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Integrated pest management for greenhouse cucumber: A validation under north Indian plains

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ABSTRACT

Cucumber is one of the most important greenhouse crops particularly because it can be grown round the year. As many as three crops under sub-tropical conditions do make it economically very profitable. However, due to such intensive production systems, the crop is often severely infested with several pests including the fungal and viral diseases etc. Integrated pest management (IPM) in greenhouses is one of the most important approaches for successful pest control. A study on comparative IPM including the contribution of individual IPM components was conducted for two seasons. Relative efficacy and economics of IPM *vis-à-vis* non-IPM modules were also worked out. In IPM module, the effects of biotic stresses particularly those caused by soil-borne pathogens, were found significantly reduced (19.81%) in comparison to non-IPM module (37.56 %). Apart from reduced pest incidences, economic analysis indicated that the IPM approaches were much superior, as the mean cost-benefit ratio under IPM was 1:3.98 as compared to 1:3.18 with non-IPM treatment. Combination of azadirachtin and agrospray® (0.5%) was the most effective component of IPM for controlling the sucking pests of cucumber under protected cultivation. Of the potential biological control agents tested in this study, combination of *Pseudomonas fluorescens* and *Trichoderma harzianum,* was most consistent and effective in controlling disease and nematode incidences. These results have the potential for field use under greenhouse conditions similar to north Indian sub-tropical plains.

Key words: Cucumber, greenhouse, integrated pest management, mites, *Trichoderma*, *Pseudomonas*, azadirachtin, *Meloidogyne incognita*.

INTRODUCTION

Parthenocarpic greenhouse cucumber (*Cucumis sativus* L.) has tremendous yield potential under subtropical conditions like north-Indian plains it can be cultivated during all the three seasons. However, biotic stresses especially sucking arthropods and soil-borne pathogens limit its potential thereby compelling farmers for adopting injudicious levels of pesticide application. Under such conditions, good agricultural practices (GAP) coupled with integrated pest management (IPM) are advocated as comprehensive solutions (Sabir *et al*., 13). Eco-friendly management measures including the biological control options particularly for soil-borne pathogens such as the use of fungal bioagent, *Trichoderma harzianum* and bacterial bioagent, *Pseudomonas fluorescens* are very effective components of IPM (Sabir *et al*., 14) and a lot of extensive studies against a wide range of pathogens have been carried out (Roberts *et al*., 12). Recently, biorational based management of pests have been demonstrated successfully under greenhouse conditions (Smith and Krischik, 17). Similarly, the use of azadirachtin and in combination with eco-friendly use of oils has been demonstrated for the management of sucking pests in cucumber (Deka *et al*., 3). However, not many concerted studies have been taken on integrated management of pests in greenhouse vegetables. Therefore the investigation on IPM in greenhouse cucumber was carried out.

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MATERIALS AND METHODS

The trials were conducted in the greenhouse of Centre for Protected Cultivation Technology (CPCT), IARI, New Delhi for two seasons during 2009-10 with two treatment modules (IPM and Non-IPM) for managing pests of cucumber cv. Satis in plot size of 6 × 1 sq.m. for each replicate in a randomized block design (RBD) with 15 replications with spacing at 30 cm × 30 cm. A border row of crop was planted between each replicate. Details of the treatment modules are mentioned in Table 1. Recommended package of practices were followed for both the treatments including. GAP protocols for IPM treatments. Preventive measures were taken for both the treatments from sucking pests to keep the pest below Economic Threshold Level (ETL) by treating seeds with imidacloprid @ 10 g/ kg at the time of sowing. The chemicals used under non-IPM were those used by common farmers.

The bioagents, collected from NCIPM, New Delhi, were incorporated in the greenhouse soil in which seedlings were transplanted 15 days after treatment.

Table 1. Application of different treatments under IPM and non-IPM modules.

