YIELD LOSS ASSESSMET OF COTTON STEM WEEVIL, *PEMPHERULUS AFFINIS* (FAUST) IN PROTECTED (IPM MODULES AND FARMERS PRACTICE) AND UNPROTECTED CONDITION

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Abstract. The most devastating pest besides bollworm in cotton is stem weevil, *Pempherulus affinis* which decreases the cotton productivity as it affects the plant survival, boll production and seed cotton yield. The purpose of the investigation was to understand the infestation stage of the crop prone to heavy yield loss. The field experiment was carried out at Bannari, Erode district, India during summer 2021 to assess the yield loss caused by *P. affinis* in protected condition namely IPM module 1, IPM module 2 farmers' practice and unprotected condition. The results revealed that among the infested plants the mean survival of plants, boll production and yield was maximum in IPM module 2 of 90.10%, 20.90 bolls/plant and 29.93 g/plant respectively followed by farmers' practice with 89.25%, 11.37 bolls/plant and 29.17 g/plant respectively and the unprotected condition recorded the least mean survival of plants (82.25%), boll production (9.34 bolls/plant) and yield (23.87 g/plant). There was no significant difference among the treatments pertaining to mean survival of plants in healthy plants which recorded 100% survival. The mean number of bolls produced from healthy plants (at harvest) were high in IPM module 2 (20.90 bolls/plant) followed by farmers' practice which registered 19.87 bolls/plant while untreated plot recorded only 15.60 bolls/plant. The mean yield recorded from the healthy plants (at harvest) was 57.64 g/plant followed by farmers' practice (55.88 g/plant). The minimum yield of 39.24 g/plant was obtained in unprotected condition from healthy plants.
Keywords: *Pempherulus affinis, plant survival, boll production, stem gall, healthy plants, infested plants*

Introduction

Cotton is a significant cash crop which is affected by numerous pests leading to higher usage of pesticides in the ecosystem. India is one of the largest producer of cotton in the world accounting for about 26% of the world cotton production. During 2021–2022, India shares 11.91 million hectares with production of 31.20 million bales and productivity of 445 kg/ha (Agricultural statistics at a glance, 2022). *Pempherulus affinis* was earlier recorded as an important pest in Tamil Nadu (Ayyar, 1918), Andhra Pradesh, Karnataka, Bihar, Kerala, Orissa, Rajasthan, Uttar Pradesh, Gujarat and Assam (Khan and Rao, 1960). In all cotton growing districts of Tamil Nadu, particularly in Coimbatore, Madurai, Erode, Salem, Dharmapuri, Dindigul, Ramanathapuram and Nellai districts, *P. affinis* has been a major pest. The extensive outbreak of stem weevil was initially reported in Bhavanisagar and Gopichettipalayam due to the large-scale cultivation of improved varieties like MCU

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5 and MCU 9 and subsequently started spreading in other cotton growing areas (Thirumurthi et al., 1974).

Cotton production with high yielding long staple cotton varieties has increased though, the occasional outbreak of insect pests was one of the reasons of its decline (Parameswaran, 1983). Cotton grown in regular season, infested with *P. affinis* recorded only 10% mortality (Murugesan, 1998). The summer irrigated crops of Madurai, Theni, Salem, Erode, Dindigul and Virudhunagar districts were found to be infested with *P. affinis* severely and recorded 60% mortality (Murugesan et al., 2010).

The cotton plant infested by *P. affinis* is able to withstand the injury either by repair and development of galls or by releasing the gummy exudate at the infested site. The gummy exudate might kill the grub. There was 65.8% plant mortality, 72% boll reduction and 78.9% reduction of seed cotton yield. Symptoms are noticeable only when the damage by the pest has been completed (Parameswaran and Chelliah, 1983).

Integrated Pest Management leads to decrease in cotton pest population, reducing the pesticides usage level and ensures long term sustainability of agricultural ecosystem (Shelton and Badenses-Perez, 2006). The cotton crop is affected in both regular and off season by cotton stem weevil leading to heavy mortality of plants and yield loss. Thus the present study was undertaken in protected and unprotected condition to elucidate more information on the effect of IPM module against cotton stem weevil, infestation stage of the crop prone to yield loss.

