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Module analysis for insect pest management of khasi mandarin (*Citrus reticulata* Blanco) under climatic conditions of north-eastern India

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Abstract
Citrus is one of the most prominent commercial fruits of North-Eastern India. Among different Citrus species, the Khasi mandarin (*Citrus reticulata* Blanco) produced in this region is famous for its superior quality. Cultivation of Khasi mandarin is plagued with various problems including high incidence of insect pests, which can cause serious quantitative and qualitative losses. Efforts were made to evaluate three modules *viz.*, Bio-intensive IPM module (BIPM), IPM module and Farmers' Practice (FP) based on the earlier field studies for the management of insect pest in Khasi mandarin under the climatic conditions of North-Eastern India. Among the three management modules, IPM proved to be the promising one with better net returns followed by BIPM. This study is targeted to provide Khasi mandarin growers with a sustainable IPM module which may be used as better knowledge kit for higher production.

Keywords: IPM, bio-intensive IPM, module, khasi mandarin, north eastern region

1. Introduction
Citrus is one of the largest fruit industries in the world. In India, it holds a prominent place among the major commercial fruits covering an area of about 10.42 lakh ha with an annual production of 100.90 lakh tonnes and productivity of 9.7 t/ha [1]. India ranks fourth among top citrus producing countries contributing 10% of the world's production. The North Eastern region of India stretches from $21^{0}57'$N to $29^{0}28'$ N and from 89040´ E to 97025´ E is considered as one of the natural home of citrus. Citrus fruits, particularly Khasi mandarin (*Citrus reticulata*), Assam lemon (*Citrus limon*), Rough lemon (*Citrus jambhiri*) and Pummelo (*C. grandis*) are of the major commercial horticultural crops grown widely in the North Eastern region. The Khasi mandarin produced in this region is famous for its superior quality in respect of its flavour, juice content, soluble sugar and acidity ratio. Citrus cultivation in India is plagued with various problems including higher incidence of insect and mite pests, which can cause serious quantitative and qualitative losses. In India, 250 species of insects and mites have been reported infesting different species of citrus [2]. About 12 species of major insects and mite pests and many species of nematodes have been recorded in the Khasi mandarin ecosystem of North Eastern India [3]. Citrus decline has been observed in this belt from severe to mild form and insect pests are reported to play a major role in decline in North Eastern region [4]. Trunk borer (*Anoplophora versteegi*), bark eating caterpillar (*Inderbela quadrinotata*), citrus butterfly (*Papilio* spp.), leaf miner (*Phyllocnistis citrella*), blackfly (*Aleurocanthus woglumi*), whitefly (*Dialeurodes citri*), psylla (*Diaphorina citri*), fruit fly (*Dacus dorsalis*) etc. are the major pests that cause severe damage to the Khasi mandarin orchards. The citrus trunk borer is the most destructive pest of citrus in the entire North Eastern region of India [5, 6]; and responsible for the citrus decline in this region.
IPM is a holistic approach of crop protection based on the integration of multiple strategies viz. cultural, physical, mechanical, biological, botanical and chemical control. Introduction of IPM practices constitutes an essential tool for achieving sustainable development. It is the dominant paradigm that guides most aspects of current research in and implementation of insect pest management. Over the year IPM underwent different changes, the concept of Bio-intensive Integrated Pest Management (BIPM) is more in line with the original ideas of integrated pest management which seeks a natural balance in the ecosystem. The pest management programme where natural enemies of the crop pests form the core component is

Designated as BIPM. It is the recent trend to reduce the pesticide pressure. It refers to the more dynamic and ecologically informed approach to IPM that considers the farm as a vital part of an agro-ecosystem [7]. Citrus trees are long-lived and the agro-ecosystem is not disrupted by regular ploughing or planting. Properly developed IPM package will serve as a ready reference for farmers in adopting sustainable plant protection strategies. Thus, in view of sustaining productivity of Khasi mandarin with minimal adverse effects on the environment, there is an imperative need to develop and evaluate various IPM strategies. Even though, certain efforts are made in this direction, location specific studies are the need of the hour. Therefore, the present investigation was aimed to develop IPM module based on the earlier field studies from this region and were evaluated on management of major insect pests of Khasi mandarin. Three modules viz., Bio-intensive IPM module, IPM module, Farmers' Practice (FP) were tested for the management of major insect pests, mites and nematodes of this region. Farmers' management practices include indigenous traditional knowledge (ITK) and application of pesticides only.

