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Synthesis and area-wide validation of adaptable IPM technology and its economic analysis for bitter gourd (*Momordica charantia*) in a farmers' driven approach

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ABSTRACT

Field experiment was conducted in bitter gourd (*Momordica charantia* L.) during 2014-16 at Varanasi, Mirzapur and Deoria districts of eastern Uttar Pradesh with a view to study the validation, economic viability and feasibility of adaptable and rational IPM technology in a farmers' led approach.The IPM technology that synthesized for bitter gourd crop comprised seed treatment with *Trichoderma viride* @ 5g/kg of seed; need based spraying of azadirachtin (0.03%) based neem insecticide @ 10 ml/l for hadda beetle; 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 of *Bacillus thuringiesnsis* @ 2 g/l against cucumber moth, *Diaphania indica*; Imidacloprid 17.8 SL @ 1 ml/l of water for whitefly; systemic fungicide Cymoxanil l8 WP+Mancozeb 64 WP @ 2.5 g/l against downy mildew were found very effective in reducing the incidence of pests and minimizing the yield losses. The adoption of IPM technology during the three years, apart from lowering the incidence of major pests, resulted in reducing the number of chemical sprays to 7-9 from 21-25 in non-IPM fields in a season with higher bitter gourd yields of 18, 16.5 and 18.7 tonnes/ha in IPM and 14.4, 11.8 and 15.1 tonnes/ha in non-IPM fields and with marginally higher cost benefit (C:B) ratio of 1:2.19, 1:2.58 and 1:3.01 in IPM than 1:1.70, 1:1.78 and 1:2.30, respectively in non-IPM for the three consequitive years. There was a net income increase IPM fields over farmers' practice fields. On an average, IPM farmers had an average higher net return of ₹ 2.37 lakh/ha with C:B ratio of 1:2.59 as compared to the non-IPM farmers with net return of ₹ 1.49 lakh/ha with a B:C ratio of 1:1.93.

Key words: Bitter gourd, Diseases, Insect pests, IPM technology, Natural enemies, Return

Bitter gourd (*Momordica charantia* L.: Cucurbitaceae), commonly known as *karela*, is cultivated throughout the world, especially in the tropical and sub-tropical areas (Kandangath et al. 2015). It is extensively grown throughout India occupying an area of 0.08 mha with a production of 0.82 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 major constraint in realizing the productivity potential of bitter gourd. The crop is infested by several insect pests thoroughout its growing period and amongst them fruit fly, *Bactrocera cucurbitae* Coq. (Tephritidae: Diptera); hadda beetle, *Epilachna duodecastigma* and *Henosepilachna vigintioctopunctata* (Coccinellidae: Coleoptera) and cucumber moth, *Diaphania indica* (Pyralidae: Lepidoptera) are important and cause substantial yield losses, whereas amongst the diseases, downy mildew (*Pseudoperonospora parasitica*), bitter gourd mosaic diseases (*Begomovirus*) are serious problems in the eastern Uttar Pradesh.

Quicker control strategy against these pests and quest of getting higher yields, has led to indiscriminate, unnecessary, unwanted and excessive use of chemical pesticides 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.* 2010, 2013). It is not unusual for the bitter gourd growers to give 20-25 chemical sprays in a season, which most of the times are unnecessary and unjustified furthermore without any appreciable increase

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in the yield.

Development of suitable Integrated Pest Management (IPM) package for ecofriendly pest management for sustainable bitter 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 bitter gourd is scanty. Numerous management strategies for the pests of bitter gourd crops have been developed, but these have mostly been dealt in isolation and individually and thus have met with little desired success. The integration of all the pest management strategies in a farmers led approach/ mode could reduce the application of harmful chemical pesticides to a greater extent. Keeping this in view, validation of multifaceted adaptable IPM technology in bitter 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 bitter gourd crop were carried out during 2014-16 at districts Varanasi, Mirzapur and Deoria of Uttar Pradesh. Before initiation of validation of IPM technology, adaptable IPM module for bitter gourd was synthesized based on the base line information collected on the crops, pest and natural enemies status in 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 bitter gourd pest management and research literature published by eminent entomologist and plant pathologist on bitter gourd. The IPM module, thus synthesized, was validated during 2014 initially in an area of 20 acres comprising 25 farming families in the three districts of eastern Uttar Pradesh, viz. Varanasi (village Mahagaon), Mirzapur (village Adalpura) and Deoria (village Malhana) with the following interventions: seed treatment with *Trichoderma viride* @ 5 g/kg of seed, spray of azadirachtin (0.03%) based neem insecticide (@ 10 ml/l for hadda beetle; 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, two sprays of *Bacillus thuringiesnsis* var *Kurstaki* @ 2 g/l against cucumber moth, *Diaphania indica,* need based spraying of Imidacloprid 17.8 SL @ 40 g a.i./ha for whitefly and systemic fungicide Cymoxanyl 8 WP + Mancozeb 64 WP @ 1080 g a.i./ha against downy mildew.