Materials and methods

Field experiments was laid out in Bannari, Erode dt, India which is located at 11°32' N latitude and 77°7' E longitude with the plot size of 400 m^2 (plant density of around 1000 plants) for each treatments, during summer 2021, to assess the yield loss under protected condition *viz*., IPM module 1, IPM module 2, farmers' practice and unprotected condition (*Figs. 1–3*). The soil texture was red sandy soil. Co 17 (Short duration and high yielding) variety was sown during (5.4.2021) April 2021, with spacing of 90 cm × 45 cm following the agronomic practices of (Gunasekaran et al., 2020). A set of ten plants were tagged at each growth stage (30 DAS – seedling stage, 40-50 DAS- flowering stage, 50-60 DAS- Boll formation stage, 80-120 DAS- Maturation stage) when the symptoms of infestation were noticed. The experiment was designed in Randomized block design replicated thrice. The harvest was done at November 2021. Eight sets namely 30, 50, 65, 80, 90, 100, 110 and 120 days after sowing (DAS) were tagged and a set of uninfested healthy plants were also tagged at harvest. IPM components tested and farmers' practices are furnished below:

IPM module 1	Basal application of FYM 25 t/ha and 250 kg/ha of neem cake
	Seed treatment with carbosulfan 25 DS @ 15 g/kg of seed
	Soil drenching with carbosulfan 25 EC @ 250 g a.i/ha (1000 mL/ha) at 15 days after sowing (DAS)
	Placement of cotton stem bits (25 kg/500 box/ha) + chlorpyriphos dust 1.5 DP (2.5 kg/500 box/ha) @ 30 DAS followed by earthing up @ 30 DAS
	Border crop with *Jatropha curcas*
IPM module 2	Basal application of FYM 25 t/ha and 250 kg/ha of neem cake
	Seed treatment with *Beauveria bassania* @10 g/kg of seed
	Soil drenching with imidacloprid 17.80 SL @ 25 g a.i/ha (125 mL/ha) at 15 DAS
	Placement of cotton stem bits (25 kg/500 box/ha) + *Hibiscus cannabinus* stem bits (25 kg/500 box/ha) + chlorpyriphos dust 1.5 DP (2.5 kg/500 box/ha) @ 30 DAS followed by earthing up @ 30 DAS
	Border crop with *Hibiscus cannabinus*
Farmers' practice	Four rounds of plant protection chemicals at 30, 45, 60 and 80 Days after sowing (DAS)
Unprotected	-

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Observations were taken on survival of plants, number of bolls/plant, seed cotton yield from infested plants at 30, 50, 65, 80, 90, 100, 110, 120 DAS and healthy plants (at harvest). From this data, percent survival of plants (*Eq. 1*), percent boll reduction and percent seed cotton reduction were recorded.

$$\text{Survival (\%)} = \frac{\text{Number of plants survived with stem weevil infestation in tagged plants}}{\text{Total number of tagged plants}} \times 100 \quad \text{(Eq.1)}$$

Statistical analysis

The data on percent survival of plants were transformed into arc sine transformation. The data on number of bolls and yield were subjected to square root transformation. The Duncan's Multiple Range Test (DMRT) was used to compare the treatment means. In the tables presented, the means which were significantly different at 5 percent level were designated with different letters in each column and zero values were analyzed using $\sqrt{x} + 0.5$ transformations (Gomez and Gomez, 1984).

