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Evaluation of different modules for management of major insect pests in watermelon, (*Citrullus lanatus* Thunb.)

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Abstract
An experiment was conducted during Summer, 2022 for evaluation of different modules for management of major insect pests in watermelon, (*Citrullus lanatus* Thunb.). During the course of study, three pest management modules *viz*., Chemical, Bio-intensive and IPM module consisting spraying of different pesticides as well as biopesticides were evaluated with untreated control in Randomized Block Design (RBD) with five replications. The studies on evaluation of pest management modules for major pests of watermelon revealed that in for control of thrips and whitefly IPM module observed 4.35 thrips and 4.20 whitefly /3 leaves/plant, respectively.

Whereas, in case of leaf miner and fruit fly, the IPM module was significantly superior module and observed 23.45% damaged leaves and 16.94% damaged fruits, respectively. Effect of different strategies on predatory coccinellids showed that the Bio-intensive module recorded the highest grub population per plant (3.89 grubs/plant) and was at par with the IPM module which recorded 3.40 grubs/plant indicating their relative safety to the grubs of lady bird beetles. The highest yield of watermelon fruits 45.30 tonnes/ha was registered from the IPM module with highest ICBR 1:10.54 as against 32.90 tonnes /ha in untreated control.

Keywords: *Citrullus lanatus*, IPM module, *Thrips palmi*, *Bemisia tabaci*, *Liriomyza trifolii*, *Bactrocera cucurbitae*

1. Introduction

Watermelon, *Citrullus lanatus* (Thunb.), is mainly a summer vegetable crop in India. It is one of the important fruit and vegetable crop belonging to the family Cucurbitaceae, which includes about 118 genera and 825 species. In India, watermelon is grown over an area of 1,09,000 ha and annual production of 32,54,000 MT. Whereas, in Maharashtra, watermelon is grown over an area of 4,850 hectares with the annual production of 1,09,190 tonnes. (Anonymous., 2020-21) [2]. The watermelon fruits are consumed as sweet, refreshing, low-calorie summer snack and since they have great demand in the altered food scenario. Hence, most care be given to reduce pesticide residues.

The watermelon crop suffered mainly due to infestation of sucking pests *viz*; whitefly (*Bemisia tabaci* Gennadius), aphids (*Aphis gossypii* Glover and *Myzus periscae* Sulzer), Thrips (*Thrips palmi* Karny). Whereas, fruit fly (*Bactrocera cucurbitae* Coq), American serpentine leaf miner (*Liriomyza trifolii* Burgess) recorded to be the most destructive pests. Severe outbreak was noticed during 1992 in Maharashtra state on cucurbits (Wakchaure, 1998) [21]. The fruit flies accounts a major group of pests infesting cucurbitaceous crops. Two species namely *Bactrocera cucurbitae* (Coquillett) and *Bactrocera tau* (Walker) commonly called as melon fruit flies are the major species found infesting cucurbits. About 50% cucurbits are partially or completely damaged by fruit flies in India (Gupta and Verma 1992) [8]. Several insecticides have been recommended and are imposed by the farmers for control of the sucking pests. However, on account of economics and efficacy of pesticides, satisfactory control should not be obtained in many cases due to misuse of insecticides, development of resistance by pests and improper application techniques of sprays. Furthermore, heavy doses of insecticides has posed problems of residue in the fruits which cause human hazards upon consumption and also cause pest resurgence, insecticide resistance and destruction of natural enemies. However, the chemical pesticides can be minimized by Integrating it with botanical and microbial pesticides for producing healthy and good quality crop.

Recently, new molecules of pesticides are introduced in the market which are comparatively safe to natural enemies of the pest. Some pesticides are being used judiciously along with other reliable method of pest management in watermelon.

