Indian Journal of Agricultural Sciences **92** (9): 1124–1128, September 2022/Article
https://doi.org/10.56093/ijas.v92i8.118553

Synthesis and area-wide validation of IPM technology and its economic analysis for eggplant (*Solanum melongena*)

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Received: 1 December 2021 Accepted: 2 August 2022

ABSTRACT

Field experiments were conducted during 2019–21 in Varanasi, Mirzapur and Bhadohi districts of Uttar Pradesh, with a view to study validation and economic viability of IPM technology in eggplant (*Solanum melongena* L.) in a farmers' driven approach. The synthesized improved IPM technology comprising seed treatment with *Trichoderma viride* @5 g/kg seed; seedling root dip in carbendazim 50 WP @1 g/l followed by chlorantraniliprole 18.5 SC @0.5 ml/l solution against seed borne diseases and shoot and fruit borer, respectively, clipping of borer damaged shoots at weekly interval, installation of pheromone traps @25–30 traps/ha for mass trapping of brinjal shoot and fruit borer (BSFB), need based spray (ETL>5%) of chlorantraniliprole 18.5 SC @0.35 ml/l or emamectin benzoate 5 SG @0.4 g/l or fenpropathrin 30 EC @0.33 ml/l against BSFB, installation of yellow sticky traps, application of Azadirachtin 0.03% @5 ml/l and need based spray of thiamethoxam 25 WG @0.4 g/l or fenpropathrin 30 EC @0.33 ml/l against sucking pests like whiteflies and hoppers, collection and destruction of borer and Phomopsis blight infected fruits, *Sclerotinia* white rot infected twigs and branches and little leaf affected plants periodically, need based application of carbendazim 50 WP @0.5 g/l for management of *Phomopsis* blight and white rot, were found effective in reducing the incidence of pests and minimizing the yield losses. The adoption of IPM technology also resulted in reducing the number of chemical sprays to 10 from 21–24 in farmers' practices (FP) fields in a season with higher fruit yields of 51.1 and 45.3 t/ha in IPM, 39.6 and 33.7 t/ha in FP and 25.7 and 20.4 t/ha in untreated control fields with higher incremental benefit cost (B:C) ratio of 4.61:1 and 4.86:1 in IPM than 3.16:1, 3.24:1 in non-IPM and 2.53:1, 2.42:1 in untreated control plots during 2019–20 and 2020–21, respectively.

Keywords: Eggplant, Economics, Farmers' participation, Natural enemies, Pests

Eggplant or brinjal (*Solanum melongena* L.), is one of the most important vegetable crops widely grown in India for its varied fruit shape, size and colour. High production and productivity, wider adaptability and round the year availability makes this vegetable to find its place in almost every household in India. However, India is still far behind from many countries in terms of productivity, owing to attack by several pests which are a major constraint in realizing the productivity potential of eggplant. The crop is ravaged by several insect pests and diseases throughout its growing period and amongst them, Shoot and fruit borer (*Leucinodes orbonalis* Guenee), Hopper [*Amrasca biguttula biguttula* (Ishida)], Whitefly [*Bemisia tabaci* (Gennadius)], Sclerotinia rot [*Sclerotinia sclerotiorum* (Lib.) de Bary], Phomopsis blight [*Phomopsis vexans* (Sacc. & Syd.)] and little leaf of brinjal are important and cause substantial yield losses in the eastern part of Uttar Pradesh.

To control these biotic stresses, Indian farmers mostly rely on chemical pesticides which are often used indiscriminately, unwanted and excessively leading to development of resistance to pesticides, resurgence of target insects and secondary pest outbreak, residues in food and beverages, contamination of groundwater, health hazards to humans and widespread killing and decimation of non-target organisms (Halder *et al.* 2017). It is not unusual for the eggplant growers to give 20–24 rounds of chemical sprays in a crop season, often unnecessary and unjustified, furthermore, without any appreciable increase in the yield. Development of suitable and eco-friendly integrated pest management (IPM) protocol for sustainable eggplant production is the need of the hour. Information on the development of such protocols for the holistic management of pests in a wider area for eggplant is also very scanty. Keeping this in view, synthesis and validation of multifaceted, adaptable and improved IPM technology in eggplant was carried out in a participatory manner in

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farmers fields to reduce the over dependence and reliance on chemical pesticides and protecting the ecosystem as a whole.

