

Integrated Pest Management in Kinnow Mandarin

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Citrus is one of the most relevant fruit crops cultivated in sub-tropical, tropical, and temperate regions across the globe. It is second most produced fruit worldwide with cultivated area of more than 10.2 million hectares with the production of 161.8 million tonnes. Citrus play a vital role in the fruit economy of the country, next to mango and banana. India is the home of many citrus fruits, and their cultivated area is spread over more than 109.6 million hectares with a production of 14.25 million tonnes. India ranks fourth among the top citrus-producing countries in the world. In India, citrus is primarily grown in Assam, Andhra Pradesh, Maharashtra, Punjab, Haryana, Karnataka, Uttarakhand, Uttaranchal, Bihar, Orissa and Gujarat states. Among the citrus fruits, mandarin also known as Kinnow is the most valuable fruit crop that is mostly grown in Haryana, Punjab, and Rajasthan states. The cultivated area under citrus fruits in Haryana is 25.17 thousand hectares with a production of 359.08 thousand million tonnes in which Kinnow mandarin occupied 90% in both area and production. Kinnow mandarin has superseded the other oranges in terms of its high yield, good quality fruits, prolific bearing, high juice content, and more sweetness. The productivity and fruit quality of citrus fruits are adversely influenced by multiple factors, among which pest incidence plays a major role. More than 250 insect pests are reported to attack citrus in India. Asian citrus psyllid, (*Diaphorina citri* (Kuwayama)), whitefly, *Diuraphis citri* (Ashmead), Leaf miner (*Phyllocnistis citrella*), Thrips (*Scirtothrips citri*), dieback, *Colletotrichum gloeosporioides*, Gummosis (*Phytophthora nicotianae*) and sooty mould, *Capnodium citri*, are major threats to Kinnow mandarin which cause economic losses from nursery to harvesting. Baseline surveys of Kinnow growing areas by ICAR-National Research Institute for Integrated Pest Management, New Delhi revealed injudicious use of chemical pesticides and fertilizers by farmers that aggravated the pest menace, residue problems in fruits, soil & water contamination, reduction in population of natural enemies & beneficial soil microorganism, and lack of awareness of identification of major pests and their natural enemies. In this context, an interdisciplinary team from ICAR-NRIIPM with the collaboration of KVK, Sadalpur, CCSHAU, Haryana, developed IPM practices to address these problems holistically. IPM strategies were validated and disseminated in Kinnow mandarin areas at village level in Hisar, Haryana.

Validation of IPM module

IPM validation trial was initiated in Kisangarh village in farmer's participatory mode in 10 ha area covering 10 farmers in 2021. The selection of village was based on pests load in Kinnow orchards, excessive use of chemical pesticides (carbendazim, imidacloprid, ethion, beta-Cyfluthrin + imidacloprid) to an extent of 8-12 sprays for reduction of pests, lack of awareness about IPM practices and identification of pests and their natural enemies. The area was extended upto 25 ha in village Daroli covering 25 farmers in 2022 and then 65 ha areas in Sadalpur, Chuli and Khara barwala villages covering 45 farmers in 2023, respectively. Different Integrated Pest Management (IPM) strategies viz; deep summer ploughing; pruning the excess branches and bottom leaves of the tree for proper ventilation; destruction of rotten and dropped infected fruits; regular monitoring of orchard to assess the damage and severity of pests; Installation of yellow sticky traps @ 20/ha followed by a need-based spray of neem seed kernel extract (NSKE) @ 5% on young leaves and if pest population exceeded above ETL then applied need-based spray of label claim imidacloprid 17.8SL @ 200ml in 500 litres of water or thiamethoxam 25% WG in 50g/500 litres water to manage psylla and whitefly; spray of 1% starch against sooty mould disease during August, September and October months and dipping sooty mould infected fruits in a bleaching solution @ 0.1%; pruning and destruction of dieback infected dead twigs in the month of March and July followed by spray of copper oxychloride 50 WP @ 3 g/l were validated in IPM fields. In farmers' practice (FP), farmers used only FYM (100kg) and urea (700g/plant) and not practiced IPM techniques. Injudiciously they used 8-12 sprays of pesticides such as copper oxychloride 50 WP @ 3g/l (dieback); cymoxanil 8% + mancozeb 64% WP @ 1.5g/l (sooty mould); carbendazim 50 WP @ 2g/l (dieback); imidacloprid 17.8SL @ 2ml/l (whitefly); ethion 50 EC @ 1ml/l (whitefly); beta-Cyfluthrin + imidacloprid 300 OD (8.49 + 19.81 % w/w) @ 1ml/l (psylla and whitefly); lambda cyhalothrin 2.5% EC @ 1.5ml/l (psylla); chlorpyrifos 20 % EC @ 2ml/l (psylla); diafenthiuron 50% WP @ 1g/l; quinalphos 25% EC @ 2ml/l and chlorantraniliprole 18.5% w/w @ 1.5ml/l (psylla and whitefly); farmers mostly depend on local pesticide dealer for advice and used higher than the recommended dose of pesticides.