2. Materials and Methods

The three modules with untreated control replicated five times were evaluated in R.B.D. during *Summer*, 2022 at the Instructional Farm, Post Graduate Institute, MPKV, Rahuri. watermelon cv. Super queen dibbled on 30th December, 2021 in a plot size 7 m x 3 m with 2 m x 0.75 m plant spacing. Spraying was under taken in the morning hours using manually hand operated knap sack sprayer by using 500 litre of water per hector. Five sprays in each module were given at fortnightly interval. The three module consists of

A. Chemical Module

1. Spraying of imidacloprid 30.5% SC @ 0.70 ml/L at 15 DAS.
2. Foliar application of cyantraniliprole 10.26 OD @ 0.70 ml/L at 30 DAS.
3. Spraying of spiromesifen 22.9% SC @ 0.50 ml/L at 45 DAS.
4. Spraying of lambda cyhalothrin 5% EC @ 1.0 ml/L at 60 DAS.
5. Spraying of spinosad 45% SC @ 0.32 ml/L at 75 DAS.

B. Bio-intensive Module

1. Spraying of *Lecanicillium lecanii* @ 5 g/L at 15 DAS.
2. Spraying of *Azadirachtin* 1500 ppm @ 3 ml/L at 30 DAS.
3. Spraying of pongamia oil @ 1% at 45 DAS.
4. Spraying of *Metarhizium anisoplae* @ 5 g/L at 60 DAS.
5. Spraying of neem oil (300 ppm) @ 5ml /L at 75 DAS.

C. Integrated Pest Management Module

1. Installation of yellow sticky traps @ 8 traps/acre.
2. Spraying of *Lecanicillium lecanii* @ 5 g/L at 15 DAS.
3. Spraying of *Azadirachtin* 1500 ppm @ 3 ml/L at 30 DAS.
4. Installation of Cu-lure traps @ 4 traps/acre.
5. Spraying of fipronil 5% SC @ 1.0 ml/L at 45 DAS.
6. Spraying of abamectin 1.9% EC @ 0.3 ml/L at 60 DAS.
7. Spraying of cypermethrin 25% EC @ 0.5 ml/L at 75 DAS.

D. Untreated control

Observations on sucking pests such as thrips and whitefly were recorded on five randomly selected plants from each replication**.** Total number of thrips and whitefly were recorded from three leaves of each selected plant. Observations on percent damaged leaves were recorded on randomly selected plants in each replication. The observations were recorded by counting total number of leaves per plant and number of leaf miner infested leaves. The observations for post treatment counts were recorded on 15, 30, 45, 60 and 75 DAS. At the time of harvesting at picking, the entire marketable size fruits of the crop irrespective of healthy and infested fruits were plucked and infested and healthy fruits were sorted out to calculate the percent fruit infestation Adult coccinellid beetles were counted per five plants in each replication at 15, 30, 45, 60 and 75 DAS.

The data on yield of watermelon fruits from each plot was recorded at the time of each harvesting and then total yield from the plot (kg/plot) was converted $\sqrt{x+0.5}$ to tonnes per hectare. The data on average survival population of pests were translated into square root formation as well as data on the percent infestation caused by the pests was transformed into arcsine formation and then subjected to statistical analysis as suggested by Panse and Sukhatme (1985) [14]. The yield data was subjected to statistical analysis. Finally Incremental Cost Benefit Ratio (ICBR) was worked out for each treatment.

3. Results and Discussions

The cumulative data of five sprays pertaining to effect of different modules on the average population of thrips, whitefly, leaf miner, fruit fly and adult coccinellid beetles were counted and presented at 15, 30, 45, 60 and 75 days after sowing presented in Table 1-5.

A) Thrips

The overall results from Table 1 states that IPM module (4.35 thrips/3 leaves/plant) was effective in controlling the thrips on watermelon was found at par with Chemical module (5.15 thrips) as against 11.12 thrips/3 leaves/plant in untreated control.

