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Development of integrated pest management strategies for the management of cotton stem weevil, *Pempherulus affinis* (Faust)

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Abstract
In the present study, the effect of different Integrated Pest Management Strategies for the management of cotton stem weevil, *Pempherulus affinis* (Faust) was studied in cotton under field conditions at Agricultural Research Station, Kovilpatti. The incidence of stem weevil at four different dates of sowing revealed that the pre-monsoon crop (38th standard week) experienced minimum damage by stem weevil. Among the biointensive methods, application of neem cake 150 kg/ ha + carbofuran (1 kg a.i/ ha) at 10 days after sowing (DAG) reported minimum incidence of *P. affinis* (15.13 %) with a yield of 1102.88 kg/ ha. The cotton crop inter cropped with Cluster bean, Maize, Green gram and Field bean recorded significantly less plant mortality due to stem weevil (2.2 to 2.8 per cent). Highest cotton yield recorded with cotton crop inter cropped Cluster bean and Green gram (860 and 838 Kg/ha). Spray application of chlorantraniliprole 18.5 SC at 0.3 ml/ l or clothianidin 50 WDG at 0.2 g/ l were equally effective which showed 74.54 and 60.02 per cent reduction of *P. affinis* over untreated check and recorded 1216.05 and 1203.35 kg/ ha cotton yield, respectively.

Keywords: Cotton, stem weevil, *Pempherulus affinis*, biointensive methods, chemical control

1. Introduction
Cotton is an important commercial crop in India playing a major role in Agricultural economy. In Tamil Nadu during 2017-18, cotton is cultivated with an average area, production and productivity of 1.48 lakh ha, 6.00 lakh bales and 689 kg/ ha, respectively [24]. Cotton is being ravaged by several insect pests contributing to drastic reduction in yield. As many as 1326 insect and mite pests all over the world [7] and about 200 in India have been documented, of which 10 are economically important in Tamil Nadu [23]. Of the economically important insect species next to bollworms, the cotton stem weevil, *Pempherulus affinis* Faust. has been reported as a major pest in South India [6, 1, 15, 11, 3]. It has attained some notoriety in South India as a pest of exotic and indigenous cotton, and was at one time looked upon as the most serious enemy of the 'raiyat' in cotton growing tracts.
It is not definitely known when and how this pest was introduced into this country; in fact, it is even difficult to say whether it is one of the introduced forms at all; although the nature of its scattered and somewhat isolated distribution would appear to indicate its exotic origin. When first noticed in South India, particularly in Cambodia cotton. Since then, it has spread to almost every cotton growing centre of the presidency and to all types of cotton [5]. Adult weevil excavates a small hole on the stem and oviposits. The grubs tunnel into the stems and branches. Grubs also damage roots of young seedlings. Swelling of the stem just above the ground resulting in a gall and wilting of seedlings is seen.
In the recent years, farmers tend to raise cotton during the off-season *i.e.*, during winter season in summer irrigated cotton tract in southern Tamil Nadu *viz.*, Madurai, Theni, Salem, Erode, Dindigul and Virudhunagar districts. Similarly, farmers of winter cotton tract opt for an additional summer crop. Under such conditions, mortality of cotton plants due to stem weevil is more than 60 % and becoming serious botheration to cotton growers [12]. Stem weevil, *P. affinis* has been reported as a major pest of "Cambodia cotton" in South India and infestation occurs on 12 to 15 days old seedlings, which can cause the mortality up to 90% [8].
Thus, cotton stem weevil is found to be a serious menace in the southern parts of Tamil Nadu and the control measures so far evaluated and advocated with fair degree of success are too little. Bio efficacy of newer molecules and semio-chemicals need to be studied for devising

effective management strategies. The use of neem in Integrated Pest Management due to its relative safety to natural enemies as compared to synthetic insecticides [4]. At present some of the IPM strategies like, reduced cropping intensity, removing affected and dried plants, burning of gall plants at harvest are available, but it is not sufficient to manage these pest. More IPM strategies are needed. Hence, it is the need of the hour to develop suitable Integrated Pest Management strategies for controlling the incidence of stem weevil.

2. Materials and Methods

2.1 Incidence of stem weevil at different dates of sowing

Field experiments were conducted at Agricultural Research Station, Kovilpatti, Tamil Nadu Agricultural University, Tamil Nadu during 2015 - 2017 under rainfed in natural condition. To determine the severity of damage caused by the cotton stem weevil, the cotton seeds were sown at four different dates and assessed for the stem weevil infestation at fortnightly intervals throughout the cropping period and the per cent damage was worked out and the extent of damage was recorded.

