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ASSESSMENT OF INTEGRATED PEST MANAGEMENT MODULES FOR THE MANAGEMENT OF GRAPE MEALY BUG, *MACONELLICOCCUS HIRSUTUS* (GREEN)

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ABSTRACT

The pink hibiscus mealy bug *Maconellicoccus hirsutus* (Green) is a serious pest of the grape vine. High incidence of this pest was observed in the grape vineyards resulted in a poor fruit quality. During April pruning the chemo-intensive module has shown most effective against the mealy bug individuals and recorded lowest (2.41/ colony) mealy bug population, whereas, in adaptable module (2.54 mealy bug/colony) and biological module (3.83 mealy bug/colony) has recorded moderately higher mealy bugs per colony as compared to untreated check (i.e., 3.96 mealy bug/colony). Similarly, during October pruning the lowest egg mass (4.25/vine), mealy bug individual (3.36/colony) and mealy bug colonies (5.55/vine) were observed in Chemo-intensive module. Further, highest B: C ratio was obtained from Adaptable module (4.97) with a net return of Rs. 633450. Among the different modules, adaptable module is found superior due to economically and environmentally safer to protect the crop from insect pests.

INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the most important commercial crops grown in India. Even though their origin was in temperate regions, it perform equally well in a tropical climate in India. Improvement in yield and quality are the most important aspects of grape production (Ramteke *et al.,* 2017). Grape cultivation has been regarded as most remunerative enterprise. It is widely grown in China, Italy, United States, Africa, Australia, Algeria and India, where India stands in ninth position by sharing 3.31 per cent of world's production (Anon. 2010).

The area under grape is widening by year by year in India due to its inexhaustible yield, forex trading and good returns, which aroused considerable interest among the cultivators for its cultivation in large area. But wine grapes are more sensitive to the climate in which they grow than are many other crops. At present, in India grapes are cultivated in an area of 136.00 (000ha) with a production of 2683.3 (000MT/Year) and Productivity of19.7 (MT/ha). The leading grape cultivating states are Maharashtra state stands first with 103.98 (000 ha) followed by Karnataka 24.23 (000 ha) and Tamil Nadu 2.31 (000'ha) with an annual production of 2137.74,24.23 and 30.59(000Mt) respectively. Whereas, with respect to major grape growing districts are Bengaluru, Bagalkot, Vijayapura, Belagavi, Kolar and Gulbarga (Anon. 2017).

The magnitude of this fruit crop created interest in the cultivators to go for extensive and intensive cultivation of grapes, simultaneously which invited diverse insect pests to the vineyards (Alexandri, 1973). As many as 132 insect pests are recorded on grapevine in the world as documented by Bournier (1977) and over 85 species of insect pests are known to occur on grapes in India as per the reports of Butani (1979). Similarly, Balikai and Kotikal (2003) recorded 26 pests' infesting grapevines in northern Karnataka. Among them, mealybug, *Maconellicoccus hirsutus* (Green) is considered as one of the important pest of grape. And the important reasons behind the downfall of production and productivity may be due to lack of adoption of canopy management technology and outbreak of pest and diseases (Basu, 2014)

According to Babu and Azam, 1987 around 20 species of mealy bugs have been reported on grape vine in the world, but only six species have been reported from different states in India. Among them the most distressing species in India is unquestionably the grape mealy bug, *Maconellicoccus hirsutus (Green)*. The infestation is becoming more severe every year. In case of severe attack in the main field up to 90 per cent clusters are damaged. Lower (1968) called the mealy bug as "hard to kill pest" because if we see the eggs, late instars and adults of the mealy bugs they are protected by waxy filaments, are almost impossible to be penetrated with insecticidal sprays (McKenzie, 1967).

We know about the principle of IPM and what significance it has with growing fruit crops. Simply IPM is a combination of all possible methods of pest control or a combo pest control method. Since long back we are using chemical pesticides to control pests without thinking about other management methods like biological, cultural, physical methods and other, which are eco-friendly, adaptable, easily available and have a lesser impact on non target organisms, human health, and the environment.