Details	IPM	Non IPM
Seed treatment	Imidacloprid @ 2 ml/ kg seed	Imidacloprid @ 2 ml/ kg seed
	Soil solarization	Soil solarization
Soil drenching	Carbosulfan@ 1g/l (Marshal®)	Carbosulfan@ 1g/l (Marshal)
Soil treatment	FYM 1 kg/ sq.m +	FYM 1 kg/ sq.m.
	T. harzianum (10 g/ sq.m) +	
	P. fluorescens (10 ml/ sq.m)	
	P. fluorescens (20 ml/ sq.m)	
	T. harzianum (20 g/ sq.m)	
Spray details	Agricultural spray oil (Agrospray®) @ 1%	Imidacloprid @ 0.25g/l (Admire®)
	Azadirachtin @ 1%	Ethion @ 1 ml/l (Ehiol®)
	Azadirachtin @ 1%	Spiromesifen @ 1 ml/ 1.5 l (Oberon®)
	Mixture of Agrospray® @1% + azadirachtin @ 1%	Spiromesifen @ 1 ml/ 1.5 l (Oberon®)
		Ethion @ 1 ml/l (Ehiol®)
		Ethion @ 1 ml/l (Ehiol)
		Spiromesifen @ 1 ml/ 1.5 l (Oberon®)
		Spiromesifen @ 1 ml/ 1.5 l (Oberon®)

Bioagents conc. applied: *T. harzianum* (2×10^9 cfu) and *P. fluorescens* (1×10^{12} cells)

Second (*P. fluorescens*) and third (*T. harzianum*) application of bioagents was applied 15 days and 30 days after transplanting, respectively. Soils were sampled (100 g) one month after application of the bioagents and at the end of crop season to determine the multiplication of bioagents by adopting serial dilution technique. Spraying was done on infested leaves, two weeks after natural pest infestation based on pest load on the crop when the population exceeded recommended treatment thresholds of 5 mites/ leaf, while it is approximately 25-30 mites/leaf (John and Belisle, 6) for open field cultivation.

Pest data were recorded from five plants/ replication and converted to percent infestation. Methodology of Rachana *et al.* (11) was followed in order to record the incidence of mites. At the time of bed preparation and termination of the experiment, soil samples were collected from the rhizosphere region, 5-6 cm away and at a depth of 8-10 cm from the root base of the plant for recording nematodes and other soil-borne pathogens. Initial population of J2 (second stage juvenile) of nematodes *Meloidogyne incognita* in soil was recorded using Cobb's method of decanting and sieving followed by the modified Baermann`s technique for nematode extraction from soil samples before planting, while root gall index was recorded for the level of root knot infestation. The final nematode (J2) count in the soil and the root gall index were recorded on the date of termination of the experiment. The root galls induced by *M. incognita* was indexed on a scale of 0-5 (0 = no gall, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, 5 = > 100 galls per plant root).

The net profit and cost:benefit ratio was worked out both for IPM and non-IPM modules. Fruits were harvested from 5 plants/ replication and extrapolated for cumulative yield/plant and total area based on fruit weight and numbers. Quality attributes were determined by taking composite fruit samples from each treatment. The variable costs of cucumber production for both the treatments were calculated. The economics of the crop was calculated using depreciation of 10% per annum prevailing bank rate of interest by taking the life of the basic steel structures as 20 years. The cost of production was calculated by taking into account the operational cost and fixed cost of the greenhouse separately.

The effectiveness of major IPM components was also, determined individually. Two experiments were separately set to determine the efficacy of bioagents and biopesticides in the adjacent plot of the same greenhouse. The experiments were laid out in RBD with four treatments including control and replicated five times. The plot size was 1 × 3 sq. m. Two-spotted spider mite was the major pest recorded. The biorationals included agricultural spray oils, azadirachtin and combination of both at 1% each along

Table 2. Effect of biotic stress on cucumber in IPM and non IPM plots.