MATERIALS AND METHODS

Two year trials (2019–21) on validation of IPM technology in eggplant crop were carried out in Varanasi, Mirzapur and Bhadohi districts of eastern Uttar Pradesh. Before initiation of validation of IPM technology, adaptable IPM module for eggplant was synthesized based on the base line information collected on the crops, pests and natural enemies status in Varanasi and recommendations made by ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh; ICAR-National Research Centre for Integrated Pest Management, New Delhi; Banaras Hindu University, Varanasi, Uttar Pradesh and research literature published by eminent plant protection scientists. The IPM module, thus synthesized, was validated during 2019–21 in an area of 15 acres comprising 51 farming families in villages Marachh, Arazaline Sultanpur, Adalpura of Mirzapur district; and Villages Nidiur, Kurauna and Dilkoeran of Bhadohi district and Kachhariya village of Varanasi district with the following interventions: seed treatment with *Trichoderma viride* @5 g/kg seed; seedling root dip in carbendazim 50 WP @1 g/l for 20 min followed by chlorantraniliprole 18.5% SC @0.5 ml/l solution for 3 h against seed borne diseases and brinjal shoot and fruit borer (BSFB), respectively; clipping of borer damaged shoots and fruits at weekly intervals, installation of yellow sticky traps, installation of pheromone traps @25–30 traps/ha for mass trapping of BSFB; application of need based spray (ETL>5%) of chlorantraniliprole 18.5 SC @0.35 ml/l or emamectin benzoate 5 SG @0.4 g/l or fenpropathrin 30 EC @0.33 ml/l against BSFB; application of azadirachtin 0.03% @5 ml/l for sucking pests like whitefly, hoppers, mites; need based spray of thiamethoxam 25 WG @0.4 g/l or fenpropathrin 30 EC @0.33 ml/l against sucking pests collection and destruction of Phomopsis *blight*, *Sclerotinia* rot damaged twigs, branches, fruits and little leaf affected plants periodically; during winter rains and foggy weather, need based application of carbendazim 50 WP @0.5 g/l for management of Phomopsis blight and white rot, were found effective in reducing the incidence of pests and minimizing the yield losses. 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 series of chemical pesticides. For the same, three non-IPM farmers from each village were selected and data were collected periodically. Local farmers often used higher than the recommended doses of pesticides and thus the accurate doses of pesticide application by the non-IPM farmers were difficult to calculate as the container lid was generally 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 the hope to rejuvenate their crops. Apart from these, a separate field of about 660 m^2 was maintained as untreated control in the experimental farm (82°52′E and 25°12′N) of ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh where no pesticides were applied throughout the crop growth period.

Periodical observations were made to enlist the major biotic fauna on brinjal ecosystem at selected farmers' fields. Per cent fruit damage by *Leucinodes orbonalis* in brinjal was calculated as:

$$\text{Fruit damage (\%)} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruits}} \times 100$$

Similarly, jassids (both nymphs and adults) and whitefly (adults) populations were calculated by counting the insects per five leaves per plant. As such 20 plants were taken from each plot and expressed as number of sucking pests (jassids/whitefly) per leaf/plant. In case of predator population, number of predators i.e. number of spiders and lady bird beetles (grubs/pupae/adults) were counted per plant during February–March of each experimental year (2019–20).

Two major diseases i.e. white rot caused by *Sclerotinia sclerotiorum* and *Phomopsis* blight caused by *Phomopsis vexans* were encountered during the observation in the region. The incidence was calculated based on the number of infected twigs out of total number of twigs on a plant in five spots/field and in each spot, 10 plants were observed.

The per cent disease incidence of Phomopsis blight and Sclerotinia white rot and little leaf of brinjal caused by Phytoplasma transmitted by leaf hopper [*Hishimonas phycitis* (Distant)] were computed as:

$$\text{Sclerotinia incidence (PDI)} = \frac{\text{Number of infected units (twigs, branches)}}{\text{Total number of units (twigs, branches)}} \times 100$$

$$\text{Phomopsis incidence (PDI)} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits}} \times 100$$

$$\text{Little leaf disease incidence (\%)} = \frac{\text{Number of infected plants in a spot}}{\text{Total number of plants}} \times 100$$

For economic analysis, numbers of chemical sprays, cost of cultivation (/ha), yield (tonnes/ha), net returns (/ha) and incremental cost: benefit ratio (ICBR) were computed and analyzed.