IPM will work based on focusing on preventing problems, monitoring pest populations, identifying pests and choosing a combination of tactics to maintain pest populations at an minimal level or below ETL. We should properly plan the IPM modules or methods to combat the pest infestation, control pest resistance and as well as pest resurgence, secondary pest outbreak, environmental contamination, residual toxicity and toxicity to beneficial organisms (Tamoghna *et al.*, 2014)

The grape mealy bug has become serious on account of indiscriminate use of pesticides. The natural enemies are usually present in crop ecosystem, but their effectiveness is impaired by excessive use of pesticides. Hence, the use of integrated components is thought as a possible solution to combat the lowdown pesticide residue problem as well as menace of the mealy bug on grape vine. Urgent measures to mitigate the losses caused by this pest, to explore possibilities of arresting its future spread and to evolve suitable measures for its effective control are necessary. In grape crop there is a need of integrated pest management package for combating pesticide residue problem and as well as human beings and environment health point of view, to avoid only chemical means of management the present study was planned with the objective of assessing integrated pest management modules for management of mealy bug in grape crop.

MATERIALS AND METHODS

The study was taken up at University of Horticultural Sciences, Bagalkot (in Seemikeri village at farmer field) as farmer's participatory research. The experiment was conducted with Thomson seedless grape hybrid and the imposition of treatments were made two times, during April pruning and October pruning. The experiment was laid out in Factorial Randomized Complete Block Design (FRCBD). And the experiment was conducted for two year in 2015-16 & 2017-18. The modules were developed by integrating of different components based on the previous work. (V.V.L. Renuka, 2018)

Treatments imposed during April pruning

Module 1 (Bio-intensive): Application of neem cake @ 250 kg/ha -Spraying of NSKE 5 % - Spraying of *Lecanicilium leccanii* 2g/l

Module 2 (Adaptable): Application of neem cake @ 250 kg/ha -Drenching of imidacloprid200 SL @ 400 ml/ Acr through drip-Spraying of buprofezin 25% SC @ 1.25ml/l

Module 3 (Chemi-intensive): Drenching of Imidacloprid 200 SL@ 400 ml/Acr through drip - Spraying of buprofezin 25 % SC @ 1.25 ml/l - Spraying of Imidacloprid 17.8% SL @ 0.3 ml/l.

Untreated control

Treatments imposed during October pruning

Module 1 (Bio-intensive): Release of *Cryptolaemus montrouzieri* @ 5000/ha - Spraying of *Lecanicilium lecanii* 2g/l -Release of *Cryptolaemus montrouzeri* @ 5000/ha-Azadirachtin10,000 PPM @2ml/l

Module 2 (Adaptable): Drenching of Imidacloprid 200 SL @ 400 ml/Acr through drip - Spraying of buprofezin 25 %SC @ 1.25 ml/l - Spraying of FORS @ 5g/l - Spraying of azadirachtin10,000 PPM @ 2ml/l

Module 3 (Chemi-intensive): Drenching of Imidacloprid 200 SL @400ml/Acr through drip - Spraying of thiomethoxam 25 % WG @ 0.2g/l - Spraying of buprofezin 25 %SC @ 1.25 ml/l - Spraying of Acetamaprid 20% SP @0.3 g/l

Untreated control

Observations were recorded during both April and October time of imposition of treatments and continued up to harvesting of the grape bunches. The treatments were imposed at 10 days interval during the experiment. Whereas, observations were made on 5 tagged grape vines per treatment. And the method of observations is as follows:

Number of egg masses per vine: Five tagged vines were selected and numbers of egg masses in each vine were counted and average was worked out.

Number of individuals per colony: Number of individuals present was counted from the 25 mealy bug colonies and average was worked out.

Number of colonies per vine: Five vines were selected at random and numbers of colonies in each vine were counted and average was worked out.