Results

Yield loss by cotton stem weevil on plant survival, boll production, and yield in IPM module 1

The percentage of plant survival was at its lowest (76.66%) in crops aged 30 days, with slightly higher survival rates observed in crops aged 50 days (80.00%), 65 days (80.00%), and 80 days (83.33%). Plant survival tended to decrease in the earlier stages of crop age (*Table 1).* However, survival rates reached 90.00% in crops aged 90 and 100 days. In the later stages, namely 110 and 120 days, no plant mortality was observed, with a mean survival rate of 100.00%. Boll production per plant varied across crop ages, with 3.90 bolls per plant in 30 days old crops, 4.30 in 50 days old crops, 6.90 in 65 days old crops, and 11.87 in 80 days old crops. Beyond 80 days, there was a gradual increase in boll production. Infested plants in crops aged 90, 100, 110, and 120 days exhibited higher boll counts per plant, ranging from 14.43 to 14.96. The percentage reduction in boll production was lowest (16.42%) in 120 days old crops and highest (78.21%) in 30 days old crops. Yield per plant also varied, with the lowest recorded in 30 days old crops (10.17 g/plant) and the highest in crops aged beyond 80 days (ranging from 35.81 to 36.68 g/plant).

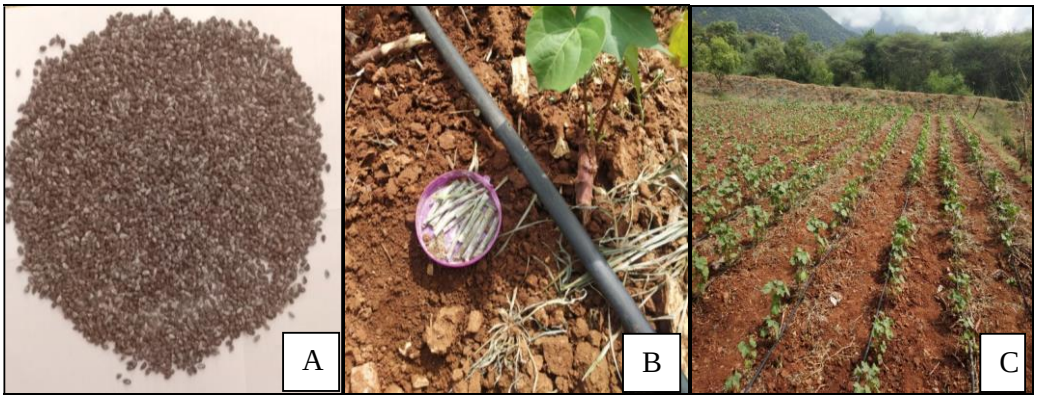

Figure 1. *(A) Seed treatment with B. bassiana. (B) Cotton stem + H. cannabinus stems mixed with chlorpyriphos dust. (C) Earthing up*

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Figure 2. *IPM module I and 2*

Figure 3. *Farmers practice and unprotected condition*

Table 1. *Yield loss due to P. affinis assessed in IPM module 1*

Crop age at infestation (days)	Mean survival of plants (%)*	No. of bolls/plant**			Cotton yield (g/plant)**		
		Infested plants	Healthy plants	Percent reduction	Infested plants	Healthy plants	Percent reduction
30	76.66 (61.19)[a]	3.90 (2.21)[a]	-	78.21	10.17 (3.34)[a]	-	79.28
50	80.00 (63.41)[ab]	4.30 (2.31)[a]	-	75.81	12.28 (3.70)[b]	-	74.98
65	80.00 (63.41)[ab]	6.90 (2.82)[b]	-	61.45	15.49 (4.06)[c]	-	68.44
80	83.33 (66.12)[b]	11.87 (3.59)[c]	-	33.69	26.94 (5.28)[d]	-	45.11
90	90.00 (71.54)[c]	14.43 (3.93)[d]	-	21.06	35.81 (6.07)[e]	-	27.04
100	90.00 (71.54)[c]	14.50 (3.94)[d]	-	18.99	36.26 (6.10)[e]	-	26.12
110	100.00 (90.00)[d]	14.70 (3.97)[d]	-	17.88	36.34 (6.11)[e]	-	25.96
120	100.00 (90.00)[d]	14.96 (3.99)[d]	-	16.42	36.68 (6.14)[e]	-	25.26
Harvest	-	-	17.90	-	-	49.08	-
SE.d	1.672	0.051	-	-	0.114	-	-
CD (P = 0.05)	3.653	0.110	-	-	0.247	-	-

