to the value of the protected crop. Based on the field experimentation and positive results of 2023–2025, this technology was rapidly adopted by >500 farmers in Southern Karnataka, who installed nets during the fruiting period (September–December) and dismantled them post-harvest. Farmers consistently reported complete elimination of FPSM damage and were able to avoid pesticide sprays entirely. A survey conducted in 2025 involving 559 farmers revealed that 516 farmers (92.3%) harvested FPSM-damage-free pomegranates using whole-orchard netting. Given that FPSM typically causes 25% or more fruit loss (Mote *et al.* 1991, Yoon and Kim 1977), and considering a farm-gate price of ₹150/kg, this translates to a potential saving of ₹2,10,000/acre, with an exceptionally high benefit-cost ratio of ₹10,500 returned for every rupee invested. Netting, regularly used in grapes to prevent bird and bat damage (Verghese 1998) has thus proven to be a versatile, ecologically sound, and residue-free intervention for pomegranate as well, supporting both domestic and export-quality production (Meena *et al.*

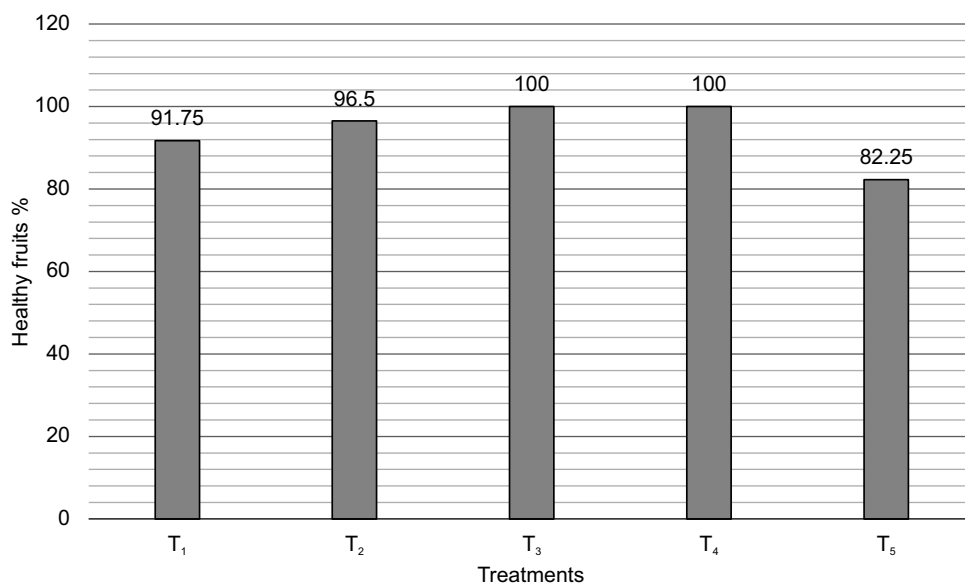


Fig. 1 Percentage of non-infested healthy pomegranate fruits in different treatments pooled over three years in both orchards. Refer to Methodology for treatment details.

2016, Pottappa *et al.* 2025). Overall, the findings strongly support whole-orchard netting as the core IPM strategy for FPSM management due to its zero pesticide residue, complete elimination of fruit damage, high economic returns, and excellent farmer acceptance. Although banana baiting was an earlier recommendation, it poses risks to non-target organisms and therefore cannot be promoted as a safe or sustainable option. Some farmers experimented with fruit bagging, but quickly abandoned it because it was highly labour-intensive, impractical for pomegranate, and according to experts, interfered with uniform colour development. Azadirachtin sprays provided only moderate suppression and were insufficient to prevent economic loss under high pest pressure.

Netting whether implemented at the whole-orchard or single-tree scale provided complete protection, eliminating fruit damage (Fig. 1) even under high pest pressure and outperforming all other interventions. However, whole-orchard netting is operationally superior, as it minimises labour requirements, is easier to manage, and is therefore more practical for commercial adoption.

The experiments conducted during 2023 and especially 2024 coincidentally and inadvertently became demonstration to neighbouring farmers, clearly showing that whole-orchard netting is an effective and practical strategy for managing FPSM. The consistent success observed in 2025 further strengthened farmers' confidence. By the end of 2025, 516 out of 559 farmers (92.3%) across Dodaballapura, Kolar, Devanahalli, and Chikkaballapura in the semi-arid regions of Karnataka had adopted whole-orchard netting and reported harvesting fruits completely free from FPSM damage. Adoption exceeded 90% across these regions, indicating rapid dissemination and acceptance of the technology.

The strong economic returns, residue-free produce, and operational simplicity of whole-orchard netting facilitated

rapid adoption, with more than 90% of farmers in the study region adopting the technology by 2025. These results established whole-orchard netting as a practical, ecologically sound, and economically viable core component of integrated pest management for FPSM in pomegranate. Wider promotion through farmer collectives, contractor-based installation services, and supportive financial mechanisms is warranted to ensure broader regional adoption and long-term sustainability of pomegranate production.

#### SUMMARY

Fruit piercing and sucking moth (FPSM) causes serious pre-harvest losses in pomegranate in Southern Karnataka during the peak fruiting season (September–November). Adult moths pierce the fruit rind, leading to secondary rots, while chemical control is ineffective and undesirable due to residue concerns. A three-year field study (2023–2025) conducted in two commercial orchards in Devanahalli Taluk evaluated four management options whole-orchard netting, single-tree netting, banana baiting with chlorpyrifos, and azadirachtin spray. Whole-orchard and single-tree netting consistently resulted in zero fruit damage across all years, whereas banana baiting and azadirachtin provided partial control. Statistical analysis confirmed highly significant treatment effects. Whole-orchard netting, costing about ₹20,000/acre, offered complete protection with a favourable benefit-cost ratio. Demonstration effects led to rapid farmer adoption, with over 92% adoption across major pomegranate-growing regions by 2025. Whole-orchard netting, thus, represents an effective, residue-free, eco-friendly, and economically viable strategy for FPSM management.

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