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Wider area validation and economic analysis of adaptable IPM technology in bell pepper (*Capsicum annum*)*

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Bell pepper or sweet pepper (*Capsicum annuum* var. *frutescens* (L.), is the most popular, widely grown and highly remunerative vegetable all over the country. Due to its tender and supple nature and its cultivation under high moisture and input regimes, bell pepper is more prone to pest attack. Several pests, viz thrips (*Scirtothrips dorsalis* Hood) (Krishna Kumar *et al*. 1996), white fly (*Bemisia tabaci* Gennadius), aphids (*Myzus persicae* Sulzer), broad mites (*Polyphagotarsonemus latus* Banks), fruit borer (*Helicoverpa armigera* Hubner), tobacco caterpillar (*Spodoptera litura* Fabricius), *Phytophthora* leaf blight/ fruit rot (*Phytophthora capsici*), virus mosaic complex: bacterial leaf spot (*Xanthomonas campestris* pv. *Vesicatoria*.) and disorder like sun scald hamper the crop growth and production potential. These pests are the major constraints in getting higher bell pepper yields (Sorensen 2005, Krishana Kumar and Srinivasan 1994). Quicker control strategy for these pests and quests of getting higher yields, led to indiscriminate use of pesticides. In that scenario, bell pepper fruits are likely to retain unavoidably high level of pesticide residues which may not only be hazardous to consumers but may affect the export quality as well. Numerous management strategies for the pests of bell pepper have been developed but these have mostly been dealt in isolation and individually and thus have not met with the desired success. The integration of all the pest management strategies in a participatory approach could reduce application of harmful pesticides to a great extent. Keeping this in view, validation of multifaceted adaptable IPM technology in bell pepper crop was carried out in a participatory approach at farmers' fields to reduce the dependence on chemical pesticides and protecting the ecosystem as a whole.

Three years trials on validation of IPM technology in bell pepper were carried out during 2007–10 at Daha-Jagir, Karnal District, Haryana. Before initiation of validation of IPM technology, adaptable IPM module for bell pepper crop was synthesized based on the base line information collected on the crops, pests, pest status and their management in Daha-Jagir, recommendations by CCS Haryana Agricultural University, Hisar for bell pepper pest management and research literature published by eminent workers on bell pepper. The synthesized IPM module was thus first validated during 2007–08 in an area of 10 acres comprising 10 farming families with the following interventions: Raised nursery beds (about 10 cm above ground level) for good drainage, soil solarization with transparent polyethylene sheet of 45 gauge thickness for about three weeks, mixed fungal antagonist *T. harzianum* (c.f.u. 2×10^9/g) (@ 10 g/100 g FYM/m^2) in soil with FYM before sowing, need based spray of *neem* (Neem Baan 1 500 ppm @ 10 ml/litre) in nursery against aphids, dipping seedlings in *Pseudomonas fluorescens* @ 5 ml/litre for 10 min. before planting, spray of *neem* (Neem Baan 1500 ppm @ 10 ml/litre) against thrips and aphids at 15–20 days after transplanting (DAT), spray of spinosad 45 SC (75 g ai/ha or 0.5 ml/litre) if thrips population was high, installation of pheromone traps @ 2/acre for monitoring fruit borer immediately after transplanting in March-April, five releases of egg parasite *T. chilonis* @ 1.0 lakh/ha for fruit borer, spray of *Ha*NPV 250 LE/ha in initial stages of larvae in evening with surf powder, one spray of Emamectin benzoate 5 WG @ 0.25 g/lit of water, two to three need-based sprays of chemical insecticide indoxacarb 14.5 SP @ 500 g ai/ha or rynaxpyr 18.5 SC @ 3.5 ml /ltre of water for fruit borer, periodic removal and destruction of damaged fruits due to borer or fruit rot or mosaic complex and a shade crop *dhaincha* was grown as border line to protect the fruit from sun scald

The results on the pest incidence/natural enemies population and the economic viability of IPM were compared

*Short note

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with FP (farmers' own way of managing the pests) which consisted of only chemical pesticides such as: Imidacloprid 17.8 SL @ 0.01%, indoxacarb 14.5 SP @ 500 g ai/ha, acetamiprid 20 SP @ 005%, cypermethrin 20 EC @ 0.02%, phorate 10 G @ 3 kg ai/ha, chlorpyriphos 50 EC + cypermethrin 5 EC (Megha) @ 5 ml/litre , copper oxy chloride 50 WP @ 2 g/litre and dithane M 45 80 WP @ 2 g/litre.

The farmers usually tend to give higher than the recommended dose and thus the accurate dose of pesticide application by the non-IPM farmers is difficult to present as the container lid is oftenly used to measure the dose.

During 2008–09, the adaptable IPM technology was then refined and revalidated in a larger area of 25 acres comprising 25 farming families. During 2009–10, validated IPM technology was further refined and revalidated in Daha-Jagir village in 50 acres area involving 50 farming families.

