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Trap cropping efficacy of an alternate host *Physalis angulata* against brinjal hadda beetle *Epilachna vigintioctopunctata* (Coccinellidae: Coleoptera)

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Abstract
Eggplant or brinjal is one of the most important vegetable crops cultivated in tropical and sub-tropical countries of the world. Insect pests are the major biotic factor which leads up to 21 % yield loss. Among them hadda beetle- *Epilachna vigintioctopunctata* (Coccinellidae: Coleoptera) is the major defoliator causing heavy yield loss. It is a polyphagous pest feeding on wide host range. Due to its multiple host range, this pest occurs throughout the year. Using trap crops in pest management is one of the important components of IPM. Many alternate hosts of crop pests support their survivability and some of the alternate hosts attract the pest than the crop. To know the preferred alternate hosts of hadda beetle field, a survey was conducted for the year 2017-2018. Following hosts were recorded with a considerable level of hadda beetle incidence in the field such as *Datura metal, Solanum xanthocarpum, Physalis angulata, Solanum nigrum* and *Solanum trilobatum.* Net cage and laboratory evaluation resulted that the hierarchy of preference towards different alternate hosts was *P. angulata* > *S. nigrum*> *D. metal* > *S. trilobatum*> *S. xanthocarpum*. The highly preferred host *P. angulata* was evaluated for its trap cropping efficacy along with brinjal under net cage condition and the results showed the highest oviposition on *P. angulata* during the entire study period. The number of grubs and feeding damage were recorded on *P. angulata* than the brinjal up to 90 days after release.

Keywords: Alternate host, trap crop, brinjal, hadda beetle, *Physalis angulata*

1. Introduction
Brinjal, *Solanum melongena* Linnaeus is one of the highly nutritious vegetables extensively cultivated in India (Sarker *et al*., 2006; Saravaiya *et al*., 2010) [1, 2]. It is a perennial crop but grown commercially as an annual crop. Insect pests are the major draw in brinjal production among them, hadda beetle, *Epilachna vigintioctopunctata* (Fabricius) (Coccinellidae: Coleoptera) is heavily defoliating pest of the brinjal. Grubs and adults of *E. vigintioctopunctata* are destructive and feed on the epidermal tissues of leaves, flowers and fruits by scrapping the chlorophyll content and cause considerable yield loss during every crop season, adversely affecting both quality and quantity of crop output. The fruit yield reduction recorded up to 60 per cent under heavy infestation (Mall *et al*., 1992; Ali *et al*., 2017) [3, 4]. It is widely distributed in Southest Asian countries, and it is common in south India, also occurs in other parts of India (Kapur, 1950) [5]. Apart from eggplant, the Hadda beetle is reported as the key pest of many cultivated and weed plants of Solanaceae and Cucurbitaceae family including *S. tuberosum, Datura stramonium* L., *D. metel* L., *D. innoxia* Mill., *S. nigrum* L. and *Withania somnifera* L. (Mathur and Srivastava, 1964; Shirai and Katakura 1999; Islam *et al*., 2011) [6-8]. Wide host range increases the survivability of hadda beetle, especially during the off-season. Ganga and Chetty (1982) [14] recorded the importance of alternate host plants of hadda beetle life cycle. The management of hadda beetles mostly based on chemical pesticides. Non-judicial and repeated application of insecticides at improper may cause several problems such as disrupting natural enemy complexes, secondary pest outbreaks and environmental pollution. Farmers can shift the practice of sole reliance on insecticides to alternative approaches to solving these problems. Trap cropping is one of the eco-friendly pest management practices which manipulate the crop environment by adding up with pest attracting crop. Preference level of pest varies in host to host. Keeping in this view, a survey conducted to identify the alternate hosts of hadda beetle in selected locations and evaluating the highly preferred host as a trap crop.

2. Materials and Methods

2.1. Incidence of hadda beetle on alternate hosts

The weekly field survey conducted at ten brinjal growing villages of Cuddalore district to identify the alternate hosts of hadda beetle for ten months.

