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Evaluation of different IPM modules against ber stone weevil, *Aubeus himalayanus* in hot arid region of India

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Abstract

The ber stone weevil, *Aubeus himalayanus* Voss (Coleoptera: Curculionidae) appeared to be an emerging pest reported from various region of India. The stone weevil is an emerging threat for ber production in India especially in Northern India. The results showed that organic IPM module-II registered significantly lower stone weevil population (12.04 % on retained fruits & 15.04% in dropped fruits) followed by module-I (21.26 % on plant fruits & 26.15% in fallen fruits). The highest stone weevil population was observed under control module (49.23 % on retained fruits & 54.91% in dropped fruits). The marketable yield of ber fruits differed significantly under different modules. The fresh fruit yield of ber was observed in the order of organic IPM module-II (82.26 kg/ plant)> module-I (78.25 kg/ plant)> module-IV (73.14 kg/ plant)> module-III (64.81 kg/ plant) and least under control module (56.27 kg/ plant) in pooled both years. It can be inferred from the results that organic IPM module-II (Moderately resistant genotype (Umran), deep summer ploughing after pruning of plants, neem oil spray @ 5 ml per litre of water in October month, hand picking of damaged fruit and adult in November month and spray of spinosad 46 SC @ 0.4 ml per litre of water in December month) was highly effective and gave higher yield of marketable ber fruits. The benefit-cost ratio of the tested ber production systems in the control of stone weevil decreased in the following order: module-II (B: C ratio 10.41:1)> module-I (B: C ratio 9.41:1)> module-IV (B: C ratio 7.08:1)> module-III (B: C ratio 3.66:1).

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Introduction

The ber, *Ziziphus mauritiana* is native to Province of Yunnan in southern China to Afghanistan, Malaysia and Queensland, Australia (Morton 1987). It is native of South and Central Asia, found throughout the arid and semi-arid tracts. It is cultivated to some extent throughout its natural range on commercial scale and has received much horticultural attention in India (Morton 1987). *Z. mauritiana* is a gregarious spiny shrub or a small tree, ends of branches curved or drooping. Branches and branchlets armed with short stipular spines. The plant is a vigorous grower and has a rapidly-developing taproot. The richness of the pulp in nutritive compounds has been widely recognized. Nonetheless, there are no definitive values for pulp composition. However ber is richer source of protein, phosphorus, calcium, carotene and vitamin C (Bakhshi & Singh 1974). The crop is gaining popularity among the growers because of its adaptability to adverse climatic conditions and good returns of yield. The crop is suffered great losses due to insect-pests and diseases (Singh 2008) and more than 130 species of insect-pests were found to attach the crops in India. Balikai (2009) reported a total of 22 insect and non-insect species and likewise, Kavitha & Savithri (2002) documented about 23 insect species on ber. In addition to these, the ber stone weevil, *Aubeus himalayanus* Voss (Coleoptera: Curculionidae) appeared to be an emerging pest reported from various region of India (Karuppaiah et al. 2010; Balikai et al. 2013, Haldhar et al. 2012; Haldhar et al. 2016). The stone weevil is an emerging threat for ber production in India especially in Northern India (Haldhar et al. 2013; Haldhar et al. 2018). In light of above facts, attempts to integrate the promising technologies into operational IPM programme have been made in the present study for management of stone weevil. Continuous and indiscriminate use of chemical insecticides found to be ecologically unsafe and resulted in accumulation of pesticide residue on fruits. Therefore, it has become necessary to evaluate the new IPM modules for maximum reduction in stone weevil with least or no ill-effects on plant, consumer and environment. Keeping this in back drop, an attempt was made to formulate a sound management programme with organic IPM modules.

Materials and Methods

Field experiments were conducted at experimental farm of Central Institute for Arid Horticulture (CIAH), Bikaner (at 28°06'N latitude, 73°21'E longitude and altitude of 234.84m above sea level) to evaluate the effectiveness of an organic IPM module against ber stone weevil in planted field with a spacing of 6 x 6 m during 2015-16 and 2016-17. All the recommended agronomic practices (*e.g.* weeding, fertilization, hoeing, *etc*.) were performed equally in each experimental plant. Twenty fruit were randomly selected in each of 4 replicates and average incidence was calculated as the per cent of fruit infested with *A. himalayanus* during 2015-16 and 2016-17. The infested fruits were sorted and the percent fruit infestation was calculated. The yield of fruit per plant was taken from all picking stages of ber crop. The avoidable loss and increase in fruit yield over control was calculated for each treatment by the following formula.

$$\text{Avoidable loss \%} = \frac{\text{Highest yield in treated plot - Yield in the treatment}}{\text{Highest yield in treated plot}} \times 100$$

$$\text{Increase in Yield \%} = \frac{\text{Yield in treatment - Yield in control}}{\text{Yield in control}} \times 100$$