Observations were recorded as pre-treatment count as number of mealy bug colonies per vine was recorded at one day before treatment. Subsequent observations on post treatment counts were recorded at five and ten days after each spraying. And also the yield of the grape bunches per vine per treatment is also recorded and converted in to hectare basis. The data obtained from the field experiment from various treatments during the two years is pooled and subjected to data analysis using WASP software.

Fruit yield

Harvesting of the grapes was done module wise separately during 2015 and 2017. The total fruit yield from each plot was taken and expressed in terms of fruit yield per kg, hectare basis and subjected for statistical analysis.

Cost economics

The grape yield per plot was recorded and computed to quintal per hectare. The data thus tabulated, pooled and analyzed. The benefit cost ratio (B:C ratio) of different modules were worked out by estimating different cost of cultivation, plant protection and profit obtained from fruit yield after converted them to hectare basis. The average market price of table grape (Cv. Thomson seedless) was rupees 25 per Kg during the experimentation. The following formula was used for calculation of B: C ratio.

1. Gross return = Yield × Market price of grape

2. Net Returns = Gross return - Total cost

3. B: C ratio = Gross return / Total cost

The data on mean population of mealy bug, egg mass and colonies were transformed to $\sqrt{x+1}$ and then subjected to ANOVA using M-STATC ® software package.

RESULTS

The results pertaining to reduction of population of *M. hirsutus* (Green) in IPM modules and control treatments are presented in Table 1. The post count of mealy bug infestation was distinguishable between IPM modules and control treatment.

Evaluation of IPM modules against mealy bug egg masses and individuals during April pruning

Treatment imposition were made after the April pruning and subsequently the observations were recorded from the treated plots and observed the least number of egg masses (2.12/ vine) in module-III (Chemo- intensive) followed by the module II (Adaptable) and in module I (bio-intensive)recorded 3.14 egg mass per vine and 4.62 egg mass per vine respectively, as compared to untreated check (i.e., 5.25egg mass/vine). The same trend was recorded during the year 2017-18 and pooled also (Table 1). Similarly the module-III has shown more effectiveness against the mealy bugs and recorded lowest population (i.e., 2.41mealy bug / colony) and module II and module I has recorded moderately higher mealy bugs per colony i.e., 2.54 and 3.83 mealy bugs/colony, respectively and showed significance difference as compared with untreated check (3.96 mealy bug/colony) here also the same trend was recorded from the 2017-18 and pooled data also. Whereas, number of mealy bug colonies were recorded lowest in module III i.e.,3.46 colony per vine followed by module II and module I recorded the 4.13 colonies/vine and 7.84 colonies/vine, respectively as compared to untreated check (8.97 colonies/vine) and same trend was recorded in 2017-18 and pooled as given in Table 2.and Table 3.

Evaluation of IPM modules against egg masses and mealy bug individuals during October pruning.

During the 2015-16 October pruning the average range of egg mass was 4.25 to 8.75 as compared to UTC (Untreated check) 8.40/vine, Individual mealy bug ranges from 3.36 to 6.23/colony as compared to UTC 6.93/colony and similarly 5.55 to 11.40 mealy bug colonies/vine as compared to UTC i.e. 11.13/vine was recorded. Further, the lowest egg mass, mealy bug individual and mealy bug colonies (i.e. 4.25/vine, 3.36/colony and 5.55/vine respectively) were recorded from the module III (Chemo-intensive).There is no much difference in distribution of pest, incidence etc. So, the same pest trend was recorded during the year 2017-18 and pooled also.

Yield

With regards to the yield of the grape, the highest yield was recorded from module III (32.19 t/ha) followed by module II recorded 31.75 tones/ha. Whereas, low grape yield 21.92 tones/ha was recorded from the control plot.

Cost economics

Among the modules, highest B: C ratio was obtained with M2-Adaptable module (4.97) with a net return of Rs. 633450. Although, M3-Chemo-intensive module bestowed with highest yield (32.19 t/ha) but resulted in lower B: C ratio (4.94) from (Table 4). Whereas, M1-Biointensive module offered less net returns (Rs. 463335) and B: C ratio (3.43) and superior over untreated check which recorded least net returns (Rs. 396500) and B: C ratio (3.62).

