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Synthesis and validation IPM technology and its economic analysis for bottle gourd (*Lagenaria siceraria*)

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ABSTRACT

The field experiment was conducted (2016-18) at Varanasi, Mirzapur and Deoria districts of Uttar Pradesh with a view to study the validation and economic viability of adaptable IPM technology in a farmers' led approach. The IPM technology that synthesized comprising seed treatment with *Trichoderma viride* @5 g/kg of seed; installation of cue lure traps (MAT) for fruit flies @10/acre; raking of soil for exposing fruit fly pupae and removal of weeds, need based application of *Bacillus thuringiensis* @2 g/litre against *Sphenerches caffer*; need based spraying of Azadirachtin based neem insecticide @10 ml/litre and Imidacloprid 17.8SL @0.33 ml/litre of water for mirid bugs and whiteflies; fungicide Cymoxanyl 8WP+Mancozeb 64WP @2.5 g/litre against downy mildew were found effective in reducing the incidence of pests and minimizing the yield losses. The adoption of IPM technology, apart from lowering the incidence of major pests, also resulted in reducing the number of chemical sprays to 5–7 from 14–18 in non-IPM fields in a season with higher bottle gourd yields of 28, 29.5 and 21.7 tonnes/ha in IPM and 17.5, 18.1 and 10.9 tonnes/ha in non-IPM fields and with marginally higher cost benefit ratio of 1:1.91, 1:2.05 and 1:2.41 in IPM than 1:1.14, 1:1.19 and 1:11, respectively in non-IPM. On an average, IPM farmers had an average net return of ₹ 145472/ha with C:B ratio of 1:2.09 as compared to the non-IPM farmers with net return of ₹ 20992/ha with a C:B ratio of 1:1.15.

Key words: Bottle gourd, IPM technology, Insect pests, Natural enemies

Bottle gourd (*Lagenaria siceraria*) belonging to the family Cucurbitaceae, is a climbing perennial plant widely cultivated round the year as a vegetable crop across the country. It is extensively grown throughout India occupying an area of 0.103 mha with a production of 1.819 mt (NHB 2014). India is still far behind from many countries in terms of productivity, which is quite low owing to attack by several pests which are a major constraint in realizing the productivity potential of bottle gourd. The crop is infested by several insect pests throughout its growing period and amongst them fruit fly, *Bactrocera cucurbitae* Coq. (Tephritidae: Diptera); mirid bug, *Nesidiocoris cruentatus* (Ballard) (Miridae: Hemiptera); whitefly, *Bemisia tabaci* Gennadius (Aleyrodidae: Hemiptera) and white plume moth, *Sphenerches caffer* (Pterophoridae: Lepidoptera) are important and cause substantial yield losses, whereas amongst the diseases, downy mildew (*Pseudoperonospora parasitica*) and *Cercospora* leaf spot are serious problems in the eastern Uttar Pradesh. To control these biotic stresses, Indian farmers mostly rely on chemical pesticides which often indiscriminate, unwanted and excessive leading to problems like resistance to pesticides, resurgence of target insects and secondary pest outbreak, residues in food and beverages, contamination of groundwater, adverse effect on human health, and widespread killing of non-target organisms (Halder *et al*. 2014, 2016). It is not unusual for the bottle gourd growers to give 12–18 round of chemical sprays in a season, very often they are unnecessary and unjustified furthermore without any appreciable increase in the yield. Development of suitable and ecofriendly Integrated Pest Management (IPM) package for sustainable bottle gourd production is the need of the hour. Moreover, information on the development of such modules for the holistic management of pests in a wider area in bottle gourd is very scanty. Keeping this in view, synthesis and validation of multifaceted adaptable IPM technology in bottle gourd was carried out in a participatory manner in farmers' fields to reduce the over dependence and reliance on chemical pesticides and protecting the ecosystem as a whole (Sardana *et al*. 2012).

MATERIALS AND METHODS

Three year trial on validation of IPM technology in bottle gourd crop were carried out during 2016–18 in