2.2 Evolving suitable inter crop for the management of stem weevil

Cotton crop was intercropped with Black gram (*Vigna mungo*), Green gram (*Vigna radiate*), Cowpea (*Vigna unguiculata*), Bhendi (*Abelmoschus esculentus*), Cluster bean (*Cyamopsis tetragonoloba*), Field bean (*Lab lab purpureus var lignosus*) and Onion (*Allium cepa*). Sowing was taken with KC2 Cotton in Randomised Block Design. Stem weevil incidence were recorded.

2.3 Evaluation of bio-intensive methods against cotton stem weevil, *P. affinis*

The different bio-intensive methods were evaluated under field conditions and the effective method was identified. The treatments are as follows. T_1: Basal application of FYM 25 t/ ha and neem cake @ 250 kg/ ha; T_2: Seed treatment with *Beauveria* and *Pseudomonas* at 10 g/kg and soil application at 2.5 kg/ ha at 15 and 25 DAS and earthing up; T_3: Stem drenching with neem seed extract 5 % four times at weekly intervals from 10 DAS; T_4: Application of neem cake 150 kg/ ha + carbofuran (1 kg a.i/ ha) at 10 - 15 DAS; T_5: Growing of marigold as intercrop and incorporation into the soil at 30 DAS; T_6: Intercropping with Bhendi; T_7: Seed treatment with chlorpyriphos 20 EC at 10 ml/ kg of seeds and drenching with 2.5 ml/ l four times from 10 DAS; T_8: Untreated check. Stem weevil incidence (Presence of gall) and Seed cotton yield were recorded.

2.4 Effect of different insecticides against cotton stem weevil, *P. affinis*

The different insecticides belonging to various groups were evaluated in the field condition and the efficacious insecticides against *P. affinis* were screened. Treatment details are as follows. T_1: Flubendiamide 20 WG @ 0.50 g/ l; T_2 : Fipronil 5 SC @ 2.0 ml/ l; T_3: Chlorantraniliprole 18.5 SC @ 0.30 ml/ l; T_4 : Imidacloprid 17.8 SL @ 0.30 ml/ l; T_5 : Clothianidin 50 WDG @ 0.20 g/ l; T_6 : Triazophos 40 EC @ 3.0 ml/ l; T_7 : Chlorpyriphos 20 EC @ 2.5 ml/ l; T_8 : Monocrotophos 36 SL @ 2 ml/ l; T_9 : Carbofuran 3 G @ 1.5 g/ plant; T_{10} : Untreated check. The experiment was laid out in Randomized Block Design (RBD) with ten treatments including check and each treatment was replicated three times. Plant mortality due to stem weevil, Stem weevil incidence (Presence of gall) and Seed cotton yield were recorded.

3. Results and Discussion

3.1 Influence of different dates of sowing on stem weevil incidence

The extent of damage caused by cotton stem weevil at four different dates of sowing showed that the crop raised during the post monsoon period (42nd std week) experienced more damage (51.94%) when compared to the crop sown during pre monsoon (38th std week) season (37.17%) (Fig 2). The study on the impact of time of sowing and sun drying of cotton stalks on the management of cotton stem weevil, *P. affinis* in South India and the results contrary to our findings that in early sown cotton crop stem weevil infestation and plant mortality was more when compared to the late sown cotton crop [12]. In Maharastra 16th March sowing resulted in less incidence of leafhoppers, aphids, whitefly and bollworms [13], whereas delayed sowing at 1st May recorded the highest incidence of pests. Samewhile, higher incidence of pink bollworm and leafhoppers were noted in late sown cotton[16]. Higher incidence of stem weevil reported in the crop sown on August 1 compared to that crop sown in August 16 and August 30 [21].