2.2. Net cage evaluation for host preference of hadda beetle

The 30 days old seedlings of *D. metal, S. xanthocarpum, P. angulata, S. nigrum* and *S. trilobatum* were transplanted and caged using nylon net. Ten plants maintained for each host and three net cages maintained as three replications. Fifty pair of adult insects released inside of all the three cages. Observations were taken on the number of eggs, grubs and adults present on each host at 10, 20, 30, 40 and 50 days after the transplanting.

2.3. Preference experiment under laboratory condition

Preference of hadda beetle towards different alternate hosts using choice and no-choice test. In the choice test leaf discs of selected hosts were prepared and kept circularly in 9 cm dia Petri plate and four hours pre-starved adult released in the centre of the Petri plate. Whereas in no-choice test, individual hosts kept in separate Petri plates. Feeding preference of hadda beetle observed by fed area of each host at 12, 24, 36 and 48 hours after release (HAR). In the same manner oviposition preference also evaluate using branches of host plants in choice and no-choice condition. Numbers of eggs laid on different hosts were count at 3, 5 and 7 days after release (DAR).

2.4. Evaluation of trap cropping efficacy of *P. angulata* under net cage condition

Brinjal seedlings were transplanted in 6 m X 5 m sized three micro plots. A single row of 30 days old seedling of *P. angulata* was transplanted around each plot and covered by the net cage with 6.5m X 5.5 m X 2 m size. Observations were taken on five brinjal and *P. angulata* plants for numbers of eggs, grubs and adults of hadda beetle at 45, 60, up to 90 days after release.

2.5. Statistical analysis

The data obtained from the experiment was analyzed as per the methods described by Panse and Sukhatme (1978) [9].

3. Results and Discussion

3.1. Incidence of hadda beetle on alternate hosts

Survey results showed the considerable level of hadda beetle incidence recorded on following hosts *viz., Datura metal, Solanum xanthocarpum, Physalis angulata, Solanum nigrum* and *Solanum trilobatum.* The hierarchy of incidence level of hadda beetle population during January - April was *P. angulata >S.nigrum > S. trilobatum >D. metal > S. xanthocarpum*. Hadda beetle population peak was recorded during the march. The peak population during March was reported by Muthukumar and Kalyanasundaram (2003) [10]. The population fluctuations of *E. vigintioctipunctata* on recorded solanaceous weed hosts during different months. Comparatively less incidence of hadda beetle recorded on weed hosts during brinjal growing season than the off-season. Incidence on *P. angulata* on throughout the study was not varied that indicated brinjal is not able attracts the population on *P. angulata* this result were supported by Nagia *et al*, (1992) [11] who reported preference of hadda beetle on the weed host *Physalis minima* Linn than brinjal. Ganga and Chetty (1982) [14] who mentioned about the many alternate hosts as well as their important in the survivability of hadda beetle throughout the year.

3.2. Net cage Field evaluation of weed hosts for hadda beetle

Mean population data of overall experiment revealed that maximum adult and grubs found on *P. angulata* followed by *S.nigrum, D. metal, S. trilobatum* and *S. xanthocarpum*. Incidence of hadda beetle on the solanaceous host was reported by Rajagopal and Trivedi (1989) [12]. Number of eggs on host plants were recorded maximum on *P. angulata* and lowest egg population recorded on *S. xanthocarpum*. (Table-2). Very limited attempt made on alternate host preference evaluation for hadda beetle. Sushilkumar and Puja Ray (2018) [13] conducted the study on preference of *Spodoptera litura* on different weed hosts and reported the higher preference

3.3. Preference experiment under laboratory condition

In both choice and no choice condition highest leaf area consumption recorded on *P. angulata* and lowest leaf area consumption recorded on and *S. xanthocarpum*. Same trend recorded in oviposition (Table-3). Imura and Ninomiya (1978) [15] also recorded the feeding of hadda beetle by image processing method on different host and reported the variability in the leaf consumption. Nagia *et al.,* (1992) [11] who recorded higher larval, pupal weight of hadda beetle on *Physalis minima* Linn, by comparatively higher consumption than brinjal.