Mean of three replications. *Figures in parentheses are arc sine transformed values **Figures in parentheses are square root transformed values. In columns, means followed by different letters significantly different at 5% level (Duncan's Multiple Range Test). 30 DAS – seedling stage, 40-50 DAS – flowering stage, 50-60 DAS – Boll formation stage, 80-120 DAS – Maturation stage

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Yield loss by cotton stem weevil on plant survival, boll production, and yield in IPM module 2

The percent survival of plants was the least (80.00%) in 30 days old crop followed by 50 days old crop of 83.33%. Both 65 and 80 days old crop recorded mean percent survival of plants of 86.66%. Plant survival was observed to be less pronounced with the early stages of the crop age. Later stages of beyond 80 days old crop recorded mean percent survival of plants of 93.33% and 96.66% in 90 and 100 days old crop. The 110, 120 days old crop exhibited no mortality of plants and mean percent survival of plants was 100%. The number of bolls produced per plant was minimum (4.20 bolls/plant) in 30 days old crop followed by 50 days old crop (5.23 bolls/plant), 65 days (7.56 bolls/plant) and 80 days old crop of 12.96 bolls/plant. The minimum number of bolls was noticed in the early stage infested crop. Later stages of the crop of beyond 80 days old recorded a progressive increase in boll output. The infested crop at 90, 100, 110 and 120 days old crop recorded increased number of bolls/plant of 16.03, 16.30, 16.80 and 16.93 respectively which are on par with each other. The lowest percent reduction (18.99%) was pronounced in 120 days old crop while the highest percent reduction was recorded in 30 days old crop of 79.90%. The yield recorded was minimum (11.01 g/plant) in 30 days old crop followed by 13.65, 17.54 and 30.56 g/plant in 50, 65 and 80 days old crop. There was decrease in yield with early stages of the crop age. Later stages viz., 90, 100, 110 and 120 days old crop recorded increase in the yield to the tune of 40.69, 41.05, 42.29 and 42.62 g/plant which were on par with each other respectively. The percent reduction was recorded minimum in 120 days old crop (26.06%) whereas maximum reduction was noticed in 30 days old crop (80.89%) followed by 76.32%, 69.57%, 46.98% in 50, 65 and 80 days old crop respectively (*Table 2*).

Table 2. *Yield loss due to P. affinis assessed in IPM module 2*

Crop age at infestation (Days)	Mean survival of plants (%)*	No. of bolls/plant**			Cotton yield (g/plant)**		
		Infested plants	Healthy plants	Percent reduction	Infested Plants	Healthy plants	Percent reduction
30	80.00 (63.90) [ab]	4.0 (2.23) [a]	-	79.87	10.99 (3.46) [a]	-	80.32
50	80.00 (63.41) [a]	4.93 (2.44) [b]	-	75.18	13.05 (3.75) [a]	-	76.64
65	83.33 (66.12) [ab]	7.37 (2.89) [c]	-	62.91	16.97 (4.24) [b]	-	69.63
80	86.66 (66.83) [ab]	12.10 (3.62) [d]	-	39.10	28.83 (5.46) [c]	-	49.48
90	90.00 (71.54) [bc]	15.13 (4.02) [e]	-	23.85	39.95 (6.40) [d]	-	28.51
100	93.33 (77.69) [c]	15.47 (4.05) [e]	-	22.14	40.15 (6.41) [d]	-	28.14
110	100.00 (90.00) [d]	15.87 (4.11) [e]	-	20.13	41.43 (6.51) [d]	-	25.86
120	100.00 (90.00) [d]	16.13 (4.14) [e]	-	18.82	41.96 (6.55) [d]	-	24.91
Harvest	-	-	19.87	-	-	55.88	-
SE.d	4.015	0.073	-	-	0.145	-	-
CD (P = 0.05)	8.694	0.158	-	-	0.315	-	-

Mean of three replications. *Figures in parentheses are arc sine transformed values **Figures in parentheses are square root transformed values. In columns, means followed by different letters significantly different at 5% level (Duncan's Multiple Range Test). 30 DAS – seedling stage, 40-50 DAS – flowering stage, 50-60 DAS – Boll formation stage, 80-120 DAS – Maturation stage