Character	IPM	Non IPM
Insect pests /plant	0.54	1.2
Use of chemicals ml/plant	0.45	1.6
Un-marketable fruit (%)	2.30 ± 0.30	13.75 ± 1.63
Mites/leaf	5.80 ± 0.80	10.50 ± 0.50
Thrips/leaf	0.59 ± 0.11	1.15 ± 0.15
Insect affected plant (%)	7.30 ± 0.89	13.75 ± 1.63
Damping off (%)	8.61 ± 1.00	17.87 ± 2.00
Fusarium wilt (%)	9.26 ± 0.26	15.77 ± 2.31
Disease affected plant (%)	8.66 ± 1.53	18.75 ± 2.00
Root knot nematode infestation (%)	3.85 ± 0.93	5.06 ± 1.00
Total affected plant (%)	19.81 ± 0.80	37.56 ± 2.30

with control. Two sprays were applied at an interval of 10 days. The observations were recorded following the methodology of Rachana *et al.* (11) for determining the effectiveness of *T. harzianum*, *P. fluorescens* and their combinations (20 g/ sq.m.). The data obtained were converted by transformations and subjected to statistical analysis (Gomez and Gomez, 5).

RESULTS AND DISCUSSION

Results showed that the IPM module effectively reduced pest population from initial to last stages of the crops compared to non-IPM. The average mites and thrips population was reduced from 5.80 and 0.59 per leaf as compared to 10.50 and 1.15 in IPM and non-IPM, respectively. The average disease incidence (damping off and fusarium wilt) was 8.61 and 9.26% in IPM as compared to 17.87 and 15.77% in non-IPM. Likewise, nematode infestation was also less in IPM. Yield and fruit quality were quantified and compared in which unmarketable fruit (%) was 2.3 in IPM as compared to 13.75 in non-IPM. Total affected plant (disease, insect and nematode) recorded was 19.81% in IPM as compared to 37.56% in non-IPM (Table 2). Similar findings were also reported in different crops where insect pest incidences were less in IPM in comparison to non-IPM module (Anon, 1).

Economic analysis indicated that the IPM treatment was superior to the non-IPM treatments. The mean cost-benefit ratio in IPM was 1:3.98 with lesser environmental risk involvement as compared to 1:3.18 with non-IPM treatment (Table 3). The reduction in the quantity of pesticides used in IPM, drastically curtailed the overhead expenditure on crop protection. Average costs of cucumber production in a 500 sq.m. greenhouse was calculated to be Rs. 37,652.50 and Rs. 38,497.50 for IPM and non-IPM modules, respectively. The net profit obtained for IPM and non IPM modules were estimated to be Rs. 112, 347.5 and Rs. 84,002.5, and breakeven costs were calculated to be Rs. 12.5 and Rs. 15.71 per kg, while earlier they worked out to be Rs. 8.71 per kg and 1:1.29, respectively (Singh *et al.*, 16). Thus, there was a positive impact of IPM practices on cucumber production under protected cultivation as suitable for the development of a sustainable and environment friendly pest management system.

Analysis of variance showed that biopesticides had significant effect on the mortality of *Tetranychus urticae*, proving that the application of these biopesticides on an average was more effective in reducing the mite population as compared to control (Table 4). The combination of agricultural spray oil + azadirachtin proved most effective throughout the treatment period followed by agricultural spray oil and azadirachtin alone. Deka *et al.* (3) also reported effective control of two-spotted spider mite, *T. urticae* on greenhouse cucumber by combined spraying of agricultural spray oil and azadirachtin (0.5%). All the biopesticides showed slightly reduced efficacy after three days of treatment, but were significantly superior to untreated control (Table 4).

Plot yield data also showed that highest yield was obtained from the combined treatment of agricultural spray oil + azadirachtin (5.30 kg/ sq.m.) which was at par with the treatment of agricultural spray oil alone (5.16 kg/ sq.m.). Petroleum oil has been shown to have a synergistic effect and is less harmful for the environment and is recommended for use in IPM programmes (Khyami and Ateyyat, 7). It does not increase pesticide resistance and has no residual killing action, but the coating it makes on leaves and stems can protect against transmission of some plant viruses and fungi. Treatment of azadirachtin was observed to be least effective in this experiment.

Table 3. Yield, C: B ratio and net profit in IPM and non IPM in greenhouse cucumber (in Rs./500 m^2).