3.2 Suitable inter crop for the management of stem weevil in cotton

The cotton crop inter cropped with Cluster bean, Maize, Green gram and Field bean recorded significantly less plant mortality due to stem weevil *i.e.* 2.2 to 2.8 per cent. The cotton crop inter cropped with Black gram, Cowpea and Bhendi were the next best in recording less plant mortality due to stem weevil *i.e.* 2.9 to 3.1 per cent, whereas the cotton crop raised alone recorded 8.1per cent plant mortality due to stem weevil. The cotton crop inter cropped with Green gram, Cowpea, Cluster bean, onion, Maize, Black gram, Bhendi, and Field bean recorded less stem weevil incidence *i.e.* 8.8 to 10.6per cent, whereas the cotton crop raised alone recorded 31.3 per cent stem weevil incidence (Fig 1). Regarding yield the cotton crop inter cropped with Cluster bean and Green gram recorded significantly high seed cotton yield of 860 and 838 Kg/ha respectively, whereas the cotton crop raised alone recorded 642 Kg/ha. The influence of intercrops on the incidence of major pests of cotton was studied in different IPM modules by [2] and reported that *Amrasca devastans*, *Bemisia tabaci*, *Aphis gossypii* and *Earias* Sp. showed more preference on bhendi and the leaf eating caterpillar *Spodoptera litura* preferred castor, sunflower and bhendi. In addition, the presence of intercrops (bhendi and sunflower) in cotton attracted a proportionate population of pests from cotton as well explained by Singh *et al*., 1993 and Simwat, 1994. Lower aphid population was noted on cotton + cowpea [14], cotton + greengram [22] than sole cotton. There was a decrease in sucking pests when cotton intercropped with cowpea, black gram and green gram [19].

3.3 Bio-intensive methods against cotton stem weevil, *P. affinis*

The efficacy of different biointensive methods against cotton stem weevil, *P. affinis* revealed that application of neem cake 150 kg/ ha + carbofuran (1 kg a.i/ ha) at 10 DAS exerted a damage of 15.13 per cent which is on par with the treated

check (16.60%). All the treatments were superior over untreated check which recorded the damage of 37.93 per cent (Table 3). The yield obtained from the application of neem cake 150 kg/ ha + carbofuran (1 kg a.i/ ha) at 10 DAS was 1102.88 kg/ ha and was on par with the treated check which recorded 1063.37 kg/ ha. Bio intensive Integrated Pest Management (including pathogens, parasitoids and border crop) modules for cotton were tested and reported that natural enemies population were more in BIPM modules than the Farmers practices module [18]. Neem cake @150 kg/ha + 1% neem oil drenching and earthing up on 25 days after sowing found to be effective after carbofuran @ 30 kg/ha soil application [10]. However, our findings neem cake 150 kg/ ha + carbofuran (1 kg a.i/ ha) at 10 DAS exerted maximum stem weevil reduction.

3.4 Effect of different insecticides against cotton stem weevil, *P. affinis*

The efficacy of different insecticide molecules against cotton stem weevil revealed that on 30 days after sowing (DAS) the minimum infestation of stem weevil (6.03 %) was noticed in chlorantraniliprole 18.5 SC at 0.3 ml/ l and 7.27 per cent by clothianidin 50 WDG at 0.2 g/ l. Chlorantraniliprole 18.5 SC at 0.3 ml/ l and clothianidin 50 WDG at 0.2 g/ l gave 74.54 and 60.02 per cent control of stem weevil, respectively and were superior over the untreated check (Table 3). Based on the damage caused by cotton stem weevil, the order of toxicity of different insecticides is as follows: chlorantraniliprole 18.5 SC > clothianidin 50 WDG > chlorpyriphos 20 EC > carbofuran 3 CG > flubendiamide 20 WG > monocrotophos 36 SL > imidacloprid 17.8 SL > triazophos 40 EC > untreated check. The treatments chlorantraniliprole 18.5 SC at 0.3 ml/ l and clothianidin 50 WDG at 0.2 g/ l recorded higher yield of 1216.05 kg/ha and 1203.35 kg/ ha, respectively. In our study recent chemicals which are recommended for cotton are tested and results showed that the chemicals *viz*., chlorantraniliprole 18.5 SC at 0.3 ml/ l and clothianidin 50 WDG at 0.2 g/ l recorded maximum stem weevil reduction and high yield. It may be due to the contact and systemic action of the newer chemicals *viz*., chlorantraniliprole and clothianidin against stem weevil. Ratna Kumara *et al*. (2008) reported that Chlorpyriphos @ 5 ml/l excelled all other treatments in minimizing the stem weevil infestation, followed by lindane, carbaryl 50 WP, neem oil 0.03%, profenophos 50EC and neem cake. Among the many recent chemicals tested Clothianidin 50 per cent WDG @ 20 g a.i./ha was the most effective treatment in reducing incidence of sucking pests on *Bt* cotton [9]. Though many chemicals were identified for sucking pest management in cotton, proven new chemicals against stem weevil in this paper will be very useful for the cotton growers.