Weekly observations on the population of aphids, coccinellids and predatory spiders were recorded per plant in 20 randomly selected plants from each field, whereas for fruit borer (*H. armigera*), per cent infestation of all the pickings was taken. Similar method was adopted for recording sun-scald-affected fruits. A visual rating of thrips infestation (0–5) (Krishna Kumar 1995) based on damage symptoms was adopted, which was 0 = no symptoms; 1= young leaves with eruptions; 2= terminal leaves with upward curling; 3= severe upward curling of terminal and few basal leaves; 4= stunted plants with severely curled leaves, 5= plants showing total defoliation. Collar and stem rot (%) and virus mosaic complex (%) incidence was recorded by counting healthy and infected plants /field at five places each of 25m^2. Weekly means of population of various pests over the season were computed and presented in Table 1. For economic analysis, number of chemical sprays, cost of cultivation (₹/ha), yield (tonnes/ha), net returns (₹/ha) and cost: benefit ratio (CBR) were computed and presented in Table 2.

The adoption of IPM technology resulted in significant reduction in incidence of all the insect pests and diseases while incidence of most of the pests was marginally higher in FP fields (Table 2). Trend and appearance of almost all the pests were similar during all the three years. i e 2007–10.

Nursery and main crop in February-March first of all were affected by migrating aphids from potato or even sometimes from mustard fields and settled in nurseries and main crop. Table 2 indicated that on an average 3.30, 1.3 aphids /plant in IPM and 8.80 and 1.6 aphids/plant in non-IPM fields were recorded during 2007–08 and 2008–09, respectively. Aphids did not appear during 2009–10. Aphids being a vector of mosaic virus complex, resulted in heavy incidence of the above disease and thus reduced the marketable yield of crop during 2007–08. Aphid population was brought down significantly by the application of *neem* (Neem Baan 1500 ppm) @ 10 ml/litre in nursery as well as main crop during February-March. Mosaic virus complex disease was not observed during 2008–09 and 2009–10.

Table 1 Pest and natural enemy scenario in IPM and non-IPM bell pepper fields in Daha - Jagir (Karnal) during 2007–10

Pest	2007–08		2008–09		2009–10	
	IPM	FP	IPM	FP	IPM	FP
Aphids/plant	3.3	8.80	1.3	1.6	0.0	0.0
Thrips (0–5)	1.18	2.90	1.10	3.54	1.38	3.86
Fruit borer/plant	0.8	1.38	0.7	1.1	0.3	0.8
Fruit borer (damage %)	6.6	9.6	5.5	8.5	4.0	8.8
Mosaic virus complex (%)	26.9	38.2				
Collar and stem rot (%)			2.3	29.5	6.0 (0–58)	16.0 (2–80)
Sun scald (%)	4.3	4.8	6.3	8.0	6.4	8.8
Coccinellids	1.5	0.4	1.00	0.6	1.2	0.4
Predatory spiders	0.8	0.2	0.7	0.3	0.8	0.4

Table 2 Economic analysis of IPM and non-IPM technologies in bell pepper fields in Daha-Bajidan, Karnal during 2007–10

Parameter	2007–08		2008–09		2009–10	
	IPM	FP	IPM	FP	IPM	FP
Number of chemical sprays	9.0	14.0	8.0	13.6	6.3	12.2
Cost of cultivation (₹/ha)	43 312.5	45 275	85 192.5	86 605.0	90 700	87 033
Yield (tonnes/ha)	14.07	12.20	24.33	15.58*	21.63	18.00**
Gross returns (₹/ ha)	129 490	112 240	365 250	233 700	346 700	288 000
Net returns (₹/ ha)	86 177.5	66 965	280 057.5	147 095	255 300	200 967
Cost: benefit ratio	1:2.99	1:2.48	1:4.29	1:2.70	1:3.81	1:3.30

*Bell pepper price: ₹ 15/kg; **₹ 16/kg

Thrips were present through out the cropping season and its population increased with the increase in temperature up to 37–38°C. Average thrips populations of 1.18, 1.10 and 1.38 in IPM and 2.90, 3.54 and 3.86 (0–5 scale) in non IPM fields were observed, respectively during 2007–08, 2008–09 and 2009–10. Population of thrips was lower in the initial stages in IPM and non- IPM fields, and *neem* and 1–2 sprays of ecofriendly spinosad 45 SC (75 g ai/ha or 0.5 ml/litre) insecticide in IPM fields, could keep the thrips population at reasonably low levels throughout the crop season (Table 1). Varghese and Giraddi (2005) reported that soil application of *neem* cake as well as its integration with schedule of chemical sprays recorded significantly lower density of thrips comparable to chemical check. Sardana and Sehgal (2008) reported spinosad to be effective against thrips in bell pepper. George (2006) recorded lower population of thrips with NSKE 5% sprays.

The borer incidence was found to be lower, i e 6.6, 5.5 and 4.0 % in IPM in comparison to higher incidence of 9.6, 8.5 and 8.80 % in farmers' practices, respectively during three years. Only two to three sprays during three years, apart from other IPM interventions, were required for borer management (Table 1) in IPM fields while six to seven sprays were given by non-IPM farmers only for borer management.