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Yield loss due to cotton stem weevil on plant survival, boll production, and yield in farmers' practices

The survival percentage of plants was recorded minimum (80.00%) in both 30 and 50 days old crop followed by 65 days old crop (83.33%) and 80 days old crop (86.66%). Plant survival was observed to be less pronounced with the early stages of the crop age (*Table 3*). Later stages of beyond 80 days old crop recorded mean percent survival of plants of 90.00% and 93.33% in 90 and 100 days old crop respectively. The later stages viz., 110, 120 days old crop recorded 100.00% mean survival of plants. The number of bolls produced per plant was the least (4.00 bolls/plant) in 30 days old crop followed by 50 days old crop (4.93), 65 days old crop (7.37 bolls/plant) and 80 days old crop of 12.10 bolls/plant. Minimum number of bolls was recorded in the early stage affected crop. The crop at the later stages of beyond 80 days old showed gradual increase in mean boll production. The infested crop in 90, 100, 110 and 120 days old recorded increased number of bolls/plant of 15.13, 15.47, 15.87 and 16.13 respectively which were on par with each other. The 120 days old crop recorded the lowest percent reduction of 18.82% while highest (79.87%) reduction was noticed in 30 days old crop. Minimum yield was recorded in 30 days old crop (10.99 g/plant) followed by 13.05, 16.97 and 28.83 g/plant in 50, 65 and 80 days old crop respectively. Decrease in yield was noticed with the early stage affected plants. Later stages viz., 90, 100 days old crop recorded increase in yield to the tune of 39.95, 40.15 g/plant followed by 110 days old crop (41.43 g/plant) and 120 days old crop (41.96 g/plant) which are on par with each other respectively. The lowest percent reduction was recorded minimum in 120 days old crop (24.91%) whereas the highest reduction was found in 30 days old crop (80.32%) followed by 76.64%, 69.63%, 49.48% in 50, 65 and 80 days old plants respectively.

Table 3. *Yield loss due to P. affinis assessed in Farmers' practice*

Crop age at infestation (days)	Mean survival of plants (%)*	No. of bolls/plant**			Cotton yield (g/plant)**		
		Infested plants	Healthy plants	Percent reduction	Infested Plants	Healthy Plants	Percent reduction
30	80.00 (63.90) [ab]	4.0 (2.23) [a]	-	79.87	10.99 (3.46) [a]	-	80.32
50	80.00 (63.41) [a]	4.93 (2.44) [b]	-	75.18	13.05 (3.75) [a]	-	76.64
65	83.33 (66.12) [ab]	7.37 (2.89) [c]	-	62.91	16.97 (4.24) [b]	-	69.63
80	86.66 (66.83) [ab]	12.10 (3.62) [d]	-	39.10	28.83 (5.46) [c]	-	49.48
90	90.00 (71.54) [bc]	15.13 (4.02) [e]	-	23.85	39.95 (6.40) [d]	-	28.51
100	93.33 (77.69) [c]	15.47 (4.05) [e]	-	22.14	40.15 (6.41) [d]	-	28.14
110	100.00 (90.00) [d]	15.87 (4.11) [e]	-	20.13	41.43 (6.51) [d]	-	25.86
120	100.00 (90.00) [d]	16.13 (4.14) [e]	-	18.82	41.96 (6.55) [d]	-	24.91
Harvest	-	-	19.87	-	-	55.88	-
SE.d	4.015	0.073	-	-	0.145	-	-
CD (P = 0.05)	8.694	0.158	-	-	0.315	-	-

Mean of three replications. *Figures in parentheses are arc sine transformed values **Figures in parentheses are square root transformed values. In columns, means followed by different letters significantly different at 5% level (Duncan's Multiple Range Test). 30 DAS – seedling stage, 40-50 DAS – flowering stage, 50-60 DAS – Boll formation stage, 80-120 DAS – Maturation stage

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Yield loss due to cotton stem weevil on plant survival, boll production, and yield in unprotected condition