Table 1: Incidence of stem weevil at different dates of sowing

Date of sowing	Stem weevil incidence (%)							Mean
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	
Pre-monsoon Sep. 21st (38th)	19.25 (25.93)	25.63 (30.33)	32.89 (34.94)	37.76 (37.87)	43.84 (41.45)	49.10 (44.48)	51.77 (46.01)	37.17
Monsoon I Oct. 1(40th)	21.80 (27.70)	27.81 (31.74)	35.90 (36.76)	47.17 (41.64)	49.49 (44.70)	52.53 (46.45)	57.12 (49.12)	41.26
Monsoon II Oct.10 (41st)	25.32 (30.13)	34.70 (36.02)	40.59 (39.55)	49.66 (44.80)	54.95 (47.86)	58.89 (50.16)	63.00 (52.59)	46.73
Post-monsoon 20.10 (42nd)	32.29 (34.51)	39.39 (38.84)	48.16 (43.94)	54.32 (47.49)	56.60 (49.77)	63.17 (52.74)	68.01 (55.69)	51.94
SE.D	1.293	1.508	1.14	0.983	0.994	1.118	0.604	-
CD (p = 0.05)	2.812	3.29	2.50	2.143	2.16	2.43	1.31	-

DAS - Days after sowing; Figures in the parentheses are arc sine transformed values

Table 2: Evaluation of bio-intensive methods against cotton stem weevil, *P. affinis*

Treatments	Stem weevil incidence (%)				Mean	Reduction over control (%)	Yield (kg/ ha)
	30 DAS	60 DAS	90 DAS	120 DAS			
Basal application of FYM 25 t/ ha and 250 kg/ ha of neem cake	16.82 (24.15)	21.69 (22.67)	24.00 (29.37)	26.03 (30.42)	22.16	41.58	944.44
Seed treatment with *Beauveria* and *Pseudomonas* (10 g/kg) and soil application at 2.5 kg/ha at 15 and 25 DAS and earthing up	19.94 (26.41)	23.43 (28.94)	26.04 (31.01)	28.66 (32.29)	24.65	35.03	915.63
Stem drenching with neem seed extract 5 % four times at weekly intervals from 10 DAS	13.43 (21.41)	18.06 (25.12)	19.39 (26.07)	22.93 (28.57)	18.40	51.48	993.57
Application of neem cake 150 kg/ ha + carbofuran (1 kg a.i./ ha) at 10 DAS	10.06 (18.43)	14.23 (22.12)	16.96 (24.25)	19.42 (26.46)	15.13	60.12	1063.37
Growing of marigold as intercrop and incorporation into the soil at 30 DAS	22.31 (24.95)	26.59 (30.97)	27.90 (31.81)	29.98 (33.57)	26.78	26.63	853.91
Intercropping with bhendi	24.52 (29.64)	27.71 (31.72)	29.61 (32.94)	32.26 (34.50)	28.43	25.05	781.86
Seed treatment with chlorpyriphos 20 EC at 10 ml/ kg of seeds and drenching with 2.5ml/ l four times from 10 DAS	9.32 (17.60)	14.32 (22.08)	16.18 (23.67)	18.63 (25.56)	16.60	61.50	1086.42
Untreated check	28.87 (32.42)	37.47 (37.72)	41.35 (40.01)	44.06 (44.09)	37.93	-	692.38
SE.D	1.55	1.39	1.33	1.29	-	-	35.75
CD (p=0.05)	3.33	2.99	2.87	2.77	-	-	76.69

DAS - Days after sowing; Figures in the parentheses are arc sine transformed values

Table 3: Effect of different insecticides against cotton stem weevil, *P. affinis*

Treatments	Dose (g or ml/l)	Stem weevil incidence (%)				Mean	Reduction over control (%)	Yield (kg/ ha)
		30 DAS	60 DAS	90 DAS	120 DAS			
Flubendiamide 20 WG	0.5	12.92 (21.01)	14.41 (22.30)	17.35 (24.59)	19.86 (26.46)	16.14	50.81	1007.2
Chlorantraniliprole 18.5 SC	0.3	6.03 (14.16)	7.90 (16.26)	9.19 (17.58)	10.19 (18.59)	8.33	74.54	1216.05
Imidacloprid 17.8 SL	0.3	14.52 (23.30)	20.29 (26.64)	20.88 (27.13)	22.92 (28.59)	19.62	40.48	909.46
Clothianidin 50 WDG	0.2	7.27 (15.71)	9.80 (18.75)	10.81 (19.17)	12.31 (20.51)	10.16	69.02	1203.35
Triazophos 40 EC	3.0	15.71 (23.32)	20.40 (26.82)	22.15 (28.05)	23.93 (29.27)	15.92	37.62	859.05
Chlorpyriphos 20 EC	2.5	8.95 (17.36)	11.10 (19.43)	13.14 (21.22)	14.59 (22.43)	11.94	63.62	1116.51
Monocrotophos 36 SL	2.0	13.36 (21.42)	15.35 (23.05)	17.08 (23.31)	19.78 (26.38)	16.40	50.10	1016.46
Carbofuran 3 G	-	11.68 (19.95)	13.98 (21.93)	19.01 (22.86)	16.71 (24.12)	14.38	56.19	1054.52
Untreated check	-	24.20 (29.44)	32.16 (34.53)	36.04 (36.87)	39.48 (38.91)	32.97	-	795.26
SE.D	-	1.34	1.27	1.33	1.07	-	-	37.87
CD (p=0.05)	-	2.83	2.71	2.82	2.60	-	-	80.29