During validation of IPM approaches, farmers were advised to use farm yard manure (FYM) (80 kg), urea (500g/plant), single super phosphate (2 kg/plant) and muriate of potash (1.75kg/plant) minerals like manganese, copper, sulphur, boron, zinc as per age and phenological stage of plant. To improve fruit size and increase yield in Kinnow mandarin, farmers were also made aware to apply three foliar sprays of 1.0% potassium nitrate (10 g/litre) at the end of May, June and July. The drip irrigation method along with intercropping with sunflower, marigold, chickpea, garlic and onion were also suggested to enhance the population of natural enemies.

Effect of IPM on major pests and their natural enemies

The populations of psylla in IPM, FP, and control treatment was recorded from 11th -52nd standard metrological weeks (SMW) and lowest population of psylla (6.11 ± 0.63 , 4.14 ± 0.28 and 4.21 ± 0.29 nymphs and adults/10cm shoot) occurred in IPM compared to FP (9.35 ± 0.77 , 5.29 ± 0.30 and 5.37 ± 0.32 nymphs and adults/10cm shoot) and control (10.86 ± 0.88 , 6.10 ± 0.30 and 6.19 ± 0.31 nymphs and adults/10 cm shoot) during 2021, 2022 and 2023, respectively. Highest reduction in psylla population over the control was also observed in IPM (37.49%) compared to FP (13.48%). The psylla appeared during 11th SMW in IPM (2.33 ± 0.63 /shoot) FP (3.55 ± 1.10 /shoot) and control (5.03 ± 1.77 /shoot) and reached peak in 17th SMW (9.43 ± 1.43 , 12.97 ± 1.55 and 14.50 ± 2.12 /

shoot), thereafter its population declined. Similarly, the lowest population of whitefly (3.81 ± 0.36 , 2.22 ± 0.25 and 2.36 ± 0.21 nymphs and adults/leaf) was noticed in IPM compared to FP (5.24 ± 0.33 , 3.17 ± 0.27 and 3.26 ± 0.20 nymphs and adults/leaf) and control (6.57 ± 0.38 , 3.98 ± 0.29 and 4.12 ± 0.21 nymphs and adults/leaf), respectively. The highest reduction of the whitefly population (42.86%) was observed in IPM followed by farmer practice (20.61%). The highest disease severity of sooty mould was recorded in control (12.41 ± 0.53 , 11.04 ± 0.37 and $10.39 \pm 0.30\%$) followed by FP (9.60 ± 0.31 , 9.35 ± 0.37 and $8.96 \pm 0.35\%$) and in IPM (7.62 ± 0.33 , 7.42 ± 0.31 and $7.20 \pm 0.28\%$). Likewise, the highest reduction in sooty mould severity was also recorded in IPM (34.30%) in comparison to farmer practice (17.46%). As well, highest reduction of sooty mould incidence over control was also seen in IPM (62.06%) compared to FP (18.12%). Highest disease severity of sooty mould was reached at peak in 43rd SMW (10.38 ± 1.03 , 12.45 ± 1.27 and $12.78 \pm 1.16\%$). In case of dieback, minimum disease severity was recorded in IPM (10.94 ± 0.45 , 9.72 ± 0.39 and $9.39 \pm 0.37\%$) while higher severity was observed in FP (13.14 ± 0.40 , 11.75 ± 0.41 and $11.44 \pm 0.37\%$) and control (15.21 ± 0.52 , 13.44 ± 0.44 and $13.08 \pm 0.40\%$) plots. In similar way, the highest reduction of dieback severity over control was recorded in IPM (28.03%) compared to farmer practice (12.94%). The dieback severity appeared in 11th SMW (4.60 ± 0.53 , 6.17 ± 0.66 and $6.70 \pm 0.83\%$) in IPM, FP and control; Thereafter, it increased and reached peak during the 19th SMW ($12.75 \pm 1.27\%$, $16.25 \pm 1.69\%$, and $18.70 \pm 1.86\%$) and again during the 41st SMW ($13.29 \pm 1.33\%$, $14.85 \pm 1.41\%$, and $16.25 \pm 1.69\%$), before declining steadily until the 52nd SMW.