S. No.	Operations	Unit	IPM	Non-IPM
A.	Fixed cost/ Infrastructure			
	1. Depreciation on fixed cost + interest on invested money	@ Rs. 500 /m^2 (considering 3 cucumber crops/year)	23,500	23,500
	2. Machinery		500.00	500.00
B	Operational cost			
	1. Tractor	Rs. 375/h 1.5 h	562.50	562.50
	2. Para plough	Rs. 40/h 2 h	80.00	80.00
	3. Rotavator	Rs. 100/h 0.75 h	75.00	75.00
	4. Labour (for all operations)	Rs. 150/persons/day	4,500.00	5,850.00
	5. fertilizers/FYM	For 500 m^2 area	350.00	350.00
	6. Soil treatment	Carbosulfon @ 1g/l (100 l)	100.00	100.00
	7. Chemicals	For 500 m^2 area	--	1,245.00
	8. Bioagent/biopesticides	For 500 m^2 area	1,750.00	--
	9. Seed/seedling cost	Seedling (1000 Nos.) at Rs. 6.00	6,000.00	6,000.00
	12. Plastic ropes		235.00	235.00
C	Total cost of production	For 500 m^2 area	37,652.50	38,497.50
D	Total production (q)		30.0	24.5
E	Break Even Cost		12.5	15.71
F	1. Gross income		150,000	122,500
	2. Net profit		112,347.5	84,002.5
	3. Cost-benefit ratio		1:3.98	1:3.18

Gross income = Yield x Price; Net income = Gross income -- total cost of cultivation; Cost: benefit ratio = Gross income/ Cost of cultivation; Total number of insecticide spraying--- 4 times in IPM, and 8 times in Non IPM; Average selling price of cucumber @ Rs.50 /kg

Table 4. Effect of biopesticides on the incidence of mites in greenhouse.

Treatment	Conc. (%)	Mortality (%) of mite population after treatment (days)					Yield (kg/m^2)
		1	2	3	7	10	
Agricultural spray oil (Servo Agrospray®)	1	51.50[a] (45.86)*	51.40[b] (45.80)	48.40[b] (44.08)	29.50[b] (32.90)	18.72[b] (24.88)	5.16[ab]
Azadirachtin	1	27.80[b] (31.82)	27.80[c] (31.82)	23.20[c] (28.79)	24.36[b] (29.53)	2.48[c] (8.91)	3.14[c]
Agricultural spray oil+ azadirachtin	1	53.60[a] (47.06)	82.67[a] (65.35)	73.84[a] (59.12)	48.46[a] (44.08)	25.46[a] (30.26)	5.30[a]
Control	0	2.86[c] (9.63)	2.53[d] (9.10)	1.80[d] (7.71)	11.12[c] (19.46)	2.40[c] (8.91)	3.38[b]
$CD_{0.05}$		6.54	14.12	11.80	4.79	2.51	1.86

*Figures in parentheses are Arcsine transformed values. In a column, 'means' followed by a common letter do not differ significantly at P = 0.05 by Duncan`s Multiple Range test.

Better control might be achieved by increasing its concentration. Cote *et al.* (2) reported that neem products may be a useful part of IPM programmes; however, its short residual toxicity may not suppress large population of mite.

The major soil-borne diseases recorded were damping off caused by *Pythium ultimum*, fusarium wilt and root knot nematode (*M. incognita*). Analysis of variance showed that bioagent application had significant effect on incidence of these diseases compared to control. The bioagents, *P. fluorescens* and *T. harzianum* were found to improve the cucumber plant growth characters and reduce the population of soil-borne pathogens compared to the untreated control (Table 5). Combined treatment of bioagents inflicted minimum diseases throughout the period as compared to single treatments. Highest yield was obtained from the combined treatment, (5.72 kg/ sq. m.), which was at par with the treatment of *T. harzianum* (4.74 kg/ m^2). In all the treatments there was a significant increase in the bioagent population by the end of the crop season (Table 5). Similar results have been shown by several other studies apparently due to antagonistic effects (Meyer and Roberts, 8; Roberts *et al.*, 12). The possible mechanism involved in *Trichoderma* antagonism had been studied intensively in terms of antibiotic and enzyme production as hyphal interactions (Elad *et al.*, 4). Previous studies done by Robert *et al.* (12) also reported that *Trichoderma* provided the most effective suppression of damping off in greenhouse bioassays. A mechanism of induced resistance and evidence for defense responses, induced by *Trichoderma harzianum* has been reported (Yedidia *et al.*, 18).