The present investigation is in agreement with the results of Rajkumar *et al.* (2002) [15] who reported that Nimbecidine (*Azadirachta indica*) significantly reduced the damage caused by thrips. The present results are also in support with the findings of Annamalai *et al*. (2014) [1] who reported that *B. bassiana* and *L. lecanii* significantly decrease the *T. tabaci* infestations in onion crop under the greenhouse as well as field conditions.

Table 1: Effect of different modules on thrips (*Thrips palmi*) population

Module	Pre count	Number of thrips /3leaves/plant on					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	10.33 (3.29)	6.14 (2.58)	5.71 (2.49)	4.76 (2.29)	4.63 (2.26)	4.49 (2.23)	5.15 (2.37)
M2	10.48 (3.31)	6.47 (2.64)	6.43 (2.63)	6.30 (2.61)	5.49 (2.45)	5.49 (2.45)	6.04 (2.56)
M3	10.64 (3.34)	4.45 (2.22)	4.55 (2.25)	4.40 (2.20)	4.50 (2.24)	3.85 (2.09)	4.35 (2.20)
M4	10.60 (3.33)	10.61 (3.33)	11.02 (3.39)	11.69 (3.49)	11.28 (3.43)	11.02 (3.39)	11.12 (3.41)
SE(±)	0.04	0.05	0.07	0.06	0.05	0.06	0.06
CD	NS	0.16	0.21	0.18	0.15	0.19	0.18

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.
(Figures in the parathenses indicates and microbial pesticides for producing healthy and good quality crop. $\sqrt{x+0.5}$ values)
M1 = Chemical Module
M3 = Integrated Pest Management Module
M2 = Bio-intensive module
M4 = Untreated module

B) Whitefly

The overall results indicates from Table 2 that IPM module (4.20 whitefly/3 leaves/plant) was effective in controlling the whitefly infestation on watermelon and was found at par with Chemical module (4.91 whitefly). The least intensity of whitefly was observed in Bio-intensive module (5.83 whitefly).

The results are comparable with the findings of Dimetry *et al.* (1996) [5] who reported that the bioactivity of different formulations of neem seed extracts against *Bemisia tabaci* reduced the population density of the adults compared with the untreated control. The present results also in agreement with the of results of Moreau and Isman (2011) [12] who observed that yellow sticky traps were effective at trapping adult whiteflies and significantly reduced adult populations on the main crops (peppers) when compared with the control.

Table 2: Effect of different modules on Whitefly, (*Bemisia tabaci*) population

Module	Pre count	Number of whitefly/3leaves/plant on					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	12.24 (3.57)	5.31 (2.41)	5.01 (2.35)	4.86 (2.32)	4.69 (2.28)	4.68 (2.28)	4.91 (2.33)
M2	12.38 (3.59	6.29 (2.61)	5.99 (2.55)	5.82 (2.51)	5.64 (2.48)	5.41 (2.43)	5.83 (2.52)
M3	12.16 (3.56)	4.47 (2.23)	4.27 (2.18)	4.53 (2.24)	3.91 (2.10)	3.84 (2.08)	4.20 (2.17)
M4	12.28 (3.57)	12.27 (3.57)	11.43 (3.45)	12.28 (3.57)	11.83 (3.51)	11.79 (3.51)	11.92 (3.52)
SE(±)	0.04	0.06	0.06	0.05	0.07	0.06	0.06
CD	NS	0.18	0.18	0.15	0.21	0.20	0.18

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.
(Figures in the parathenses indicates $\sqrt{x+0.5}$ values)
M1 = Chemical Module
M3 = Integrated Pest Management Module
M2 = Bio-intensive module
M4 = Untreated module

C) Leaf miner

The overall results seems from Table 3 that IPM module (23.45% damaged leaves) was effective in controlling the leaf miner on watermelon and found at par with Chemical module (25.98% damaged leaves).