3.4. Evaluation of trap cropping efficacy of *P. angulata* under net cage condition

Up to 45 DAR highest numbers of grubs and adults population recorded on *P. angulata* than the brinjal plants, whereas from 60 DAR to 90 DAR the maximum number of grubs and adults recorded brinjal. The maximum number of eggs recorded on *P. angulata* throughout the experiment but there is no significant different was recorded (Table-4). It indicated that young stage of the *P. angulata* was more attractive to hadda beetle grubs and adults. Many earlier findings on different host plants also supported that age of the host plants affects the feeding preference of insect pests (Baqui and Kershaw, 2009; Prager *et al*., 2014) [16, 17].

Table 1: Survey for *E. vigintioctopunctata* on different weed hosts

Host	Mean number of hadda beetle grub/adult population										Mean
	January	February	March	April	May	June	July	August	September	October	
S. xanthocarpum	1.93	1.40	1.53	2.00	4.80	4.86	2.20	1.80	1.93	2.13	2.45
S. trilobatum	3.26	3.33	3.40	3.13	7.46	7.20	2.80	2.73	2.13	2.40	3.73
D. metal	2.06	1.86	3.4	2.06	6.33	6.26	1.80	1.53	1.66	2.00	2.89
S. nigrum	4.60	3.20	4.93	4.60	5.53	6.20	2.86	2.26	2.53	1.93	3.86
P. angulata	20.73	22.13	22.45	21.12	21.46	20.00	18.73	21.39	19.86	20.06	18.54

Mean of five replications.

Table 2: Preference of *E. vigintioctopunctata* on different solanaceous weed hosts under net cage condition

Host	Mean number grub/adult on weed hosts at						Mean	Mean number of eggs on weed hosts at						Mean
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT		10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	
S. xanthocarpum	0.20 (1.08)	0.40 (1.15)	0.40 (1.15)	0.40 (1.15)	0.40 (1.15)	0.60 (1.20)	0.27	0.00 (1.00)	1.40 (1.37)	0.00 (1.00)	0.00 (1.00)	2.20 (1.58)	2.20 (1.33)	0.97
S. trilobatum.	1.40 (1.47)	0.80 (1.28)	1.00 (1.35)	0.80 (1.29)	1.60 (1.45)	0.40 (1.15)	1.00	1.00 (1.29)	0.40 (1.15)	1.00 (1.29)	1.60 (1.49)	5.00 (2.19)	4.20 (2.17)	2.2
D. metal	0.40 (1.15)	0.20 (1.08)	0.20 (1.08)	1.00 (1.35)	3.00 (1.74)	1.40 (1.47)	1.03	1.40 (1.37)	0.80 (1.25)	0.00 (1.00)	1.40 (1.36)	2.40 (1.63)	2.40 (1.39)	1.4
S. nigrum,	1.00 (1.40)	2.20 (1.65)	4.40 (2.11)	4.60 (2.25)	1.80 (1.54)	3.20 (1.94)	2.86	2.20 (1.62)	0.60 (1.20)	7.00 (2.52)	1.20 (1.33)	8.20 (2.84)	5.00 (2.21)	4.03
P. angulata	6.60 (2.73)	3.20 (2.03)	9.80 (3.09)	11.20 (3.28)	12.20 (3.38)	11.00 (3.24)	7.94	7.80 (2.94)	10.40 (2.87)	10.40 (3.13)	8.60 (2.88)	8.60 (2.88)	6.40 (2.48)	8.70
SE(d)	0.25	0.32	0.50	0.49	0.63	0.50		0.38	0.59	0.65	0.49	0.70	0.61	
C.D.	0.53	0.68	1.05	1.04	1.36	1.04		0.82	1.27	1.40	1.05	N/A	N/A	

*****Mean of five replications. Values in parenthesis are arc sin transformed. Value with different alphabets differs significantly.