The percent survival of plants was the lowest in 30 days old crop (73.33%) and in 50 days old crop (76.66%) followed by gradual increase of 80.00% in 65 days old crop and 83.33% in 80 days old crop (*Fig. 4*). Both 90 and 110 days old crop recorded 86.66% mean survival of plants. Later stages viz., 110 days old crop recorded 90% plant survival and 120 days old crop recorded no mortality of plants and percent survival of plants was 100.00%. The number of bolls produced per plant was 3.46 bolls/plant in 30 days old crop. The 50 days old crop recorded 4.03 bolls/plant, 65 days old crop of 6.06 bolls/plant and 80 days old crop of 10.83 bolls/plant. Later stages of the crop of beyond 80 days old crop recorded gradual increase in boll production. The infested plants at 90, 100, 110 and 120 days recorded increased number of bolls/plant of 12.26, 12.57, 12.60 and 12.93 respectively which are on par with each other. The lowest percent reduction (17.11%) was obtained in 120 days old crop while the highest percent reduction was documented in 30 days old crop of 77.82%. The yield recorded was minimum (9.53 g/plant) in 30 days old crop followed by 10.60 g/plant in 50 days old crop. The 65 and 80 days old crop recorded 14.47 and 24.25 g/plant respectively. The yield was observed to be less pronounced with early stage of crop age. Later stages of beyond 80 days old crop recorded increase in yield to the tune of 32.10, 32.81 in 90 and 100 days old crop respectively followed by 33.23 g/plant in 110 days old crop and 33.68 g/plant in 120 days old crop which are on par with each other. The lowest percent reduction was recorded in 120 days old crop (14.17%) whereas maximum reduction was noticed in 30 days old crop (75.71%) followed by 72.99%, 63.12, 38.20 in 50, 65 and 80 days old crop respectively.

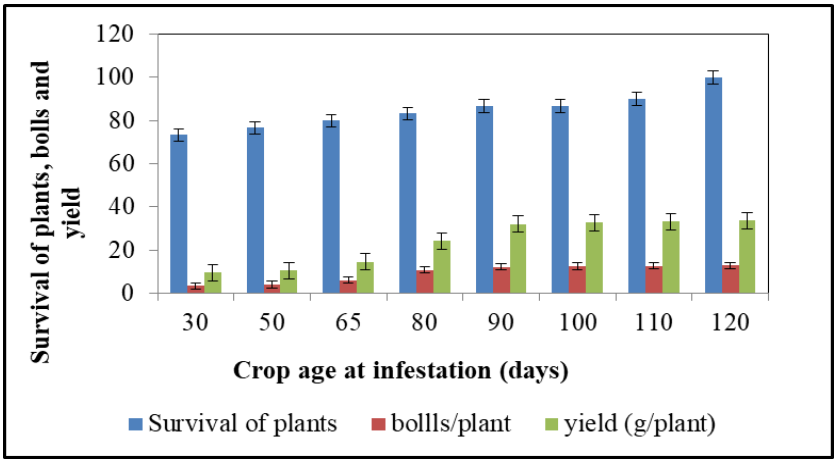

Figure 4. *Yield loss due to P. affinis assessed in unprotected condition*

Effect of IPM modules, farmers' practice and unprotected condition on percent survival of plants, boll production and yield in infested and healthy plants.

The results pertaining to mean percent survival of plants among infested plants revealed that IPM module 2 recorded maximum (90.10%) survival rate followed by farmers' practice of 89.25% survival of plants (*Fig. 5*). The IPM module 1 recorded mean percent survival of 87.60% whereas in unprotected condition it was only 82.25%. The mean percent survival of plants in all the treatments pertaining to healthy plants