The results are confirmatory with the findings of Schuster and Taylor (1987)[17] who stated that single application of abamectin @ 4.54 g a.i./378.5 liters of water, control the *Liriomyza trifolii* on tomato in the field and concluded that single application of abamectin at a suitable dose controlled *Liriomyza trifolii* on tomato in the field for at least a week.

The present investigations are also supporting with findings of Apte (2001) [3] who documented average efficacy of 66.95, 51.95 and 48.04% on azadirachtin, fipronil and quinalphos against *Liriomyza trifolii* on gerbera respectively as well as Gahbiche (2001) [6] who studied the toxicity of spinosad against *L. trifolii* and observed 100% mortality of first instar and 89.3% mortality of third instar larvae, respectively.

Table 3: Effect of different modules on infestation of leaf miner and fruit fly

Module	Infestation of leaf miner (percent damaged leaves) on							Percent fruits damaged by fruit fly at harvesting		
	Pre count	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean	I	II	Mean
M1	46.98 (43.27)	27.54 (31.65)	25.35 (30.23)	27.24 (31.46)	26.41 (30.92)	23.37 (28.91)	25.98 (30.64)	27.50 (31.63)	16.37 (23.87)	22.94 (28.31)
M2	47.18 (43.38)	33.94 (35.63)	33.05 (35.09)	29.72 (33.03)	28.80 (32.46)	28.07 (31.99)	30.72 (33.64)	31.28 (34.01)	24.06 (29.37)	27.67 (30.14)
M3	46.88 (43.21)	24.10 (29.40)	23.98 (29.32)	23.72 (29.15)	24.25 (29.50)	21.19 (27.40)	23.45 (28.96)	20.38 (26.84)	13.49 (21.55)	16.94 (24.19)
M4	47.13 (43.36)	47.12 (43.35)	46.18 (42.81)	46.02 (42.72)	43.75 (41.41)	42.19 (40.51)	45.05 (42.16)	43.10 (41.03)	39.69 (39.05)	41.40 (40.04)
SE (±)	0.75	0.82	0.84	0.78	0.76	0.88	0.82	0.84	0.76	0.80
CD	NS	2.46	2.53	2.34	2.29	2.65	2.45	2.52	2.28	2.40

(Figures in the parathenses indicates arcsine transformed values)
M1 =Chemical Module M3 = Integrated Pest Management Module
M2= Bio-intensive module M4= Untreated module

D) Fruit fly

The overall results indicates from Table 3 that IPM module (16.94% damaged fruits) was effective in controlling the fruit fly on watermelon followed by Chemical module (22.94% damaged fruits). In Biointensive module least control of fruit fly was observed (27.67% damaged fruits). The present investigation are in support with Ranganath *et al.* (1997) [16] who tested a number of botanicals and chemical insecticides against *B. cucurbitae* on cucumber and ridge gourd in Southern Andaman, India and revealed that neem oil (1.20%) was the most effective in reducing the damage in cucumber and recorded 6.20 percent infestation over 39.00 percent in the control. The present results also confirmatory with the findings of Vargas *et al.* (2009) [20] who tested various traps with methyl eugenol and cu-lure for capturing fruit flies and observed that *B. dorsalis* was captured in methyl eugenol traps and *B. cucurbitae* in cu-lure traps. The present investigation is also in agreement with the findings of Sharma and Sinha (2009) [18] who reported that for the control of *B. cucurbitae* most effective insecticide was emamectin benzoate (15 g a.i./ha) followed by neem ban (1 ml/liter of water).

E) Natural enemy

The overall results seems from Table 4 that Bio-intensive module (3.89 grubs/plant) was most favourable and safest module for coccinellids on watermelon and was found at par with IPM module (3.40 grubs /plant). The chemical module that was found most toxic to natural enemies and recorded least coccinellids population (1.41 grubs/plant). The present investigation are in agreement with the findings of Hoelmer *et al*. (1990) [9] who observed that the commercial neem insecticide was not toxic to adult coccinellid predators. The results of present investigation support findings of Kaspi and Parrella (2005) [10] who reported that abamectin residues on plants negatively affect the natural enemies. Earlier, Bade *et al*., (2017) [4] who reported the use of *L. lecanii* @ 2.5 kg/ha recorded highest population of 4.49 lady bird beetles/plant and it was superior over all the treatments for control of aphid except, untreated control also support the present findings.