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Varanasi, Mirzapur and Deoria districts of Uttar Pradesh. Before initiation of validation of IPM technology, adaptable IPM module for bottle gourd was synthesized based on the base line information collected on the crops, pest and natural enemies status in the districts Varanasi, Mirzapur and Deoria from farmers, recommendations made by ICAR- Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, ICAR-National Research Centre for Integrated Pest Management, New Delhi and Banaras Hindu University (BHU) for bottle gourd pest management and research literature published by eminent entomologist and plant pathologist on bottle gourd.The IPM module, thus synthesized, was validated during 2016 initially in an area of 15 acres comprising 20 farming families in the three districts of eastern Uttar Pradesh, viz. Varanasi (villages Mahagaon and Kachahariya), Mirzapur (villages Adalpura, Araziline Sultanpur and Chaudharypur) and Deoria (village Malhana) with the following interventions: seed treatment with *Trichoderma viride* @5 g/kg of seed, installation of cue lure traps (MAT) for fruit flies @10/acre, raking of soil for exposing fruit fly pupae to sunlight and predatory fauna and removal of associated weeds, need based application insecticides like of *Bacillus thuringiensis* @2 g/litre against white plume moth, *Sphenerches caffer*; need based spraying of Azadirachtin (0.03%) based neem insecticide @10 ml/litre and Imidacloprid 17.8 SL @0.33 ml/litre of water for mirid bugs and whiteflies and systemic fungicide Cymoxanyl 8 WP+ Mancozeb 64 WP @2.5 g/litre against downy mildew and *Cercospora* leaf spot.

The results on the pest incidence/natural enemies population and the economic viability of IPM were compared with non-IPM (farmers' own way of managing the pests) which consisted of only chemical pesticides such as: Imidacloprid 17.8 SL @0.5–1 /lit, Thiamethoxam 70 WG @0.5–1 g/ lit, Acetamiprid 20 SP @0.33 g/lit, Cypermethrin 25 EC @1 ml/lit, Quinalphos 25 EC @2 ml/lit; Mancozeb 75 WP @2 g/lit, Metalaxyl 8 WP+ Mancozeb 64 WP @2.5 g/lit and Streptocycline @0.2 g/lit etc.

The local farmers often used to give higher than the recommended doses of pesticides and thus the accurate doses of pesticide application by the non-IPM farmers were as difficult to calculate as the container lid was usually used to measure the doses. Moreover, during the study it was also observed that farmers frequently applied different micronutrients or herbal tonic mixing with different pesticides with apprehension to rejuvenate their crops. During 2017–18, validated IPM technology were further refined and revalidated in 30 and 45 acres area comprising 36 and 43 farming families, respectively, of the same places.

Periodical observations made on to the major biotic fauna on the bottle gourd ecosystem at selected farmers' field, number of fruit flies trapped in cue lure traps (at weekly basis), number of fruits damage due to cucurbits fruit fly in bottle gourd were recorded.

Fruit fly incidence was calculated as:

$$\text{Per cent fruit fly incidence} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruits}} \times 100$$

For recording the incidence of plume moth, five randomly selected plants from each acre area per farmer were taken and the number of larvae of plume moth per plant were counted. Similarly, for mirid bug population, number of bugs (both nymphs and adults) per fruit were counted and expressed in number of bugs per fruit. Two beneficial fauna, viz. *Apanteles paludicole* Cameron (Braconidae: Hymenoptera), a larval parasitoid of *Sphenerches caffer* and polyphagous predator, i.e. spiders were counted per plant as five randomly selected plants from each acre area per farmer were sampled.

For recording the severity of downy mildew, 50 leaves were selected randomly from each plot and grading had been done on 0-5 scale according to Jamadar and Desai (1997); which was: 0=no symptom; 1=0–10% leaf area covered with mildew growth; 2=10.1–15% leaf area covered with mildew growth; 3= 15.1–25% leaf area covered with mildew growth; 4=25.1–50% leaf area covered with mildew growth; 5= >50% leaf area covered with mildew growth. Similarly, for *Cercospora* leaf spot randomly 50 leaves were selected from each plot and grading has been done according to Jamadar and Desai, 1997: which was: 0=No symptom; 1=0–10% leaf area covered with leaf spot; 2=10.1–15% leaf area covered with leaf spot; 3=15.1–25% leaf area covered with leaf spot; 4=25.1–50% leaf area covered with leaf spot and 5= >50% leaf area covered with leaf spot.