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 ml/l, Thiamethoxam 70 WG @ 0.5 g/l, Acetamiprid 20 SP @ 0.33 g/l, Spinosad 45 SC @ 0.5 ml/l, Cypermethrin 25 EC @ 1 ml/l, Profenophos 40 EC + Cypermethrin 4 EC @ 1 ml/l, Quinalphos 25 EC @ 2 ml/l; Dimethoate 30 EC @ 2 ml/l, Mancozeb 75 WP @ 2 g/l, Metalaxyl 8 WP+ Mancozeb 64 WP @ 2.5 g/l and Streptocycline @ 0.2 g/l 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 often 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 2015 and 2016, validated IPM technology were further refined and revalidated in 30 acre area comprising 32 farming families of the same places.

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

Fruit fly incidence was calculated by the following formula

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

For recording the incidence of cucumber moth and hadda beetle, five randomly selected plants from each acre area per farmer were taken and the number of larvae of cucumber moth and grubs and adults in case of hadda beetle per plant were counted. 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. Percent disease index (PDI) for the downy mildew disease was calculated using the formula:

$$\text{Per cent fruit fly incidence} = \frac{\text{Sum of all grades}}{\text{Total number of leaves observed}} \times \frac{100}{\text{Maximum grades}}$$

For viral diseases, transmitted by the whitefly (*Bemisia tabaci*), 5 spots were randomly selected from each field of one acre, and in each spot, 10 growing tips of the all plants were selected randomly. Percent occurrence of disease was calculated based on the formula.

$$\text{Per cent disease incidence} = \frac{\text{No. of growing tips having symptom}}{\text{Total number of growing tips observed}} \times 100$$

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

To estimate the targeted pesticide residue contamination

Table 1 Pests and natural enemies scenario in IPM and non-IPM bitter gourd fields at Varanasi (Uttar Pradesh), during 2014–16

Pest /natural enemy	IPM fields				Non-IPM fields			
	2014	2015	2016	Average	2014	2015	2016	Average
D. indica/ plant	11.39	10.45	6.75	9.53	23.56	21.33	16.25	20.38
Fruit fly (% damage)	12.87	8.39	7.53	9.60	23.12	18.25	15.92	19.10
Hadda beetle/ plant	3.75	2.89	1.63	2.76	8.50	6.75	4.08	6.44
Downy mildew (PDI)	12.40	16.60	9.09	12.70	25.7	34.3	21.5	27.17
Mosaic disease (PDI)	20.50	31.41	11.25	21.05	38.7	63.5	26.75	42.98
Lady bird beetles/ plant	5.87	5.11	4.33	5.10	1.53	1.85	1.67	1.68
Spiders/ plant	3.27	3.56	3.47	3.43	0.87	0.95	1.05	0.96

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

Parameter	IPM				FP			
	2014	2015	2016	Average	2014	2015	2016	Average
Number of sprays	10	10	7	9	25	21	22	22.67
Cost of cultivation (₹)	164371	153596	149511	155826	169050	158940	157504	161831.3
Yield (t/ha)	18.0	16.5	18.7	17.7	14.4	11.8	15.1	13.7
Gross return / income *(₹)	360000	396000	448800	401600	288000	283200	362400	311200
Net return (₹)	195629	215404	299289	236774	118950	124260	204896	149368.7
Cost benefit ratio	1:2.19	1:2.58	1:3.01	1:2.59	1:1.70	1:1.78	1:2.30	1:1.93

Average labourer charge @ ₹ 250/day; *Average costs of bitter gourd were ₹ 2000, ₹ 2400 and ₹ 2400/q during 2014, 2015 and 2016, respectively.

in/on the bitter gourd fruits at harvest, bitter gourd fruits (up to 50 g each) from IPM fields were collected for pesticide residue analysis which was carried out at ICAR-National Research Centre for Grapes, Pune, Maharashtra, India.

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. 2014–16 except minor variations which were mainly due to climatic factors.