Table 5. Comparative efficacy of different bioagents on incidence of diseases in protected cultivation.

Bioagent	Disease incidence (%)						Final bioagent population (cfu/ g soil)	Plot yield (kg/ m^2)
	Damping off (*Pythium ultimum*)			Wilting (*Fusarium oxysporum*)				
	30 DAP†	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP		
Trichoderma harzianum (Th)	2.02^a (8.53)	11.66^b (19.91)	17.52^b (24.73)	4.8^a (12.66)	12.92 (21.05)	15.12 ^{b} (22.87)	3.4 × 10^9	4.74^{ab}
Pseudomonas fluorescens (Pf)	2.37^a (8.72)	22.20^c (28.11)	19.26^b (25.99)	11.18^b (19.46)	20.45 (26.85)	14.94^b (22.71)	2.1 × 10^{13}	3.35^b
(Th) + (Pf) @ 10 g or ml/ m^2	1.64^a (7.27)	4.8^a (12.66)	7.86^a (16.22)	1.97^a (7.92)	11.33 (19.64)	7.86^a (16.22)	2.7 × 10^{9*} 9.3 × 10^{12**}	5.72^a
Control	10.62^b (19.00)	31.6^d (34.20)	26.2^c (30.79)	19.84^c (26.42)	24.6 (29.73)	22.06^c (27.97)	--	3.14^b
$CD_{0.05}$	3.93	4.25	4.59	5.08	NS	4.82		1.62

†Data based on mean of five replicates; **Trichoderma harzianum* population; ***Pseudomonas fluorescens* population; Figures in parentheses are Arc Sine transformed values; In a column, 'means' followed by a common letter do not differ significantly (P = 0.05) as per Duncan`s Multiple Range test.

Table 6. Effect of *Trichoderma harzianum, Pseudomonas fluorescens* and combination of both on root knot nematode on cucumber.

Treatment	Initial nematode population (per cc soil)	No. of egg mass/ g root	Final nematode population in soil/ml	Root knot nematode gall index after 60 days	Plot yield (kg/ m^2)
Trichoderma harzianum (Th)	7.2	9^a	6.8^b	4.6^a	3.4^a
Pseudomonas fluorescens (Pf)	7	6^b	6.6^b	4.4^b	4.8^a
(Th) + (Pf) @ 10 g or ml/ m^2 each	8	5^b	4.2^c	3.2^c	5.2^a
Control	8.6	9.6^a	9.2^a	5.6^a	3^b
$CD_{0.05}$		3.37	2.00	1.14	1.96

The bioagents, *T. harzianum, P. fluorescens* and their combination were found to significantly reduce the population of *M. incognita* and improve the yields compared to the untreated control (Table 6). The number of egg masses/g root, number of galls/ plant and final nematode population in the soil was observed to be minimum in the combined treatment of bioagents at 5, 3.2 and 4.2, respectively. Earlier, Muthulakshmi *et al*. (9) also reported that combined soil application of *P. fluorescens* (@ 10 g/plant) + *T. viride* (@ 10 g/ plant) was effective to check the root knot nematode as also the individual treatment of these bioagents. Sharma and Pandey (15) reported that *Trichoderma* not only proved to parasitize nematodes but also helped in tolerance to stress conditions by enhanced root development. Application of *P. fluorescens* with other management practices has been proved more effective in many crops for different nematodes (Oostendrop and Sikora, 10).

In India, *T. urticae*, *P. ultimum* and *M. incognita* are serious pests under protected cultivation especially in cucumber compelling farmers for intensive insecticide applications which may be a cause of development of resistance to newer insecticides. This creates the main problem in formulating an IPM programme. Combination of insecticides and bioagents are now commonly used to control multiple and resistant insect pests. The use of potentiating mixtures is a practical strategy to combat insecticide resistance. This study has shown that the use of combination of azadirachtin and agricultural spray oil was the most effective component of IPM for controlling the sucking pest of cucumber. Of the potential bioagents tested in this study, the combined treatment of *P. fluorescens* and *T. harzianum*, most consistently and effectively controlled disease and nematode incidence compared to other treatments.

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