The formulae do not give the exact losses/ increase in yield because even in the treatment some damage occurs. However, this is considered to be the most feasible method for working out the percentage loss due to the insect pests in any treatment (Pradhan, 1964)

Details of models

MODULE-I: Farmer's practices/ Conventional I

a. Spray of Monocrotophos 36 SL @ 2 ml per litre of water in October month
b. Two spray of Dimethoate 30 EC @ 2 ml per litre of water in December month

MODULE-II: Organic IPM

a. Moderately Resistant genotype (Umran)
b. Deep summer ploughing after pruning of plants
c. Neem oil spray @ 5 ml per litre of water in October month
d. Hand picking of damaged fruit and adult in November month
e. Spray of spinosad 46 SC @ 0.4 ml per litre of water in December month

MODULE-III: Conventional IPM

a. Moderately Resistant genotype (Umran)
b. Spray of NSKE 5% in October month
c. Spray of Dimethoate 30 EC @ 2 ml per litre of water in December month

MODULE-IV: Conventional II

a. Spray of Monocrotophos 36 SL @ 2 ml per litre of water in October month
b. Spray of NSKE 5% in November month
c. Spray of Dimethoate 30 EC @ 2 ml per litre of water in December month

MODULE-V: **No treatment/Control**

Statistical analysis

Square root and angular transformations was used to achieve normality in the data before analysis (Steel et al. 1997), but untransformed means are presented in tables. Yield and stone weevil populations were compared among programs through one-way ANOVAs followed Tukey's honestly significant difference (HSD) tests for multiple comparisons at $P = 0.05$. All treatments were performed in SPSS 16 software (O'Connor 2000).

Results and Discussion

Consequent to sole reliance and continuous usage of synthetic insecticides, not only control measures have lost their efficacy but also becoming economically non-viable. In this background, the results for different modules involving ecofriendly tools with minimal toxicant usage were carefully designed and verified in comparison with untreated control are presented here. A significant difference in stone weevil damage percent was observed under the different modules ($P < 0.05$). The pooled results showed that the organic IPM module-II registered had significantly lower stone weevil damage (12.04 percent in retained fruit & 15.04 percent in dropped fruit) followed by module-I/ Farmer's practices/Conventional (21.26 percent in retained fruit & 26.15 percent in dropped fruit). The highest stone weevil damage was observed for the control

(49.23 percent in retained fruit & 54.91 percent in dropped fruit) (Table 1 & Figure 1). Effectiveness of organic amendments *viz.*, neem cake and vermicompost besides neem derivatives against sucking pests has been documented by various workers (Varghese & Giraddi, 2005; Haldhar et al. 2014), which lend support to the present findings. Singh et al. (2012) revealed that module (M1) proved be the most effective treatment against shoot and fruit borer, *Earias vittella* F., yellow vein mosaic virus vector, *Bemisia tabaci* (Genn.) and red spider mite, *Tetranychus cinnabarinus* (Boisd.) in which lowest incidence was recorded as compared to other IPM modules. The module M1 comprised of hand picking and destruction of infested leaves, shoots and fruits, seed treatment with imidacloprid, application of indoxacarb, thiomethoxam, hexythiazox, deep summer ploughing and use of neem cake @ 250 kg/ha before sowing was the most effective. Haldhar et al. (2014) resulted the organic IPM module-III comprised of growing resistant genotype (RM-50), spray of neem oil at 20 DAS, installation of pheromone trap (10/ hectare) at 42 DAS, spray of tumba fruit extract (TFE 5%) at 50 DAS and spray of spinosad 46 SC at 60 DAS was the most effective. The conventional I (farmer's practices) was the second most effective system against major pests during both years. Pandey et al. (2016) showed that the IPM program provided 59.12, 57.12, 43.88, 55.98, 52.67, 49.41 and 52.24 % reduction in white-grub, cut worm, cabbage butterfly, DBM, aphids, tobacco caterpillar, painted bug infestation, respectively, as compared to non-IPM practiced fields. Similarly, there was 52.15, 52.94 and 49.41 % control of damping-off, black leg and white blight or head rot diseases, respectively, over non-IPM practice. Analysis of cost benefit ratio of IPM practice revealed that there was 58.88 % increase in yield with net return of Rs. 65.59 thousand per ha over non-IPM practiced field. The B: C ratio of IPM practice field was 2.19. Nathan et al. (2004) recorded that combination of neem seed kernel extract and *Bacillus thuringiensis* were effective in controlling the leaf folder *C. medinalis*. Spinosad 45 SC is a biological product from actinomycetes *Saccharopolyspora spinosa* was also effective in controlling rice leaf folder. Nalini et al. (2008), Karthikeyan et al. (2008), Suresh et al. (2011) and Haldhar et al. (2021) reported that application of spinosad 2.5 SC was effective against rice leaf folder.