Table 1 Pests and natural enemies scenario in IPM and non-IPM bottle gourd fields at Varanasi, Mirzapur and Deoria (Uttar Pradesh) (2016–18)

Pest/natural enemy	IPM fields				Non-IPM fields			
	2016	2017	2018	Average	2016	2017	2018	Average
Fruit fly (% damage)	6.17	5.26	5.57	5.67	14.44	12.47	14.18	13.70
Mirid bugs/fruit	5.57	6.50	4.90	5.66	11.24	14.25	12.75	12.75
S. caffer/plant	12.42	5.25	4.42	7.36	23.29	8.01	7.76	13.02
Downy mildew (PDI)	10.13	6.73	9.40	8.75	37.13	18.46	27.50	27.70
Cercospora leaf spot (PDI)	11.60	6.45	5.20	7.75	21.34	13.25	18.50	17.70
A. paludicole/plant	2.83	3.11	4.05	3.33	1.07	1.22	0.94	1.08
Spider/plant	5.54	6.75	4.38	5.56	2.33	2.92	1.13	2.13

Percent disease index (PDI) for the downy mildew and *Cercospora* diseases were calculated using the formula:

$$\text{Percent disease incidence} = \frac{\text{Sum of oil grades}}{\text{Total number of leaves observed}} \times \frac{100}{\text{Maximum grades}}$$

For economic analysis, numbers of chemical sprays, cost of cultivation (per ha), yield (ton per ha), net returns (per ha) and cost:benefit ratio (CBR) were computed and results were presented in Table 2.

RESULTS AND DISCUSSION

The adoption of IPM technology resulted in significant reduction in incidence of all the insect pests and diseases while the incidence of most of the pests was marginally higher in non-IPM plots, i.e. farmers' practices (FP) fields (Table 1). Trend and appearance of almost all the pests were similar during all the three years, i.e. 2016–18 except minor variations which were mainly due to climatic factors.

For managing cucurbit fruit fly, *B. cucurbitae* farmers are used to apply a series of insecticides to get rid of from this nefarious pest. Installation of cue lure bottle traps @ 10/acre from flowering onwards and raking of soil to expose the pupae resulted in the lower fruit damage, i.e. 6.17, 5.26 and 5.57% during 2016, 2017 and 2018, respectively, as against higher fruit fly damage registered in FP fields, i.e.14.44, 12.47 and 14.18%, respectively during the same period (Table 1). Effectivity of cuelure bottle traps for the management of cucurbit fruit fly in vegetable ecosystem has been confirmed by several authors, including Rai *et al*. 2014 a, b.

The serious incidence of a mirid bug, *Nesidiocoris cruentatus* (Ballard) was observed on tender leaves and young fruits in many parts of eastern Uttar Pradesh. On tender leaves, a minute puncture spot with yellow hallow were observed. The damage was more prominent in young fruits. Brown puncture spots with on the rind with sap oozing out from the tender fruits was the characteristic symptoms of this sucking pests. The affected fruits often failed to fetch a good market price (Halder *et al*. 2017). To control these sucking pests, IPM adopted farmers were suggested with two sprays constituting one each of Imidacloprid 17.8 SL @40 g a.i./ha followed by a neem based insecticide (Azadirachtin 0.03%) @10 ml/l. Need based application of these two insecticides resulted in control of the sucking pests effectively. In paradox, non-IPM farmers applied a series of chemicals which not only increased the cost of production, but also caused the unintended residues in the final produce. Interestingly, the mirid bug population per fruit were 11.24, 14.25 and 12.75 in non-IPM plots during 2016, 2017 and 2018 year trials as against IPM plots (5.57, 6.50 and 4.90, respectively) wherein these were very low. The same trend was also observed in case of white plume moth, *S. caffer*, whose population was relatively higher in non-IPM plots during 2016, 2017 and 2018 being 23.29, 8.01 and 7.76 per plant, recpectively, with an average of 13.02, whereas in the IPM plots the corresponding larval populations were just 12.42, 5.25, 4.42 per plant, respectively, with an average of 7.36 per plant. Population of this delicate insect was significantly brought down by the application of *Bacillus thuringiensis* var *Kurstaki* @2 g/l during vegetative as well as reproductive stages during September - October.

Amongst the diseases, downy mildew and *Cercospora* leaf spot diseases were serious in the region. In farmers' fields, severity of downy mildew ranged from 18.46–37.13 PDI with an average of 27.70 PDI during the above period as against the IPM fields where the corresponding values ranged from 6.73–10.13 PDI with an average of 8.75 PDI. The same trend was observed in the incidence of *Cercospora* leaf spot disease. IPM fields suffered less from *Cercospora* leaf spot disease severity during the three years, i.e. 2016 (11.60 PDI), 2017 (6.45 PDI) and 2018 (5.20) than the non-IPM fields. A similar observation was recorded by Halder *et al*. (2018) who observed incidence of downy mildew and mosaic disease complex in bitter gourd to be significantly lower in IPM fields where the neem, cuelure traps and green labeled pesticides were integrated than the non-IPM ones which included only chemical insecticides.