2. Materials and Methods

The trial was conducted in the 10-15 years old farmers' orchard of Tinsukia and Dibrugarh districts of Assam during 2013-14 and 2014-15. The trial has been laid out in randomized block design and replicated four times. The different treatments were applied according to the programmed schedule mentioned below. Plants were raised according to the recommended package of practices, except the plant protection measures. The data were recorded on incidence of pest population, incidence of natural enemies and extent of damage. Incidence of Trunk borer and Bark eating caterpillar were observed in the tree trunk and recorded at fortnightly interval for the whole year. Likewise, total leaves and number of leaves infested by lemon butterfly, leaf miner, psylla, aphid, looper and mealy bug on each twig were recorded. Incidence of major diseases like *Phytophthora* root rot and Scab were also recorded. Nematode population in soil and root were recorded once in a six months. The natural enemies of the insect pests were also monitored and documented. The yield from each module was recorded and calculated in the form of B: C ratio to know the impact of the test modules on productivity and compared for the economic validation of the effective module. The mean values of insect pest incidence, fruit yield and economics of each location were treated as replicates and the overall mean of four locations were recorded. Data recorded were subjected to ANOVA test and the analysis of variance was done at 0.05%.

The management practices adopted in different modules are mentioned below

BIPM

1. Raking or ploughing the soil and application of *Beaveria bassiana* at the rate of 5 kg/ha and *Metarrhizium anisopliae* at the rate of 5 kg/ha to the soil during Mar.-Apr. for mealy bugs and fruit flies, respectively.
2. Application of *Verticillium leccani* or *Beaveria bassiana* at the rate of 0.5% twice at fortnightly interval during Feb.- March, Jun.- Jul. and Sept.- Oct. for aphids, black flies, leaf miners, scales and psylla. Spraying of Neem oil at the rate of 2 % during new flush emergence.
3. Application of *Paecilomyces lilacinus* fungal infected rice grain 30g/tree at the rate of $2X10^7$ spores twice in a year for controlling citrus nematodes.
4. Application of Bordeaux paste on the tree trunk up to 1m from the ground level with gum during Mar.-Apr. and Sept.-Oct. Insert kerosene/Petrol soaked cotton wads into the hole followed by closing the exit hole with mud for management of trunk borer and bark eating caterpillar.

IPM

1. **C**ommon cultural practices - Summer deep ploughing, pruning of affected shoots, destruction of ant colonies, destruction of rotten and dropped fruits, mechanical shaking of plants (Apr. to Aug.), and hand picking and destruction of citrus butterfly larvae.
2. Installation of Light traps (wave length of 550 nm with exit option for natural enemies of smaller size) at the rate of 1 trap/acre, yellow sticky trap at 10 no./ha for soft bodied insects and pheromone trap at 4-5/acre for fruit fly.
3. Smearing of the tree trunk up to 1m from the ground level by the mixture of 50 ml dimethoate 30 EC + 2 kg lime in 10 litres of water along with gum during Feb.-Mar. Insert kerosene/petrol socked cotton in trunk borer infested hole and plaster the hole with the help of cowdung-soil mud mixture.
4. Spraying of NSKE 4% during new flush emergence, under heavy infestation spraying of dimethoate 30 EC @ 2 ml/l or quinalphos @ 2 ml/l (need based).
5. Application of *Paecilomyces lilacinus* fungal infected rice grain 30g/tree at $2X10^7$ spores twice in a year for controlling citrus nematodes.

Framers Practice (FP)

1. Spraying of monocrotophos 36 SL @ 1.5 ml/l or chlorpyriphos 20 EC @ 2 ml/l or dimethoate 30 EC @ 2 ml/l during Mar.- Aug. at 15 days interval.
2. ITK (Paddy straw is tied at a height of 1m around the tree trunk during Mar. – Apr. to prevent insect from crawling upward)

Control

1. A control module with no inputs either chemical or non-chemical

3. Results and Discussion

The BIPM and the IPM modules recorded significantly (Table 1) lower pest population with significant results compared to farmers' practice. The highest insect pests' damage was observed in the untreated control followed by farmers' practice. Among the three management modules, IPM proved to be the most effective and economic exhibiting significantly minimum percent infestation followed by BIPM module. The significantly higher marketable yield was also observed in IPM followed by BIPM (Table 2). A field view of the experimental plot is shown in Fig.1.