RESULTS AND DISCUSSIONS

Adoption of IPM technology resulted in significant reduction in incidence of major insect pests and diseases while the incidence of these pests was higher in non-IPM plot i.e. farmers' practices fields and untreated control plot (Table 1). Trend and appearance of almost all the pests were similar during both years (2019–21) except minor variations which were mainly due to weather factors.

For managing shoot and fruit borer, farmers of the region installed sex pheromone traps for mass trapping of this nefarious pest from 30 days onwards after transplanting of the crop. Need based spraying of (when economic threshold

Table 1 Pests scenario in IPM, non-IPM and untreated control fields of eggplant

Year	Fruit damage (%)	Jassid/ leaf)	Whitefly/ leaf	Spiders/ leaf	Lady bird beetles/plant	Sclerotinia rot (PDI)	Phomopsis blight (PDI)	Little leaf of brinjal (%)
	IPM fields							
2019–20	9.89	2.59	3.35	5.21	10.55	17.05	8.79	12.5
2020–21	8.79	2.87	3.13	4.59	7.47	1.50	4.5	10.5
Average	9.34	2.73	3.24	4.90	9.01	9.28	6.65	11.5
	Non-IPM fields							
2019–20	24.18	8.36	6.94	1.69	3.17	34.20	66.20	21
2020–21	22.99	6.51	7.24	1.43	2.08	8	13.5	26
Average	23.59	7.44	7.09	1.56	2.63	21.10	39.85	23.50
	Untreated control							
2019–20	48.33	12.67	13.75	8.14	13.25	27.64	21.63	15.50
2020–21	46.75	11.57	13.08	7.89	13.67	12.5	18	33.64
Average	47.54	12.12	13.42	8.02	13.47	20.07	19.82	24.57
SEm (±)	3.73	1.72	1.83	1.47	1.88	1.60	3.56	1.63
LSD (P=0.05)	8.61	3.95	4.19	3.38	4.29	3.58	8.59	3.73

level exceeded 5% of fruit damage), chlorantraniliprole 18.5% SC @0.35 ml/l or emamectin benzoate 5 SG @0.4 g/l or fenpropathrin 30% EC @0.33 ml/litre against BSFB was done. This had resulted in lower fruit damage, i.e. 9.89 and 8.79% during 2019–20 and 2020–21, respectively, as against higher fruit damage registered in FP fields i.e. 24.18 and 22.99% during the same period (Table 1). However, the untreated control plots, maintained at the institute research farm, had maximum fruit damage of 48.33 and 46.75% during the experimental year.

Lowest jassids population 2.7/leaf was noted from the plants grown in IPM plots followed by non-IPM plots (7.44/ leaf) whereas highest population of jassids (12.1/leaf) was recorded from the untreated control plots. Same trend was also observed in whitefly incidence. Based on the two years pooled data, the ascending order of whitefly population per leaf was from the plants of IPM (3.2), non-IPM (7.1) and untreated control (13.4) plots. Severity of Sclerotinia white rot ranged from 8–34.2% with an average of 21.1% during the above period as against 1.5–17.1% in IPM fields with an average of 9.3%. IPM fields suffered less from Phomopsis blight with severity of 8.8% (2019–20) and 4.5% (2020–21). Little leaf of brinjal incidence was minimum (11.5%) in IPM fields followed by non-IPM (23.5%) and maximum incidence of 24.6%was recorded in untreated control plots (Table 1).

Natural enemies: A large build-up of natural enemies, especially predatory spiders and predatory *Coccinellid* beetles population was observed in untreated control and IPM fields. High populations of spiders in IPM fields (5.2