Bio-intensive and adoptable modules comprising of bio-agents has been considered to be compatible and a sound tool of IPM. These modules are considered as safest and ecofriendly IPM components and there is a tremendous scope for their exploitation of bio-agents such as *L. lecanii* and neem based insecticides. Fortunately, Adaptable module comprises of application of neem cake @ 250 kg/ha -Drenching of imidacloprid 200 SL @ 400 ml/ Acr through drip -Spraying of buprofezin 25% SC @ 1.25ml/l(imposed during April pruning) and drenching of Imidacloprid 200 SL @ 400 ml/Acr through drip-spraying of buprofezin 25 %SC @ 1.25 ml/l - Spraying of FORS @ 5g/l Spraying of azadirachtin 10,000 PPM @ 2ml/l ((imposed during October pruning)proved to be quite effective hence it is most advisable to this module with a slight compromise on yield returns as compared to chemo-intensive module.

DISCUSSIONS

The best viable, safe and eco-friendly strategy to manage grape mealy bug is only by IPM. Incorporation of neem cake and spraying of neem seed kernel extract etc. For the effective mealy bug management we should initiate treatment imposition during the April pruning time only because during off season the mealy bugs will be hiding in the loose bark of the grape vine, soil cracks and crevices, weed plants. Hence, bringing down of mealy bug infestation during the April pruning is very important. So in our experiment we have imposed different treatments both during April and October pruning in order to manage mealy bug effectively.

The present investigations are in line with Shelke (2001) he observed that, Fish oil rosin soap (0.5%) with *V. lecanii* (0.4%) or *C. montrouzieri* was the safest and most suitable treatment against grapevine mealybug, *M. hirsutus*. The fungus, *V. lecanii* (2×10^5 cfu/ml) caused 80.20 per cent mortality of sucking pest, *M. hirsutus* in Maharashtra, India within two weeks of spray (Jayachakravarthy, 2002). According to Koli (2003) *V. lecanii* 0.3% was found to be the best against nymphs and adults of grape mealybug in Maharashtra. Mukhopadhyay *et al.* (2011) reported that application of 1.5 per cent *Pongamia* oil, 2 per cent Neem oil and 1 per cent Neem oil + *Pongamia* oil (1:1) at 14 days after spray revealed consistent reduction in pink mealybug population and proved effective in management of this pest. Khan *et al.* (2012b) reported that the natural product tobacco extract comprising nicotine as active ingredient was found to be the best in causing mortality (98.60%) of the mealybug at 24 hours after treatment, followed by neem oil comprising azadirachtin as active ingredient (89.32%), neem seed extract (80.37%) and garlic extract (75.82%), respectively. Similar trend of mortality was observed even after 48 and 72 hours of treatments on *M. hirsutus* under field condition. Maduri (2012) reported that, seed kernel

Table 1: Evaluation of IPM modules against grape mealy bug during April pruning

Modules	No. of egg masses/vine						Individuals /colony						No. of mealy bug colonies/vine					
	2015-16		2017-18		Pooled		2015-16		2017-18		Pooled		2015-16		2017-18		Pooled	
	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS
Module I	5.20	4.62	3.74	3.33	4.47	3.98	4.50	3.83	3.24	2.76	3.87	3.29	8.70	7.84	6.26	5.65	7.48	6.75
Module II	5.40	3.14	3.89	2.26	4.64	2.70	3.90	2.54	2.81	1.83	3.35	2.19	8.20	4.13	5.9	2.98	7.05	3.56
Module III	4.15	2.12	2.99	1.53	3.57	1.82	4.20	2.41	3.02	1.74	3.61	2.07	7.90	3.46	5.69	2.49	6.79	2.98
Untreated check	5.32	5.25	3.83	3.85	4.57	4.17	4.30	3.96	3.1	2.87	4.38	3.41	8.30	8.97	5.98	5.83	7.14	6.90
S.Em ±	NS	0.18	NS	0.13	NS	0.16	NS	0.16	NS	0.11	NS	0.13	NS	0.32	NS	0.23	NS	0.27
CD @ 5 %		0.55		0.40		0.48		0.47		0.34		0.40		0.94		0.68		0.81
CV %		12.38		12.48		12.32		11.96		11.84		12.06		12.74		12.75		12.74