The incidence of cucumber moth, *D. indica* started from September onwards when the bitter gourd was in early reproductive stage. Since this pest is delicate and easy to control, IPM beneficiaries of the area were advised to apply only two sprayings one each of *Bt* @ 2 g/l followed by a neem based insecticide (Azadirachtin 0.03%) @ 10 ml/l. Need based application of these two insecticides resulted in control of these two pests effectively. In contrast, non-IPM farmers applied a series of chemicals which not only increased the cost of production, but may also caused the unintended residues in the final produce. Interestingly, the larval population per plant of *D. indica* was 23.56, 21.33 and 16.25 in non-IPM plots during 2014, 2015 and 2016 year trials as against IPM plots (11.39, 10.45 and 6.75, respectively) wherein it was very low. The same trend was also observed in case of hadda beetle, whose population was relatively higher in non-IPM plots during 2014, 2015 and 2016 being 8.50, 6.75 and 4.08/plant, respectively, with an average of 6.44, whereas the in IPM plots the corresponding beetle populations were just 3.75, 2.89, 1.63/ plant, respectively with an average of 2.76. Population of this polyphagous beetle was significantly brought down by the application of neem based insecticide containing Azadirachtin 0.03% @ 10 ml/l during vegetative as well as reproductive stages during September - October.

For managing cucurbit fruit fly, farmers used to apply a wide range 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 resulted in the lower fruit damage, i.e. 12.87, 8.39 7.53% during 2014, 2015 and 2016, respectively, as against higher fruit fly damage registered in FP fields, i.e. 23.12, 18.25 and 15.92%, respectively during the same period (Table 1). Effectivity of cuelure bottle traps for the management of melon fruit fly in vegetable ecosystem has been confirmed by several authors, including Rai *et al.* (2014 a and b).

Amongst the diseases, downy mildew and bitter gourd leaf curl mosaic disease complex were serious in the region. In farmers' fields, severity of downy mildew ranged from 25.7 – 34.3 PDI with an average of 27.17 PDI during the above period as against the IPM fields where the corresponding values ranged from 9.09–16.6 PDI with an average of 12.70 PDI. The same trend was observed in the incidence of bitter gourd mosaic disease. IPM fields suffered less from leaf curl mosaic disease severity during the three years, i.e. 2014 (20.5 PDI), 2015 (31.4 PDI) and 2016 (11.25) than the non-IPM fields. A similar observation was recorded by Sardana *et al.* (2012) who observed incidence of collar/stem rot and mosaic virus complex in bell pepper to be significantly lower in IPM fields where the neem, pheromone traps, and green labeled insecticides 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 coccinellids were observed in IPM fields. High populations of spiders in IPM fields (3.27, 3.56 and 3.47/plant) than non-IPM fields (0.87, 0.95 and 1.05/plant) were observed during 2014, 2015 and 2016, respectively (Table 1). The same trend was also recorded with lady bird beetle population. IPM fields harboured higher population (5.87, 5.11 and 4.33/plant during 2014, 2015 and 2016, respectively, of this predator than the non-IPM fields (1.53, 1.85 and 1.67/plant during the same period). IPM technology, thus resulted in increased biodiversity. Chakraborti (2001), Sardana *et al.* (2012) and Sardana and Bhat (2016, 2017) also from their studies concluded that neem based integrated schedule was safer to Coccinellid beetles and predatory spiders in pepper and onion ecosystems.

Economic analysis

The mean fruit yields obtained were higher, i.e. 180, 165 and 187 q/ha with an average of 177.3 q/ha in IPM fields as compared to farmers' practices fields where it was 144, 118 and 151 q/ha during 2014, 2015 and 2016, respectively, being lower to IPM fields. During the first year, i.e. 2014, the cost of cultivation, including plant protection measures was slightly higher in both IPM (Rs. 164371/ha) as well as non-IPM (₹ 169050/ha) fields compared to 2015and 2016 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 ₹ 3.60, 3.96 and 4.488 lakh/ha during 2014, 2015 and 2016, respectively, compared to ₹ 2.88, 2.832 and 3.624 lakh/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 1:2.19, 1:2.58 and 1:3.01 during 2014, 2015 and 2016, respectively, whereas non-IPM farmers had relatively lower C:B ratio of 1:1.70, 1:1.78 and 1:2.30 for the same period. Higher severity of fungal (downy mildew) and viral diseases (leaf curl virus) 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 second year (2015) and thereby registered higher C:B ratio than 2014. In contrast, during 2016, the incidence of all biotic stresses was lower than the previous years, i.e. 2014 and 2015. This was also lead to highest fruit yield (187 q/ha). 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 bitter gourd. Moreover, the adoption of IPM technology resulted in reducing the number of sprays to 10 during both the years from an average number of 23 (Table 3) 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.

Mature fruits of bitter gourds (up to 50 g each) from IPM plots at harvest when analyzed for pesticides residues content, fruits from IPM plots had only Imidacloprid residue which was also below the maximum residue limit (<MRL). 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 bitter 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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