The populations of natural enemies were higher in IPM compared to farmer practice. The average highest populations of coccinellid ($1.57/m^2$), *Chrysoperla* ($1.21/m^2$) and spider ($2.19/m^2$) were recorded in control followed by (1.02 , 0.80 and $1.60/m^2$) in IPM and (0.47 , 0.36 and $0.91/m^2$) in farmer practice. The first appearance of coccinellid populations dynamics was noticed in the month of March (11th SMW) and it persisted until 52nd SMW in the range of 0.69 to $2.67/m^2$ in control, 0.67 to $1.52/m^2$ in IPM and 0.08 to $0.90/m^2$ in farmer practice. Likewise, *Chrysoperla* was observed in the range of 0.82 to $1.63/m^2$ in control, 0.40 to $1.27/m^2$ in IPM and 0.00 to $0.70/m^2$ in farmer practice. Population dynamics of the spider were also recorded from 11th SMW to 52nd SMW in the range of 0.92 to $3.90/m^2$ in control, followed by 0.67 to $2.89/m^2$ in IPM and 0.29 to $1.65/m^2$ in farmer practice, respectively.

Impact of IPM on economic parameters

Economics of Kinnow mandarin in IPM, farmer practice and control from 2021-2023 were computed considering various relevant parameters. The average number of chemical sprays was reduced to 4.7 in IPM compared to 11 in farmer practice. The total cost of plant protection alone in IPM was less (Rs.19555/ha) compared to farmer practice (Rs. 30909/ha). Similarly, the average total cost of cultivation in IPM was lower (Rs.135708/ha) compared to farmer practice (Rs.148125/ha) and control (Rs.128250/ha), respectively. The highest fruit drop was noticed in control (88.56%) followed by farmer practice (75.57%) compared to IPM (69.07%) Highest average no. of fruits/tree, average fruit weight (g) and average fruit yield (kg/tree), respectively were also recorded in IPM (357, 230 & 82) compared to farmer practice (336.67, 204.33 & 68.67) and control (194.33, 139.67 & 27). Lower average fruit yield (7.42 tons/ha) was recorded in control and farmer practice (18.88 tons/ha) compared to IPM (22.46 tons/ha). The highest fruit yield loss caused by psylla, whitefly, sooty mould and dieback was recorded in control (66.96%) compared to farmer practice (15.94%). Similarly, the maximum increase in fruit yield (ton/ha) over control and increase

in fruit yield (ton/ha) over farmer practice, respectively (15.04% & 31.19%) was also found in IPM. Similarly, the highest average net income was also noticed in IPM (Rs.518436/ha) compared to farmer practice (Rs.387366/ha) and control (Rs. 94450/ha). Additional net profit due to increase in fruit yield over control, additional net profit due to increase in fruit yield over farmer practice, and additional profit due to reducing no. of spray were also higher (Rs.423986/ha, Rs.131070/ha & Rs.11354/ha) in IPM compared to control. Overall, the IPM increased the net profit of Rs. 529790/ha compared to farmer practice and control. IPM implementation significantly reduced the number of pesticide sprays (57.27%) and increased the average kinnow yield (15.93%) against the farmer's practice (FP). The number of natural enemies' population was more in IPM compared to FP orchards due to the adoption of ecological engineering. No pesticide residue was detected in IPM orchard fruits, while acephate, imidacloprid and tebuconazole were detected in farmer practice. In terms of benefit-cost ratio, the highest benefit-cost ratio was recorded in IPM (4.34) compared to farmer practice (3.16) and control (1.73), respectively. The IPM technology was well adopted by the farmers, which resulted in the wide area dissemination among the farmers in cluster villages covering >100 ha in 2024-25. Besides, Farmer's field school (FFS), *Kisan ghosti*, Kinnow day and awareness programmes were organised at 15–30 days interval in adopted villages during each crop season for the dissemination of integrated pest management strategies. FFS included the training on identification of insect pests, diseases and beneficial, Economic Threshold Level (ETL) concept, use of bio pesticides and bio agents and management tactics including safer pesticides. About 45 farmers were trained through FFS, trainings, scientist-farmers interaction and 150 farmers were made aware about the IPM technology through Kinnow field days.

Socio-economic studies and impact analysis

Socio-economic studies and impact analysis of IPM technologies used in kinnow was carried out in five selected villages covering 17 farmers at Hisar, Haryana. Various impact analysis parameters were used to determine the IPM impact on kinnow farmers. It was found that cent percent farmers know IPM, minimizing the number of sprays, all technical information related to IPM, usefulness and economics of IPM, different components of IPM, use of pheromone traps, yellow, blue sticky traps, neem oil, *Trichoderma*, *Pseudomonas*, *Bacillus*, awareness of contamination of air, water, soil by pesticides and their adverse effect on beneficial insects, pesticides spraying methods, safety issues and intercropping. Likewise, 76.47% farmers know about the economic threshold limit of pests, and 70.58% farmers have identification ability to identify the natural enemies. However, 23.5% farmers still depend on the advice of local dealers. The income of kinnow mandarin farmers increased by 15-20% after the adoption of IPM technology. 11.76% farmers use increased income for repayment of loan, while 76.47% for crop insurance. Similarly, 82.35% farmers used the income for the purchase of spade, kurpi, cultivator, and sprayer. It was also observed that 66.67% farmers purchased buffalo, whereas 29.41% farmers made farm shed for their animals.