Table 3: Preference of *E. vigintioctopunctata* on the different host under laboratory condition

Host	Mean leaf area consumption (Sq.cm) by *Epilachna vigintioctopunctata*									The mean number of eggs laid						
	Free- choice				Mean	No- choice				Mean	Free choice			Mean	No-choice			Mean
	12 HRS	24 HRS	36 HRS	48 HRS		12 HRS	24 HRS	36 HRS	48 HRS		3 DAR	5 DAR	7 DAR		3 DAR	5 DAR	7 DAR	
S. xanthocarpum	0.03 (1.02)	0.06 (1.03)	0.10 (1.05)	0.10 (1.05)	0.07	0.08 (1.04)	0.27 (1.13)	0.76 (1.33)	0.97 (1.40)	0.52	0.00 (1.00)	19.00 (3.95)	42.33 (6.48)	20.44	0.00 (1.00)	11.00 (3.11)	26.00 (4.55)	12.33
S. trilobatum.	0.07 (1.03)	0.14 (1.07)	0.18 (1.08)	0.26 (1.12)	0.16	1.41 (1.55)	1.88 (1.69)	2.66 (1.91)	3.30 (2.07)	2.31	10.67 (3.08)	43.33 (6.62)	56.33 (7.55)	36.77	5.33 (2.04)	12.67 (3.30)	19.33 (4.50)	12.44
D. metal	0.09 (1.04)	0.18 (1.08)	0.23 (1.11)	0.34 (1.16)	0.21	0.86 (1.36)	1.39 (1.54)	1.95 (1.72)	2.41 (1.85)	1.65	16.33 (4.12)	48.00 (6.98)	76.33 (8.76)	46.88	13.67 (3.49)	28.00 (5.30)	43.00 (6.45)	28.22
S. nigrum,	0.11 (1.05)	0.18 (1.09)	0.28 (1.13)	0.44 (1.20)	0.25	1.69 (1.63)	2.75 (1.93)	3.41 (2.09)	3.78 (2.18)	2.91	23.67 (4.93)	45.00 (6.76)	69.33 (8.36)	46.00	5.33 (2.04)	18.67 (4.42)	31.33 (5.66)	18.44
P. angulata	0.17 (1.08)	0.30 (1.14)	0.45 (1.20)	0.89 (1.37)	0.45	1.71 (1.64)	2.94 (1.98)	3.70 (2.16)	4.59 (2.36)	3.24	30.00 (5.55)	72.33 (8.56)	112.00 (10.63)	71.44	14.33 (3.47)	41.00 (6.47)	63.67 (8.03)	39.66
SE(d)	0.01	0.02	0.03	0.04		0.12	0.10	0.10	0.09		0.77	1.06	0.75		1.45	1.10	1.35	
C.D.	0.02	0.04	0.07	0.08		0.26	0.23	0.22	0.20		1.74	2.39	1.69		N/A	N/A	N/A	

*****Mean of three replications. Values in parenthesis are square-root transformed.

Table 4: Trap cropping efficacy of *P. angulata* under-screen cage condition

Host	Number of grubs/adults						Mean	Number eggs laid						Mean
	15 DAR	30 DAR	45 DAR	60 DAR	75 DAR	90 DAR		15 DAR	30 DAR	45 DAR	60 DAR	75 DAR	90 DAR	
Brinjal	3.60 (2.13)	3.20 (2.03)	5.60 (2.56)	5.40 (2.52)	4.60 (2.33)	6.60 (2.75)	4.83	0.60 (1.25)	0.60 (1.24)	1.80 (1.65)	2.40 (1.83)	3.80 (2.18)	3.80 (2.17)	2.17
P. angulata	5.80 (2.60)	6.80 (2.79)	3.60 (2.13)	2.00 (1.72)	1.20 (1.45)	0.60 (1.24)	3.33	1.00 (1.40)	1.40 (1.52)	3.00 (1.94)	3.00 (1.98)	5.00 (2.44)	4.8 (2.40)	3.03
SE(d)	0.14	0.13	0.10	0.13	0.24	0.13		0.15	0.15	0.14	0.14	0.10	0.15	
C.D>	0.33	0.31	0.24	0.32	0.57	0.32		N/A	N/A	N/A	N/A	0.25	N/A	

*****Mean of five replications. Values in parenthesis are square-root transformed

4. Conclusion

Alternate weed hosts have a major impact on hadda beetle survivability by providing food and shelter during the off-season. We can reduce or delay the population build-up by removing alternate hosts around the field. In another way, we can use the most attractive alternate host as a trap crop. *P. angulata* was an attractive alternate host can be used as a trap crop after further field study.

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