Table 1. Incidence of stone weevil (*Aubeus himalayanus*) on plant in different management modules of ber crop

Treatments	Percent of stone weevil damage in retained fruit			Percent of stone weevil damage in dropped fruit		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Module-I	21.38 (27.45)*	21.13 (27.27)	21.26 (27.36)	26.25 (30.69)	26.05 (30.56)	26.15 (30.63)
Module-II	12.15 (20.30)	11.93 (20.10)	12.04 (20.15)	15.13 (22.86)	14.95 (22.72)	15.04 (22.79)

Module-III	38.88 (38.53)	38.65 (38.40)	38.77 (38.47)	43.50 (41.23)	43.30 (41.11)	43.40 (41.17)
Module-IV	31.48 (34.09)	31.33 (33.99)	31.41 (34.04)	33.08 (35.03)	32.93 (34.94)	33.01 (34.99)
Control	49.33 (44.59)	49.13 (44.48)	49.23 (44.54)	55.08 (47.94)	54.73 (47.74)	54.91 (47.84)
SEm±	0.96	0.92	0.94	0.97	0.99	0.98
LSD (P = 0.05)	3.00	3.03	3.02	3.02	3.07	3.05

*Values in parenthesis are angular-transformed
Value following different letter are significantly different using Tukey's HSD test

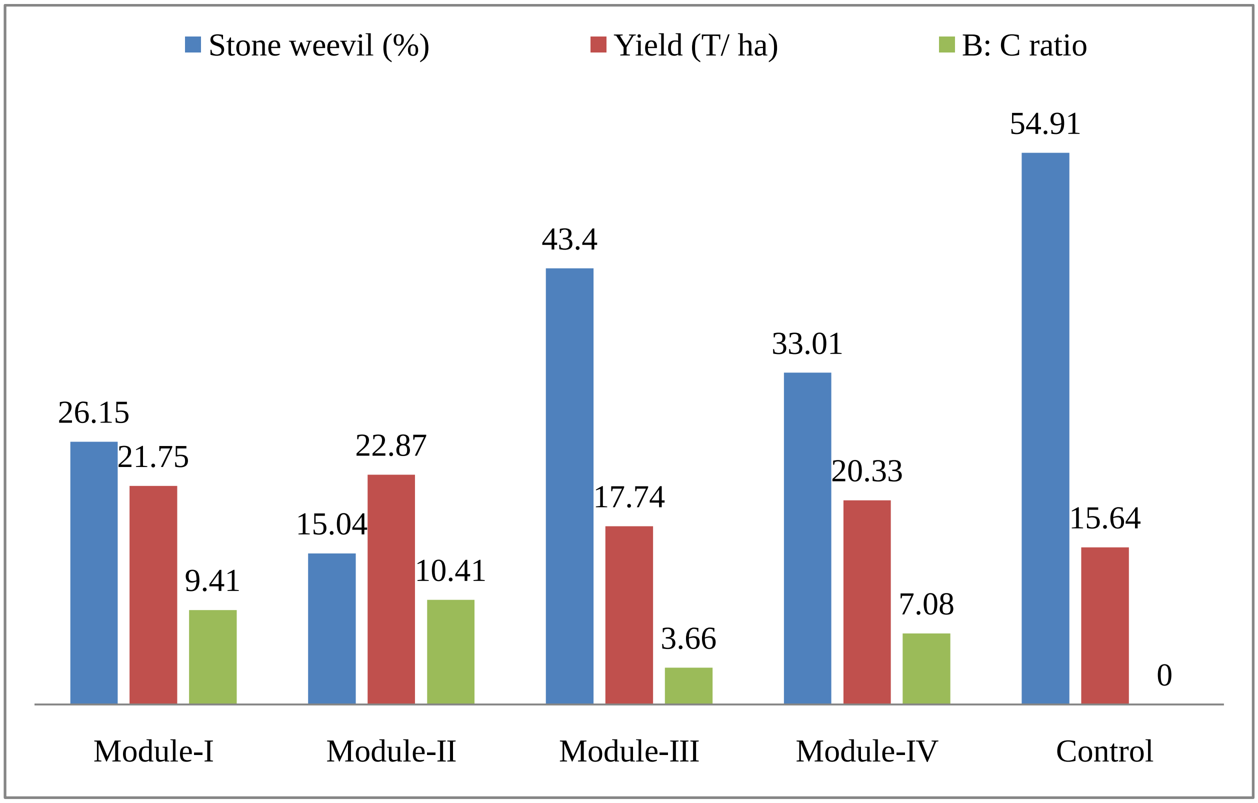

Figure 1. Association of stone weevil, yield and B: C ratio in different management modules of ber crop