Table 4: Effect of different modules on coccinellids per plant

Module	Number of coccinellids (grubs/plant)						
	Pre count	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	Mean
M1	4.36 (2.20)	2.23 (1.65)	1.49 (1.41)	1.15 (1.28)	1.34 (1.36)	0.85 (1.16)	1.41 (1.37)
M2	4.26 (2.18)	3.74 (2.06)	3.65 (2.04)	3.64 (2.03)	3.89 (2.10)	4.55 (2.25)	3.89 (2.09)
M3	4.34 (2.20)	3.40 (1.97)	3.28 (1.94)	3.23 (1.93)	3.30 (1.95)	3.80 (2.07)	3.40 (1.97)
M4	4.30 (2.19)	4.31 (2.19)	4.44 (2.22)	4.97 (2.34)	5.37 (2.42)	5.69 (2.49)	4.96 (2.33)
SE(±)	0.05	0.04	0.05	0.07	0.06	0.06	0.06
CD	NS	0.13	0.15	0.21	0.18	0.19	0.17

*Average of five observations taken at 15, 30, 45, 60 and 75 DAS.
(Figures in the parathenses indicates $\sqrt{x + 0.5}$ values)
M1 = Chemical Module M3 = Integrated Pest Management Module
M2 = Bio-intensive module M4 = Untreated module

F) Yield

The overall yield seems from Table 5 that the IPM module obtained maximum (45.30 tonne/ha) yield of marketable fruits of watermelon as against (32.90 tonne/ha) in untreated control. Whereas, the Chemical module which was found at par with IPM module and recorded (43.80 tonne/ha) yield of watermelon fruits. The Bio- intensive module observed less yield (39.24 tonne/ha) as compared to IPM module and Chemical control. The highest incremental cost benefit ratio (ICBR 1:10.54) was recorded in the IPM module. Considerable yield advantages due to effective control of pests of watermelon particularly through the use of IPM was observed in the present investigation is in agreement with Gundannavar (2007) [7] and Pandey and Satpathy (2009) [13], Mondal and Mondal (2012) [11] and Tripathy *et al.* (2013) [19]. These workers reported IPM to be effective in controlling pests in various crops with highest yield. Thus, the observations of earlier workers in respect of these strategies influencing yield of crops could support the findings of present investigation.

Table 5: Effect of different modules on yield of watermelon and ICBR

Module	Yield of watermelon fruits (kg)						Tonne/ha	ICBR
	R 1	R II	R III	R IV	R V	Mean (Kg/plot)		
M1	89.22	95.66	90.14	88.30	96.58	91.98	43.80	1:8.32
M2	86.52	78.28	81.58	79.93	85.70	82.40	39.24	1:4.33
M3	91.32	93.23	100.84	92.28	97.98	95.13	45.30	1:10.54
M4	67.71	67.02	72.54	68.40	69.78	69.09	32.90	-
SE(±)	-	-	-	-	-	1.42	0.67	-
CD	-	-	-	-	-	4.39	2.09	-

4. Conclusion

Among the four management modules for controlling pests of watermelon, the Integrated Pest Management Module was found to be most effective for the suppression of whitefly, thrips, leaf miner and fruit fly on watermelon. The Bio-intensive pest management strategy was observed to be less toxic to predatory coccinellids, while chemical control showed toxic effects on the coccinellids on watermelon. Among the different pest management strategies IPM was found effective for the control of whitefly, thrips, leaf miner and fruit fly with good marketable yield of watermelon (45.30 tonne/ha) with 1:10.54 ICBR.

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