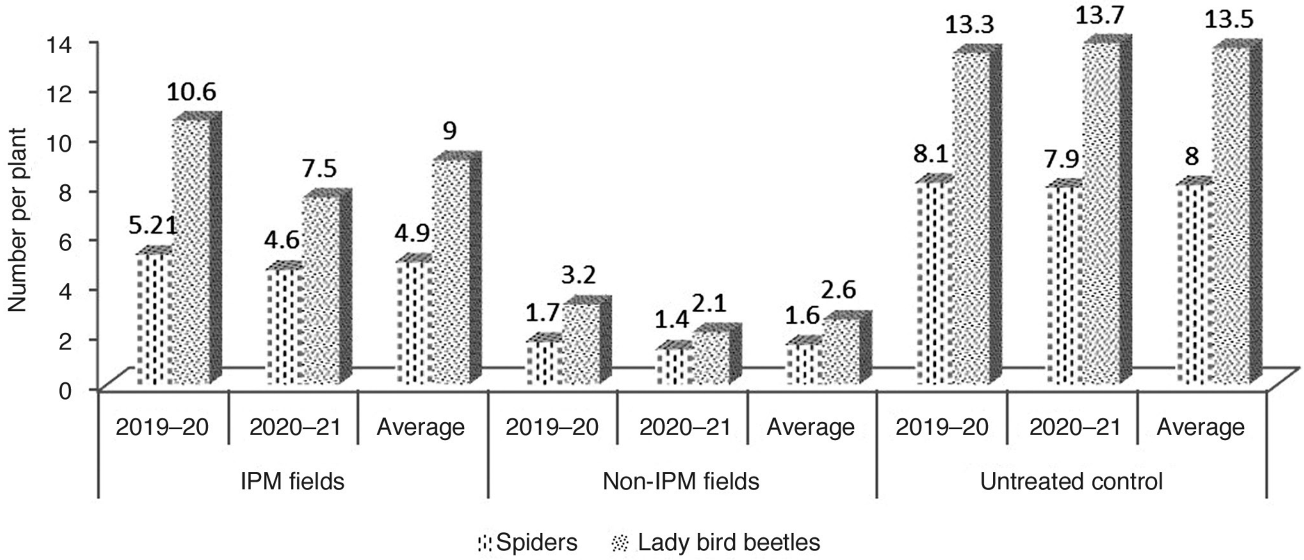

Fig 1 Natural enemies scenario in IPM, non-IPM and untreated control brinjal fields.

and 4.6/plant with an average of 4.9/plant) than non-IPM fields (1.69 and 1.43 per plant with a meagre average of 1.6/plant) were observed during 2019–20 and 2020–21, respectively (Fig 1). Similar trend was also observed with predatory *coccinellid* beetles population. IPM fields harboured higher lady bird beetle population of 10.6 and 7.5/plant during 2019–20 and 2020–21, respectively, than the non-IPM fields i.e. 1.69 and 1.43/plant during the same period. However, untreated control plots conserved maximum predators than the other treatments.

Economic analysis: Mean fruit yields obtained from eggplants were higher i.e. 51.1 and 45.3 t/ha with an average of 48.2 t/ha in IPM fields as compared to farmers' practices fields where it was 39.6 and 33.7 t/ha during 2019–20 and 2020–21, respectively. It was evident that IPM adopted farmers had higher net returns of ₹8.00 and 8.63 lakhs/ha during 2019–20 and 2020–21, respectively, compared to ₹5.41 and 5.58 lakh/ha in case of non-IPM farmers (Table 2). Same trend also reflected in case of incremental benefit:cost (B:C) ratio. IPM farmers registered higher IBCR of 4.61:1 and 4.86:1 during 2019–20 and 2020–21, respectively, whereas non-IPM farmers had relatively lower IBCR of 3.16:1 and 3.24:1 for the same period. However, untreated control plots had the lowest fruit yield of 25.7 and 20.4 t/ha and there by fetched the lowest net return of ₹3.11 and 2.87 lakhs/ha during 2019–20 and 2020–21, respectively. In addition, a mere benefit cost ratio of 2.53:1 and 2.42:1 were noted during 2019–20 in 2020–21 from the untreated control plots.

It is evident that IPM adopted farmers had lowest fruit damage by *L. orbonalis* during both the years. Installation of sex pheromone traps, clipping of infested shoots, spray of neem based product, seedling dip at transplanting and need based application (ETL>5%) of insecticides like chlorantraniliprole or emamectin benzoate or fenpropathrin could prove highly effective against this nefarious pest. Singh *et al.* (2021) reported among their tested molecules, chlorantraniliprole and emamectin benzoate as highly effective and can be recommended as sole application or in rotation for effective management of BSFB (Brinjal Fruit and Shoot Borer). Chlorantraniliprole belongs to anthranilic diamide group interferes insects' ryanodine receptors (Kodandaram *et al.* 2010) whereas emamectin benzoate acts on Glutamate-gated chloride channel (GluCl) of insects as allosteric modulators (IRAC 2017). In paradox, fenpropathrin is an old generic synthetic pyrthroid molecule acts by inhibiting the axonic transmission in the insect nervous system by blocking the Na^+ gates. The diverse mode of action of these three insecticides could be the reason for higher control of BSFB in the region. In contrast, non-IPM farmers of the region often followed the advice of local pesticide dealers and fellow farmers. They spray the same pesticides or same group of insecticides recurrently as they do not have much knowledge about label claim pesticide and their mode of action. Recently, Roy *et al.* (2017) documented that farmers of the region use the same pesticides irrespective of crops grown and they don't have knowledge about label claim. This might be the reason for higher fruit damage even though more numbers of pesticides they applied involving higher expenditure for plant protection. Efficacy of sex pheromone traps for managing BSFB has been confirmed by several authors (Rai *et al.* 2014) and farmers of the region were also convinced as they visualized the trapped adult male in good numbers in the plastic funnel traps.