The marketable yield of berfruits differed significantly under different modules during both the years as well as pooled results ($P < 0.05$) (Table 2, 3 and Figure 1). The fresh fruit yield of ber observed in the different programs decreased in the following order: organic IPM module-II (228.69 q/ha)> module-I (217.54 q/ha)> module-IV (203.33 q/ha)> module-III (177.39 q/ha)> control (156.43 q/ha) in pooled results. The same trend was observed during both the years. The percent avoidable losses were lowest in Module-II followed by Module-I and maximum was recorded in control. Percent yield increase over control was maximum in Module-II (46.19%) followed by Module-I

(39.07%) and minimum was recorded in Module-III (14.40%) followed by Module-IV (29.98%). It can be inferred from the results that organic IPM module-II was highly effective and gave higher yield of marketable ber fruits. The higher Benefit-Cost Ratio was obtained in the organic IPM module-II (10.41:1) followed by module-I (9.41:1), and lowest BCR was obtained in module-III (3.66:1).

Table 2. Economic yield in different management modules of ber crop

Treatments	Yield in Kg per plant			Yield in quintal per hectare		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Module-I	77.60 (62.38)*	78.90 (63.42)	78.25 (62.90)	215.73	2.19.34	217.54
Module-II	82.01 (65.79)	82.50 (66.24)	82.26 (66.02)	227.99	229.35	228.69
Module-III	63.48 (52.94)	64.13 (53.34)	63.81 (53.14)	176.47	178.28	177.39
Module-IV	72.85 (58.83)	73.43 (59.20)	73.14 (59.02)	202.52	204.14	203.33
Control	55.98 (48.45)	56.55 (48.79)	56.27 (48.62)	155.62	157.21	156.43
SEm±	1.51	1.56	1.54	-	-	-
LSD (P = 0.05)	4.70	4.85	4.78	-	-	-

*Values in parenthesis are angular-transformed

Value following different letter are significantly different using Tukey's HSD test

Table 3. Economics and assessment of losses caused by stone weevil in ber in arid region of India

Treatments	Yield (q/ha)	Total avoidable losses (q/ha)	Percent avoidable losses	Yield increase over control (q/ha)	Percent yield increase over control	Return of increased yield (Rs)**	Total cost of module expenditure (Rs)***	B:C ratio
Module-I	217.54	11.15	04.88	61.11	39.07	58605	6226	09.41
Module-II	228.69*	00.00	0.00	72.26	46.19	69285	6844	10.41
Module-III	177.39	51.30	22.43	20.96	13.40	20100	5488	03.66
Module-IV	203.33	25.36	11.09	46.90	29.98	44970	6352	07.08
Control	156.43	72.26	31.60	00.00	00.00	00.00	00.00	00.00

* Highest yield in the module plots

** Cost of muskmelon fruit in summer season was 1500 Rs per qt.

*** It includes module and labour charges

According to Gundannavar et al. (2007) a significant higher yield (5.13 q/ha) was recorded in module-I which was at par with module-II (5.04) and module-III (4.91). However, least yield (4.29 q/ha) was registered in module IV for controlling insect pests of chilli. Praveen & Dhandapani (2001) recorded cost benefit ratio of 1:2.60 when *C. carnea*+Econeem was applied on okra against major insect pests. Das et al. (2001) recorded the highest cost benefit ratio from application of acephate (1:58) followed by imidacloprid (1:4.63) in okra. Shukla et al. (1996) found fenvalerate highly cost effective with a cost: benefit ratio of 1:10.3. Singh & Kumar (2003) found neem products effective against jassid on okra and on the basis of cost: benefit ratio, neem seed kernel extract (3%) ranked first (1:10.7) followed by endosulfan (1:10.1). Haldhar et al. (2014) observed that benefit-cost ratio of the tested muskmelon production systems in the control of insect-pests decreased in the following order: module-III (B: C ratio 8.80:1)> module-I (B: C ratio 7.74:1)> module-IV (B: C ratio 6.60:1)> module-II (B: C ratio 3.56:1). In summary, the reduction of stone weevil and increased yield of ber crop could be due to the organic IPM module-II having moderately resistant genotype (Umran), deep summer ploughing after pruning of plants, neem oil spray @ 5 ml per litre of water in October month, hand picking of damaged fruit and adult in November month and spray of spinosad 46 SC @ 0.4 ml per litre of water in December month. In future the organic IPM module-II will be economic and therefore, can be used to reduction of stone weevil, environmental safety and increased yield of ber crop.

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