Collar and stem rot caused by *Rhizoctonia solani* was observed initially in nursery where in it was effectively controlled by application of *Trichoderma harzianum* and carbendazim + mancozeb (0.2%) fungicide. From nursery it was mainly carried to main crop where it became almost unmanageable. An average disease incidence of 2.3 and 6.0 % in IPM and 29.5 and 16.0 % in non-IPM was observed over the crop period. Sun scald disorder, though difficult to manage, was marginally reduced in IPM fields (4.3, 6.3 and 6.4 %) by growing a border row of *dhaincha* to avoid the exposure of crop to westerly blowing hot winds during summer. In non-IPM fields, higher incidence of 4.8. 8.0 and 8.8 % was observed during 2007–08, 2008–09 and 2009–10, respectively (Table 1). Keeping weeds in between bell pepper rows also helped in cooling and thus reduced sun scald affected fruits in IPM fields.

A large build-up of natural enemies, especially predatory spiders and coccinellids was observed in IPM fields. High population of spiders in IPM fields (0.8, 0.70 and 0.6/ plant) than non-IPM fields (0.2, 0.3 and 0.4/plant) was observed (Table 1). IPM technology thus resulted in increased biodiversity. Chakraborti (2001) also from his studies concluded that neem based integrated schedule was safer to coccinellid beetles in chilli ecosystem.

The mean yield obtained was higher, i e 14.07, 24.33 and 21.63 tonnes/ha in IPM fields than farmer's practices fields where it was 12.20, 15.58 and 18.00 tonnes/ha, respectively, during 2007–08, 2008–09 and 2009–10.

During 2007–08, the cost of cultivation including plant protection was slightly lower in both IPM (₹ 43 312.5/ha) as well as non-IPM (₹ 45 275/ha) fields compared to costs of cultivation during 2008–09 and 2009–10 which was mainly due to packaging and transport costs owing to higher yields (24.63 and 21.63 tonnes/ha in IPM fields) obtained during 2008–09 and 2009–10. The data further revealed that spray of *Ha*NPV, release of Trichocards, rouging of affected plants and need-based application of pesticide was highly effective in reducing the pest population, which in turn resulted in increase of the yield up to some extent. Moreover, the adoption of IPM technology resulted in reducing the number of sprays to 6.3 during 2009–10 from 12.2 in non-IPM fields with a higher fruit yield in IPM than farmers' practices fields. Sunitha (2007) reported higher yields in IPM managed bell pepper fields than non-IPM fields.

Produce from IPM fields which received less number of chemical sprays might have less amount of pesticides at harvest than produce from non-IPM fields which received more number of chemical sprays which infact is more important for the environmental as well as human health. Therefore, the IPM technology used was not only directly environment friendly but also more sustainable vide increase in biodiversity (natural enemies, soil flora and fauna). Feedback from the IPM farmers also indicated the increased knowledge, awareness and adoption of 75% of the IPM components for bell pepper by majority of the adopted farmers. Adoption of IPM technology enabled the farmers to differentiate between the pests and bio- agents and avoidance of widely prevalent practice of using mixtures of pesticides.

SUMMARY

Field experiments were conducted in bell pepper (*Capsicum annum* var. frutescens L.) during 2007–10 at Daha-Jagir, Karnal, Haryana with a view to study the validation and economic viability of adaptable IPM technology in a farmers' participatory approach. The IPM technology for bell pepper crop comprising raising healthy nursery using soil solarization and mixing of *Trichoderma harzianum* (c.f.u. 2×10^9) along with FYM (@ 10 g/ 100 g FYM/m^2); seedling dip in *Pseudomonas fluorescence*, installation of delta traps @ 2/acre, one or two sprays of *neem* (Neem Baan @ 10 ml/litre) against aphids in early stages, erection of pheromone traps @ 5/ha, application of spinosad 45 SC @ (75 g ai/ha or 0.5 ml/litre) for thrips, collection and destruction of borers and disease affected fruits, five releases of egg parasitoid *Trichogramma chilonis* based on pheromone monitoring, two sprays of *Ha*NPV 250 LE/ha in evenings with UV protectant, one spray of ecofriendly emmamectin benzoate 5 WDG @ 0.25 g/lit of water, two to three need based sprays of chemical pesticides like indoxacarb 14.5 SP @ 500 g ai/ha or rynaxpyr 18.5 SC @ 3.5 ml /litre of water and carbendazim + mancozeb 75 SP @ 0.2% etc. was very effective in reducing the incidence of pests and minimizing the yield losses. The adoption of IPM technology resulted in reducing the number of chemical

sprays to 4–5 from 12–14 in non-IPM fields with higher fruit yields of 14.07–24.35 and 21.63 tonnes/ha in IPM and 12.20, 15.58 and 18.0 tonnes/ha in non-IPM fields and with higher CBR of 1:1.99, 1:3.29 and 1:2.81 in IPM than 1:1.48, 1:1.70 and 1:2.30 in non-IPM.

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