Table 2: Evaluation of IPM modules against grape mealy bug during October pruning

Modules	No. of egg masses/vine						Individuals /colony						No. of mealy bug colonies/vine					
	2015-16		2017-18		Pooled		2015-16		2017-18		Pooled		2015-16		2017-18		Pooled	
	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS	1 DBS	10 DAS
Module I	10.21	8.75	7.35	6.30	8.78	7.52	7.81	6.23	5.62	4.99	6.72	5.96	13.21	11.40	9.51	8.21	11.36	9.81
Module II	9.61	4.57	6.92	3.29	8.26	3.93	8.31	3.97	5.98	2.86	7.15	3.42	14.6	7.00	10.51	5.04	12.56	6.02
Module III	9.21	4.25	6.63	3.06	7.92	3.65	8.56	3.36	6.16	2.42	7.36	2.89	14.12	5.55	10.17	4.00	12.14	4.78
Untreated check	8.89	8.40	6.4	6.33	7.65	7.37	7.94	6.93	5.72	4.49	6.83	5.36	13.6	13.45	9.79	9.80	11.7	11.13
S.Em ±	NS	0.35	NS	0.25	NS	0.30	NS	0.28	NS	0.20	NS	0.24	NS	0.46	NS	0.29	NS	0.39
CD @ 5 %		1.03		0.75		0.89		0.85		0.61		0.73		1.37		0.86		1.18
CV %		12.50		12.40		12.53		12.33		12.45		12.60		12.38		12.29		12.42

Table 3: Influence of integrated pest management modules on grape yield

Modules	Yield (kg/plant)			Yield (tones/ha)		
	2015-16	2017-18	Pooled	2015-16	2017-18	Pooled
Module I	7.20	7.80	7.50	25.10	27.22	26.16
Module II	8.80	9.40	9.10	30.71	32.80	31.75
Module III	9.10	9.35	9.23	31.76	32.63	32.19
Untreated check	5.90	6.40	6.15	21.50	22.33	21.92
CD at 5%	1.14	0.83	0.98	2.24	2.12	2.18
S.E.m	0.40	0.31	0.35	0.78	0.81	0.79

Table 4: Cost economics of IPM modules against grape mealy bug

IPM modules	Yield (t/ha) pooled	Cost of plant protection (Rs/ha)	Cost of production	Total cost of production (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
M1- Biointensive Module	26.16	39165	151500	190665	654000	463335	3.43
M2- Adaptable Module	31.95	9800	151500	161300	794750	633450	4.97
M3- Chemo intensive Module	32.19	13000	151500	163000	804750	641750	4.94
M4- UntreatedCheck	21.92	2460	151500	151500	548000	396500	3.62

Gross return = Yield × Market price of grape (Rs. 25/kg), Net returns = Gross return - Total cost, B: C ratio = Gross returns / Total cost