Fig 1: Field view of the Experimental Plot

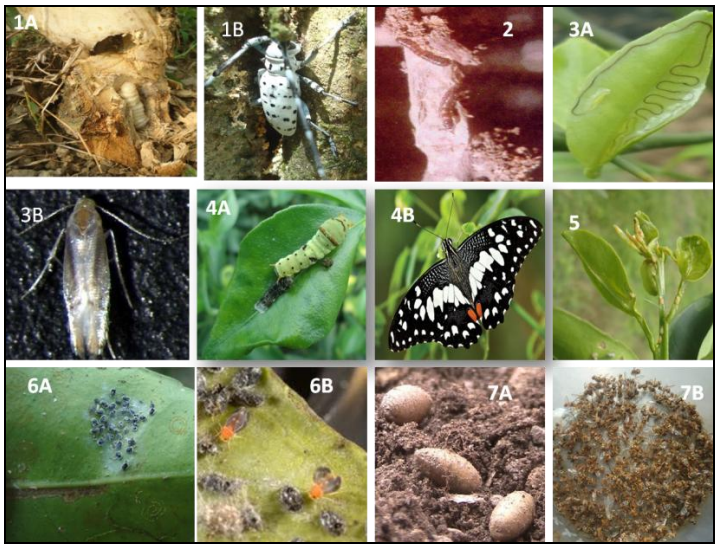

Fig 2: Major insect pests of Khasi mandarin - 1A,1B-Trunk borer larva and adult, 2- Bark eating caterpillar larvae, 3A,3B-Leaf miner larvae and adult, 4A,4B- Lemon butterfly larva and adult, 5- Citrus psylla nymphs and adults, 6A,6B- Blackfly nymphs and adults, 7A,7B- Fruitflies maggots and adults

Table 1: Effect of IPM modules against major insect pests, nematodes and diseases of Khasi mandarin

Treatments	% Reduction of insect pest, nematode and disease incidence over control* (Pooled data of 2013-14 and 2014-15)									
	Trunk borer	**Bark eating caterpillar**	**Leaf miner**	**Lemon butterfly**	**Citrus psylla**	**Citrus looper**	**Mealy bug**	**Scab**	***Phytophthora* root rot**	**Citrus nematode**
BIPM	51.00^{b} (45.57)	72.00^{a} (58.05)	38.00^{b} (38.06)	50.70^{b} (45.40)	70.70^{a} (57.23)	52.00^{b} (46.15)	78.50^{a} (62.38)	36.60^{b} 37.23)	40.50^{b} (39.52)	78.42^{b} (62.32)
IPM	56.00^{a} (48.45)	69.60^{a} (56.54)	70.70^{a} (57.29)	63.60^{a} (52.89)	74.80^{a} (59.87)	58.00^{a} (49.60)	80.70^{a} (63.94)	52.60^{a} (46.49)	46.30^{a} (33.46)	86.47^{a} (68.42)
Farmers Practice (FP)	39.60^{c} (39.00)	50.80^{b} (45.46)	30.50^{c} (33.52)	54.00^{c} (47.29)	40.50^{b} (39.52)	35.80^{c} (36.75)	50.30^{b} (45.17)	30.28^{c} (33.39)	30.40^{c} (42.88)	20.80^{c} (27.13)
Control	1.60^{d} (7.27)	1.30^{c} (6.55)	3.00^{d} (9.97)	3.20^{d} (10.30)	2.00^{c} (8.13)	3.60^{d} (10.94)	2.40^{c} (8.91)	1.52^{d} (7.08)	2.45^{d} (9.01)	1.30^{d} (6.55)
SE± (m)	1.32	0.74	0.78	1.28	2.12	2.18	2.34	1.42	1.86	2.27
CD at 5%	4.32	2.51	2.54	3.42	5.82	5.60	6.32	3.65	4.82	5.75

P= 0.05; * Mean of four replications; 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.

About a dozen of insect pest attack the crop regularly right from the nursery stage to the harvest with cognizable damage (Fig.2). The results obtained on fortnightly observation basis with respect to insect pests and nematode population recorded very severe incidence of trunk borer, *Anoplophora versteegi* (4.40% to 48.65%), bark eating caterpillar, *Inderbela quadrinotata* (10.80 - 43.76%), citrus leaf miner, *Phyllocnistis citrella* (4.00% to 49.27%), citrus butterfly, *Papilio* spp. (3.32% to 27.89%), psylla, *Diaphorina citri* (8.5-12.5%), blackfly, *Aleurocanthus woglumi* (4.50 – 28.64%), whitefly, *Dialeurodes Citri* (5.7-10.6%), mites, *Eutetranychus orientalis* (10.4-13.5), fruit fly, *Dacus dorsalis* (6.5-24.5%), and citrus aphid, *Toxoptera aurantii* (5.0-8.5%), in the experimental plot. Two minor pest, citrus looper, *Anacamptodes fragilaria*, (8.6-17.5%), and citrus mealy bug, *Planococcus citri* (5.8-14.8%) were also observed in substantial numbers infesting young leaves which can be considered to be a major pest. The present findings on the abundance of insect-pest associated with citrus ecosystem were in close conformity with the report of [8]. Six species of plant parasitic nematodes viz. *Tylenchulus semipenetrans*, *Helicotylenchus* sp., *Meloidogyne* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., and *Hoplolaimus* sp. was observed to be associated with Khasi mandarin plants. Similarly, [9] also reported these nematode species from Tinsukia district of Assam. Among these, the citrus nematode, *T. semipenetrans*