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was 100.00% and there was no significant difference among the treatments. The mean number of bolls/plant in IPM module 2 was 12.00 among infested plants which was significantly different from other treatments followed by farmers' practice of 11.37 bolls/plant. In IPM module 1, it was 10.69 bolls/plant whereas in unprotected condition, it was only 9.34 bolls/plant. The results pertaining to healthy plants revealed that IPM module 2 recorded maximum (20.90) mean number of bolls/plants followed by farmers' practice of 19.87 bolls/plant. The IPM module 1 and unprotected condition registered mean number of bolls of 17.90 and 15.60 bolls/plant respectively. The mean yield was recorded maximum in IPM module 2 of 29.93 g/plant followed by farmers' practice (29.17 g/plant) among infested plants. In IPM module 1 and unprotected condition it was 26.24 and 23.87 g/plant respectively. In healthy plants, the mean yield obtained was maximum in IPM module 2 (57.64 g/plant) which are on par with farmers' practice (55.88 g/plant). The IPM module 1 recorded mean yield of 49.08 g/plant whereas unprotected condition registered only 39.24 g/plant. In general survival of plants, boll production and yield were more in healthy plants when compared to infested plants.

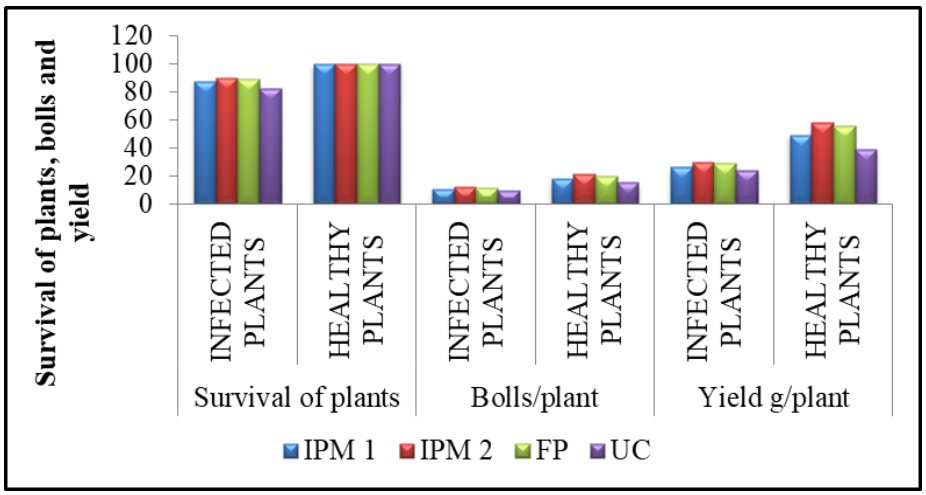

Figure 5. *Effect of protected condition (IPM modules, farmers' practice) and unprotected condition on percent survival of plants, bolls/plant and yield (g/plant) in healthy and infested plants*

Discussion

Priyatharsini et al. (2021) illustrated the infestation rate of stem weevil in IPM modules, farmers' practice and unprotected condition. The effect of IPM components against cotton stem weevil revealed that IPM module 2 recorded minimum percent stem weevil infestation of 13.21 followed by IPM module 1 (21.78) and 33.56% in farmers' practice. The mean survival of plants and yield was also high in IPM module 2 of 94.28% followed by farmers' practice of 88.57% and IPM module 1 recorded 80.00%. The maximum yield was obtained in IPM module 2 (1642.75 kg/ha) followed by farmers' practice (1588.25 kg/ha) and IPM module 1 recorded 1456.25 kg/ha.

The components integrated in IPM module results in less stem weevil incidence, high survival, boll production and yield compared to other module, farmers' practice and untreated plot. The present investigation is in agreement with the results of Mohan et al. (2009) who reported that the seed treatment performed with *Beauveria bassiana* prior to

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sowing which possessed endophytic nature resulted in endodermal thickening of stem tissues (hypersensitive reaction) and intact nature of xylem and phloem vessels prevented the movement of grub outside the cortex area. Akello et al. (2008) revealed that *Beauveria bassiana* was effective against Banana weevil (*Cosmopolites sordidus*) which reduced the survival rate of the grub supports our present findings. El Husseini (2019) proved that different concentration of *Beauveria bassiana* against Red palm weevil reduced the percent plant damage which is in accordance with our present findings. Application of liquid beauvericide (*Beauveria bassiana*) as a spray on the cv. Hill banana garden indicated the highest percentage (64.43%) of reduction in infestation of pseudostem weevil compared to untreated garden (Sharmila bharathi and Mohan, 2015). Purwar and Sachan (2005) reported that imidacloprid is more compatible with *B. bassiana* which can be used as an effective IPM component. Dannon et al. (2020) reported that the persistent use of chemical pesticides would leads to resistance to insects and this can be controlled by combining it with biopesticides like Beauveria bassiana in integrated pest management as it sounds environmentally safe and ensures crop quality.