extracts were superior in inducing nymphal mortality of pink mealybug over leaf extracts. Among the seed kernel extract, neem (78.67%) was most effective followed by *Pongamia* (56.00%) and Mahua (46.67%). Whereas, leaf extracts of *Pongamia* (41.33%) was most effective botanical followed by *Adathoda* (40.00%), neem (38.67%), Mahua (22.67%) and *Lantana* (20.00%). Makadia *et al.* (2009) conducted study to evaluate the efficacy of *V. lecanii* at 2.0 g/l water combined with spreaders/stickers: Ranipal at 1 ml/l water and Teepol at 1 ml/l water, sprayed on custard apple (*A. reticulata*) against the mealybug *M. hirsutus*. All the treatments were non-significant one day after treatment, although the highest (3.1%) crawlers' mortality of the mealybug was obtained with *V. lecanii* combined with Ranipal. The mortality increased at 3 days after treatment but all the treatments were found superior over the control. The highest percentage mortality of 18.9% was found with *V. lecanii* combined with Ranipal, which was on par with *V. lecanii* alone and *V. lecanii* combined with Teepol (18.3 and 17.8% mortality, respectively) and remained significantly different from the control. A similar trend also observed at 5, 7 and 10 days after treatments. According to Patel *et al.* (2010) more than 95 per cent reduction in mealybug population over control was observed at three days after spraying with buprofezin 25 SC in all the three dosages (250, 312.5 and 625 g a.i./ha). The efficacy of buprofezin against early and later instars nymphs of *P.solenopsis* under laboratory condition was also dose dependent and it was more toxic to early instars than later instar nymphs. It was most effective against early as well as later instars nymphs at highest dose (625 g a.i./ha). At two lower dosages (250 and 312.5 g a.i./ha), its effectiveness was comparable to chlorpyriphos 20 EC @ 400 g a.i./ha and carbaryl 50 WP @ 1000 g a.i./ha. Kulkarni *et al.* (2012) reported hat, the methomyl 40 SP @ 300 g a.i./ha and dichlorvos 75 WSC @ 2 ml/l were most effective and recorded lowest number of mealybugs (3.12 and 3.62 colonies/vine) at ten days after third spray.

Suresh *et al.* (2010) studied on efficacy of insecticides (profenophos 50 EC, dichlorvos 76 WC and acephate 75 SP) alone and in combination with fish oil rosin soap under field condition. The insecticides used in combination with fish oil rosin soap were significantly effective in reducing papaya mealybug, *Paracoccus marginatus* Williams and Granara De Willink at one day after treatment imposition than insecticides used alone. However, insecticides alone were effective after three days of treatment imposition.

Suresh *et al.* (2010) evaluated the effectiveness of different insecticides on *P. solenopsis* by leaf dip method at both 24 and 48 hours after treatment under laboratory condition. Chlorpyriphos recorded 100 per cent mortality followed by dichlorvos (90%), imidacloprid (86.66 %), thiamethoxam(80 %) and profenophos (70 %) while neem oil recorded the least mortality of 53.33 per cent after 24 hours of treatment.

Sunitha *et al.* (2009) reported that the treatments of acetamiprid 20 SP @ 0.30 g/l, imidacloprid 17.8 SL @ 0.30 g/l and thiamethoxam 25 WG @ 0.30 g/l recorded 88.08, 87.88 and 84.87 per cent reduction after second spray; 93.72, 95.52 and 90.30 per cent reduction after third spray and 97.37, 96.57 and 93.53 per cent reduction in mealybug population after fourth spray after 10 days of spraying, respectively. Whereas acetamiprid 20 SP was significantly superior by recording least bunch infestation of 11.4 per cent and highest yield of 266.80 q/ha which was on par with imidacloprid 17.8 SL (15.79% bunch infestation, 248.55 q/ha fruit yield), thiamethoxam 25 WG (12.50% bunch infestation, 242.30 q/ha fruit yield) and acephate 75 SP @ 1.00 g/l (15.12% bunch infestation, 215.08 q/ha fruit yield).

Hence the present study reveals the possibility of developing an IPM module with minimum usage of chemical insecticide, the accurate time and method of management practice and also release of bio-control agents which paves the way for conservation and build-up of natural enemies in the ecosystem for the best biological pest suppression.

CONCLUSIONS

The excessive use of chemical pesticides led to chemical residues on the fruit and a reluctance of consumers to purchase grapes, as well as have greater pressure on the environment so, the outcome of the experiment may give better option for eco-friendly pest management approach. And in grape production the weather conditions are conducive for development of mealybug pests slowly; hence, integrated pest management approach is the best way for checking the pest population. Because these integrated pest management methods are not only eco-friendly but also the integrated approach may increase the income of the farmer by reducing the cost of plant protection operations. Hence, based on all these points we can conclude that, use of adaptable model is better than chemo-intensive model with respect to cost of production, efficacy and safety of the environment.

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