DAS - Days after sowing; Figures in the parentheses are arc sine transformed values

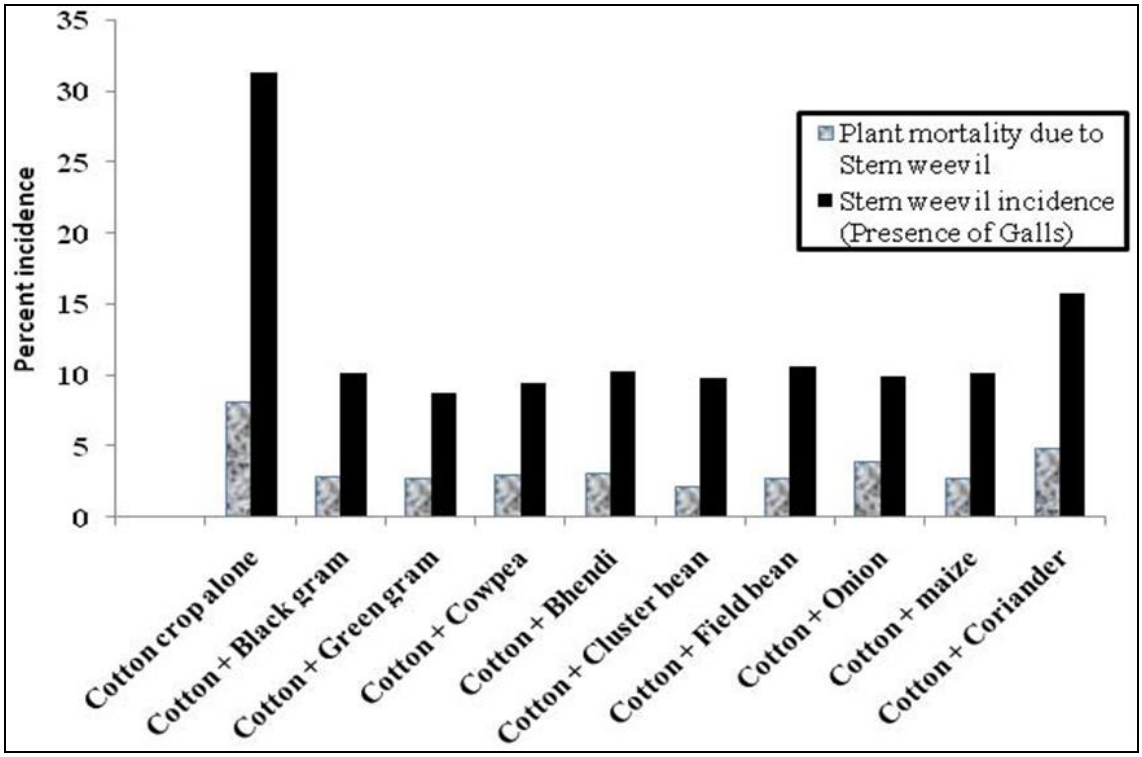

Fig 1: Evolving suitable intercrop in cotton to reduce stem weevil incidence (Pooled)

Fig 2: Cotton stem weevil, *P. affinis* infested plant

4. Conclusion

The present study concluded that pre-monsoon sowing (38th standard week) with application of neem cake 150 kg/ ha + carbofuran (1 kg a.i/ ha) at 10 days after sowing (DAG), inter cropped with Cluster bean and Green gram or application of new generation molecules chlorantraniliprole 18.5 SC at 0.3 ml/ l or clothianidin 50 WDG at 0.2 g/ l reported minimum incidence of stem weevil (15.13 %) and this strategies can be adapted by the cotton growers. These particular proposed Integrated Pest Management strategies can be incorporated under the umbrella of IPM for sustainable management of major insect pests of cotton from Integrated pest management point of view in near future.

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