Alike results were also obtained in case of sucking pests and disease management. IPM farmers had lowest sucking pests, viz. jassids and whiteflies infestation as well as minimum disease infection in their fields compared to non-IPM farmers and untreated control plots. IPM farmers were advised to have need based spray of botanicals like azadirachtin, neonicotinoid; insecticides like thiamethoxam and synthetic pyrethroid like fenproparthrin for managing these sucking pests. Rotation of these insecticides having diverse mode of action was suffice to control the sucking pests of brinjal. Neem based insecticides like azadirachtin have multicide action including antifeedant, oviposition deterrent, lethal, insect growth inhibitors etc. (Kaur *et al.* 2001, Halder and Banik 2013) whereas chloronicotinyl insecticides (thiamethoxam) act on nicotinic acetylcholine receptor (nAChR) competitive modulators (IRAC 2017). Amongst the diseases, two fungal diseases namely Sclerotinia rot and Phomopsis blight were recorded in the region particularly during winter rains and foggy weather. Need based application of carbendazim 50 WP @0.5 g/l for the management of these duo diseases were found effective in reducing the fungal infection and minimizing the yield losses. Non-IPM farmers relied on a number of fungicides (mancozeb, cooper oxychloride, metalaxyl+mancozeb, streptocycline etc.) round the brinjal growing season and finally could not achieve the desired control.

IPM technology, thus, resulted in increased biodiversity. In IPM fields different eco-friendly components like *T. viride*, spraying of azadirachtin, installation of pheromone traps, seedling root dip methods with systemic fungicides and insecticides were found safe to spiders and lady bird beetles. Need based spraying of chemical insecticides during the evening hours could prove less hazardous to non-target organisms in IPM fields than the non-IPM fields. In IPM and untreated control fields all the four species of lady bird beetle, viz. *Coccinella septempunctata* (Linn.), *Menochilus sexmaculatus* (Fabr.), *Brumoides* (=*Brumus*) *suturalis* (Fab.) and *Micraspis discolor* (Fab.) were observed whereas only a few number of *C. septempunctata* and *M. sexmaculatus* were recorded in non-IPM fields (Table 1). Moreover in non-IPM fields around 21-24 rounds of different pesticides and plant growth promoting hormones were sprayed juxtaposing 10 rounds of need based spraying of pesticides in IPM fields. This led to not only the increased cost of cultivation but also detrimental to natural enemies. Halder *et al.* (2020) and Sardana *et al.* (2012) also concluded that neem based integrated schedule was safer to parasitoids and predatory spiders in bottle gourd, bitter gourd, mustard and onion ecosystems. Whalen *et al.* (2016) reported

Table 2 Economic analysis of IPM and non-IPM technologies for eggplant during 2019–21

Parameter	IPM fields			Non-IPM fields			Untreated control		
	2019–20	2020–21	Average	2019–20	2020–21	Average	2019–20	2020–21	Average
Number of sprays	10	10	10	21	24	22.5	Nil	Nil	0
Cost of cultivation (₹)	202960	201960	202460	202960	201960	202460	202960	201960	202460
Cost of plant protection inputs (₹)	18873	21943	20408	47930	46850	47390	Nil	Nil	Nil
Total cost (₹)	221833	223903	222868	250890	249810	250350	202960	201960	202460
Yield (t/ha)	51.1	45.3	48.2	39.6	33.7	36.7	25.7	20.4	23.1
Gross return/income* (₹)	1022000	1087200	1054600	792000	808800	800400	514000	489600	501800
Net return (₹)	800167	863297	831732	541110	558990	550050	311040	287640	299340
Incremental cost benefit ratio	1:4.61	1:4.86	1:4.73	1:3.16	1:3.24	1:3.20	1:2.53	1:2.42	1:2.48

*Average costs of eggplant were ₹2000 and ₹2400 per quintal during 2019–20 and 2020–21, respectively.

chlorantraniliprole 18.5 SC at 0.068 kg a.i./ha in treated plots had no significant differences in total predators population after its application up to three weeks.