Natural enemies: A large build-up of natural enemies, especially predatory spiders and braconid parasitoids were observed in IPM fields. High populations of spiders in IPM fields (5.54,6.75 and 4.38 per plant) than non-IPM fields (2.33,2.92 and 1.13 per plant) were observed during 2016, 2017 and 2018, respectively (Table 1). The same trend was also recorded with braconid, *Apanteles paludicole* population. IPM fields harboured higher population of this endoparasitoid (2.83, 3.11 and 4.05 per plant during 2016, 2017 and 2018, respectively) than the non-IPM fields (1.07, 1.22 and 0.94 per plant during the same period). IPM technology, thus resulted in increased biodiversity. Chakraborti (2001), Halder *et al*. (2010), Sardana *et al* (2012) and Sardana and Bhat (2016, 2017) also from their studies concluded that neem based integrated schedule was safer to parasitoids and predatory spiders in mustard, pepper and onion ecosystems.

Economic analysis: The mean fruit yields obtained from hybrid bottle gourds were higher, i.e. 28, 29.5 and 21.7 q per ha with an average of 26.4 q per ha in IPM fields as compared to farmers' practices fields where it was 17.5, 18.1 and 10.9 q per ha during 2016, 2017 and 2018, respectively, being lower to IPM fields. During the first year, i.e. 2016, the cost of cultivation, including plant protection measures was slightly higher in both IPM (₹ 146511/ha) as well as non-IPM (₹ 153843/ha) fields compared to 2017–18 mainly due to purchase of staking materials, viz. bamboo and iron/plastic wire that served for more than two years. From the Table 2, it was also evident that IPM adopted farmers had higher gross returns of ₹ 280000, 295000 and 260400 per ha during 2016, 2017 and 2018, respectively, compared to ₹ 175000, 181000 and 130800 per ha in case of non-IPM farmers. Same trend also reflected in case of cost benefit (C:B) ratio. IPM farmers registered higher C:B ratio of 1:1.91, 1:2.05 and 1:2.41 during 2016, 2017 and 2018, respectively, whereas

Table 2 Economic analysis of IPM and non-IPM technologies in bottle gourd fields at Varanasi, Mirzapur and Deoria (Uttar Pradesh) (2014–16)

Parameter	IPM				FP			
	2016	2017	2018	Average	2016	2017	2018	Average
Number of sprays	7	5	5	5.67	18	14	14	15.33
Cost of cultivation (₹)	146511	144161	108313	132995	153843	152199	117782	141275
Yield (t/ha)	28	29.5	21.7	26.4	17.5	18.1	10.9	15.5
Gross return/income *(₹)	280000	295000	260400	278467	175000	181000	130800	162267
Net return (₹)	133489	150839	152087	145472	21157	28801	13018	20992
Cost benefit ratio	1:1.91	1:2.05	1:2.41	1:2.09	1:1.14	1:1.19	1:1.11	1:1.15

Average labourer charge @ ₹ 250/day; *Average costs of bottle gourd were ₹ 1000, ₹ 1000 and ₹ 1200 per q during 2016, 2017 and 2018, respectively.

non-IPM farmers had relatively lower C:B ratio of 1:1.14, 1:1.19 and 1:1.11 for the same period. Higher severity of fungal (downy mildew and *Cercospora*) diseases lead to comparatively lower yield in both IPM and non-IPM adopted farmers. Lower yield, however, also fetched comparatively overall higher market price in the third year (2018) and thereby registered higher C:B ratio than 2016. In contrast, during 2017–18, the occurrence of untimely rain during October – November, 2017 than the previous years, i.e. 2015–16 and 2016–17 lead to comparatively lower fruit yield. The data further revealed that the installation of cue lure traps, spray of *Bacillus thuringiesnsis* or neem based insecticide containing Azadirachtin 0.03%, raking of soil and need-based application of pesticides were highly effective in reducing the pest population, which in turn resulted in increase of the yield of bottle gourd. Moreover, the adoption of IPM technology resulted in reducing the number of sprays to 5 during both the years from an average number of 15.33 (Table 2) in FP fields. Sunitha (2007) reported higher yields in IPM managed bell pepper fields than non-IPM fields. Sardana *et al.* (2017) also reported higher yields in onion seed crop fields of IPM than non-IPM fields. Similarly in watermelon, Priyanka *et al*. (2018) reported that IPM module devised had reduced the thrips population and bud necrosis disease incidence to a greater extent besides increasing the fruit yield.

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 80% of the IPM components for bottle gourd by a majority of the adopted farmers. Adoption of IPM technology enabled the farmers also to differentiate between the pests and bio-agents and avoidance of the widely prevalent practice of using mixtures of pesticides.

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