The field experiments on yield loss assessment by cotton stem weevil under protected condition namely IPM modules, farmers' practice and unprotected condition (untreated plot) revealed that plant survival, boll production and yield was observed to be less pronounced with early stage of the crop (up to 80 days old) and later stage of the crop *viz.,* (110 and 120 days old) exhibited no mortality of plants and gradual increase in number of bolls and yield. Despite the IPM modules, farmers' practice and untreated plot, similar findings were revealed about the stage of the crop prone to infestation and only the percentage of survival, boll production and yield might differ based upon the treated treatments.

There is a reduction in survival of plants, boll production and yield in early stage affected crop and moderate amount of bolls and yield was produced by later stage affected crop. This may be due to the reason that the vigor of the plants gets affected as they are prone to infestation earlier thereby reduction occurs.

The present studies are in accordance with Parameswaran and Chelliah (1984) who opined that the mean number of bolls produced in 50 days old infested crop was 4.90 bolls/plant whereas the infested crop in 125 days old registered (14.90 bolls/plant) and the healthy plant recorded 17.50 bolls/plant. The mean seed cotton yield in 50 days old infested crop was 18.40 g/plant while the 125 days infested crop recorded 71.70 g/plant and the healthy plant recorded 87.30 g/plant and also stated that there was a reduction in survival of plants, number of bolls/plant and yield up to 80 days old infested crop.

The percent mean survival of plants among the infested plants was maximum in IPM module 2 (90.10%) and healthy plants recorded mean percent survival of 100.00% in all the treatments which was not significantly different from each other. The mean number of bolls/plant among the infested plants in IPM module 2 was maximum (12.00) and healthy plants recorded 20.90 bolls/plant which were significantly different from other treatments. The mean yield recorded among the infested plants was maximum in IPM module 2 (29.93 g/plant) and the healthy plants recorded the highest yield of 57.64 g/plant which were on par with farmers' practice of 55.88 g/plant.

Ayyar (1918) reported that even if the stem weevil cause infestation at later stage of crop growth, it did not cause high plant mortality but it might lead to yield loss due to lack of vigor. The present studies are in accordance with Krishnamoorthy et al. (2003)

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who reported that the higher seed cotton yield (1960 kg/ha) was obtained from IPM experimental plot which included seed treatment, application of neem cake @150 kg/ha, and border crops when compared to farmers' practice.

Kumari and Chandrasekaran (2008) reported that the plots treated with neem products such as neem cake, neem oil recorded lesser yield of 11.40, 12.65 q/ha respectively while chlorpyriphos treated plot recorded higher yield of 14.60 q/ha. Balakrishnan et al. (2005) reported that the basal application of FYM 12.50 t/ha and neem cake 250 kg/ha followed by earthing up recorded higher yield whereas basal application of FYM at 12.50 t/ha alone recorded lesser yield which supports our present findings.

Conclusion

Field investigation clearly indicated that the IPM module 2 exhibited less stem weevil infestation, high mean survival of plants, boll production and yield compared to other module and farmers' practice. The study depicted that integration of components is very important rather than to rely completely upon chemicals. The bio control agent (endophytic nature of B*eauveria bassiana* - which kills the grub, helps to withstand the crop upon damage), earthing up at early stage resists egg laying at the collar region, soil drenching with imidacloprid, basal application with FYM and neem cake promoted the yield. All these individual factors jointly play an important role in reducing stem weevil infestation and promote survival of plant, bolls and yield.

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