IPM adopted farmers had higher marketable fruit yields, maximum net return and benefit cost (B:C) ratio than the non-IPM farmers and untreated control plots. The adopted IPM farmers had applied different IPM inputs including pesticides of diverse mode of action on need based i.e., when the pest incidence crosses economic threshold level. Many of such inputs were low cost and locally available compared to non-IPM farmers who only relied on chemical pesticides which were often unnecessary and unjustified, furthermore, without any appreciable increase in the yield. In untreated control plots where no plant protection measures were given had highest insect pests and diseases incidence leading to lowest marketable fruit yield during both the experimental years (2019–21). Sunitha (2007) reported higher yields in IPM managed bell pepper fields than non-IPM fields. Sardana and Bhat (2017) also reported higher yields in onion seed crop fields of IPM than non-IPM fields.

Therefore, the IPM technology is not only directly environment friendly but also more sustainable *vide* increase in biodiversity. Feedback from IPM farmers also indicated increased knowledge, awareness and adoption of most of the IPM components for eggplant by a majority of the adopted farmers. Adoption of IPM technology enabled the farmers to diagnose plants and to differentiate between the pests and natural enemies and avoidance of the widely prevalent practice of using mixtures of pesticides.

REFERENCES

Halder J and Banik B. 2013. Botanicals in crop protection. *Concepts in Crop Protection*. Susanta Banik (Eds), pp. 335–72, Published by Studium Press (India) Pvt. Ltd., New Delhi.

Halder J, Kushwaha D, Rai A B, Singh A and Singh B. 2017. Potential of entomopathogens and neem oil against two emerging insect pests of vegetables. *Indian Journal of Agricultural Sciences* **87**(2): 220–24.

Halder J, Sardana H R, Pandey M K, Nagendran K and Bhat M N. 2020. Synthesis and validation IPM technology and its economic analysis for bottle gourd (*Lagenaria siceraria*). *Indian Journal of Agricultural Sciences* **90**(2): 341–45.

IRAC. 2017. Mode of Action, Classification Scheme. Issued March 2017, Version 8.2, Insecticide Resistance Action Committee, pp. 1–26.

Kaur J J, Rao D K, Sahgal S S and Seth R K. 2001. Effect of hexane extract of neem seed kernel on development and reproduction behaviour of *Spodoptera litura*. *Annals of Plant Protection Sciences* **9**: 171–78.

Kodandaram M H, Rai A B and Halder J. 2010. Novel insecticides for management of insect pests in vegetable crops: a review. *Vegetable Science* **37**(2): 109–23.

Rai A B, LoganathanM, Halder J, Venkataravanappa V and Naik P S. 2014. Eco-friendly approaches for sustainable management of vegetable pests. IIVR Technical Bulletin No. 53, IIVR, Varanasi, pp. 104.

Roy S, Halder J, Singh N, Rai A B, Prasad R N and Singh B. 2017. Do vegetable growers really follow the scientific plant protection measures? An empirical study from eastern Uttar Pradesh and Bihar. *Indian Journal of Agricultural Sciences* **87**(12): 1668–72.

Sardana H R and Bhat M N. 2017. Farmers' centred approach for area-wide implementation of sustainable IPM technology and economic analysis of onion (*Allium cepa*) during *rabi* season. *Indian Journal of Agricultural Sciences* **87**(1): 83–86.

Singh B K, Pandey R, Singh A K and Dwivedi S V. 2021 Efficacy of certain insecticides against brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee. *Indian Journal of Entomology* **83**. doi:10.5958/0974-8172.2020.00207.2

Sunitha T R. 2007. 'Insect pests of *Capsicum annum* var. *frutescense* and their management'. M Sc thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.

Whalen R A, Herbert D A, Malone S, Kuhar T P, Brewster C C and Reisig D D. 2016. Effects of diamide insecticides on predators in soybean. *Journal of Economic Entomology* 1–6. https://doi:10.1093/jee/tow173