was found to be the most dominant, important and serious nematode pest that parasitize citrus with frequency of occurrence 70% and population ranging from 12 - 350 nematodes per 200g of soil. This nematode is reported to be present in most citrus orchards and in all soil types of India. The application of *P. lilacinus* infected grain, which was one of the most important component of IPM and BIPM module is found to be effective in reducing citrus nematode, *T. semipenetrans* population in Khasi mandarin plants. The results are in close agreement with [10, 11] who reported the effectiveness of nematophagous fungus *P. lilacinus* infected grain for bio-control of citrus nematode, *Tylenchulus semipenetrans*.

The data presented in Table 1 revealed that there was a significantly lower pest population in all the modules as compared to untreated control in periodical observations. Trunk borer is the most devastating pest of the Khasi mandarin of this region and very difficult to control due to its feeding behaviour and prolonged life cycle. The IPM module has most effectively reduced the trunk borer population than other modules. The best result for management of trunk borer was achieved in the IPM module through the treatment by inserting a cotton swab soaked in petrol or dimethoate 30 EC inside the trunk borer hole and then sealing of hole with cowdung or mud. Similarly, [12, 13] reported this treatment as the best treatment for trunk borer management.

Economic effectiveness of various pest management modules showed an increase in marketable yield over untreated check. The IPM plots registered a higher mean yield of 131.78 kg/tree with a cost: benefit ratio of 1: 3.95 compared with 97.67 kg/tree with a cost: benefit ratio of 1:1.95 in Farmer's Practice. The results are also in close agreement with [14] who reported that IPM module was the most effective in controlling shallot pests and diseases with a higher cost: benefit ratio in comparison to farmer's approach in Tamil Nadu.

Table 2: Effect of IPM modules on yield of Khasi mandarin (Pooled data of 2013-14 and 2014-15)

Treatments	Fruits/tree	Yield (kg/tree)	% increase in yield over control	B:C ratio
BIPM	760.60	104.75	173.35	3.10
IPM	936.25	131.78	243.89	3.95
Framers Practice (FP)	695.25	97.67	154.87	1.95
Control	357.10	38.32	-	

The Bio-intensive IPM module holds a key role in reducing pest damage without causing ecological disturbance. The BIPM plots registered higher natural enemy population compared to farmers' practice. Two coccinellids and one spider was found in every two twigs in BIPM plots compared to none in FP plots, indicating the congenial conditions provided by BIPM treatments for the augmentation of the natural enemies. The major predators were recorded as spiders, ladybird beetles, long horned grasshoppers, common green lacewing, earwigs, etc.

The beneficial effects of applying biocontrol agents to citrus orchards persisted for several years. Benefits achieved by application of the bio agents in BIPM module may carry long term effect but the optimum effect is observed sometime after its applications. However it was observed that the IPM module is more effective than BIPM in the initial period. The experiment showed that BIPM was also effective as effects of bio control agents were long lasting but the long term analysis and further research is required in this aspect. It is generally assumed by growers that pesticides are cheap. This is because of the benefits from pesticide use are based on the direct crop returns. Indirect costs such as environmental pollution and human health problems are not included in the pesticides' price and are usually paid by the society [15, 16]. If these costs are included in the comparison between chemical and biological control, the latter turns out to be the more economical. The research was targeted to provide the citrus growers with a sustainable module which may be used as a better knowledge kit and to assist them in higher production of the Khasi mandarin of North Eastern region.

4. Conclusion

Based on the results it can be concluded that IPM treatment would not only reduce the incidence of pests and diseases in Khasi mandarin but also improves the quality of marketable fruits. The treatment of IPM registered a higher mean yield of 131.78 kg/tree with a cost: benefit ratio of 1: 3.95 compared with 97.67 kg/tree with a cost: benefit ratio of 1:1.95 in Farmer's Practice. Application of synthetic insecticides in Khasi mandarin can be reduced to a minimum possible level by incorporating these IPM management tools. Such an approach poses a lower risk to people, wildlife and the environment while simultaneously protecting economic interests among farmers.

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