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# Influence of Ecological Engineering on Major Lepidopteron Pests and Natural Enemies of Paddy in Tungabhadra Project Area

***Raghavendra Yaligar*, Shivanna B.K., Sreenivas A.G., Jaylaxmi Narayana Hegde and Sharanabasappa***
*Krishi Vigyana Kendra, Gangavathi, College of Agriculture, Shivamogga, College of Agriculture, Raichur, University of Agricultural and Horticultural Sciences, Shivamogga, (Karnataka) India.*

*(Corresponding author: Raghavendra Yaligar*)*
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**ABSTRACT: Continuous usage of pesticides in paddy over several decades has resulted in the development of resistant strains of insects to insecticides and resistant cultivars and reduction in natural enemy population. The present investigation aims to make the agro-ecosystem suitable for the better survival of natural enemies of pests and habitat manipulation aims to provide natural enemies of pests with nectar, pollen, physical refuge, alternate prey, alternate hosts, and living sites. The experiment was conducted at ARS, Gangavathi, Koppal district during Kharif 2016 and rabi-summer 2016-17 to evaluate the influence of ecological engineering on major lepidopteron pests and natural enemies of paddy in Tungabhadra Project Area. The pooled data showed that the mean-field incidence of stem borer and leaf folder ranged from 1.26 to 5.38 and 0.78 to 3.33 percent, respectively. Among all ecological engineering crops, paddy + cowpea as bund crop significantly enhanced the more number of natural enemies population viz., spider (3.31/hill) and *Ophionea indica* (2.40/hill). In addition, suppress the incidence of stem borer i.e., dead heart (3.53 % with 34.39 % ROC), white ear (5.39 %), and the leaf folder damage (2.01 % with 39.64 % ROC). Followed by paddy + marigold and paddy + sunhemp bund cropping system. The egg mass parasitization and extent of egg parasitization of yellow stem borer were recorded highest in paddy + sunhemp was 38.40 per cent and 26.70 per cent, respectively. The maximum yield was recorded highest in the paddy + Cowpea cropping system. This approach is eco-friendly and conserves the natural enemy population through which the herbivorous insect pests can be managed.**

**Keywords:** Cowpea, ecological engineering, leaf folder, paddy and yellow stem borer.

## INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food crop for more than two-thirds of the population of India and plays a significant role in national food security and a means of livelihood for millions of people. Rice contributes about 42 per cent of total food grain production and 45 per cent of cereal production. As many as 100 species of insect pests are known to attack rice crops. Around 20 insects are considered pests of economic importance that include stem borers, gall midge, defoliators and vectors like leafhoppers and plant hoppers that cause direct damage and transmit various diseases (Pathak, 1970).

Continuous usage of pesticides over several decades has resulted in developing resistance strains of insects to insecticides and resistant cultivars and reducing the natural enemy population (Horgan *et al.,* 2016). These conditions leads to interest in recent times in the conservation of existing entomophagous in rice cropping systems with enhanced biological attributes through conservation biological control (CBC).

Ecological engineering is a relatively new concept of habitat manipulation for the benefit of man and the environment. Habitat manipulation is growing nectar producing flowering plants combined with trap plants on the rice bounds, reducing the intensity of pesticide use and nitrogenous fertilizers, and managing the vegetation in non-rice habitats including the rice-free season (Sree Latha and Jesu Rajan, 2018).

Application of ecological engineering for pest management includes the use of cultural practices, usually based on vegetation management to enhance biological control or the 'bottom-up' effects that act directly on pests (Gurr *et al.,* 2004). The latter include trap crops that divert pests away from crops and change monocultures to polycultures to reduce pest immigration or residency. Providing resources such as nectar and pollen to natural enemies promotes biological control. Habitat manipulation/management to enhance biological control has been explored in a wide range of crop systems (Landis *et al.,* 2000). These resources include alternate foods when prey or hosts are temporarily unavailable (Gurr, 2010).

In this article, the aim is to make the agro-ecosystem suitable for the better survival of natural enemies of pests, and habitat manipulation aims to provide natural enemies of pests with nectar, pollen, physical refuge, alternate prey, alternate hosts and living sites. This can be through the planting of appropriate companion plants like floral trap crops and repellent crops, through which the population of pollinators, predators and parasitoids can be enhanced to manage the herbivorous insect pests.

## MATERIAL AND METHODS

The field experiment was conducted during Kharif 2016 and rabi-summer 2016-17 at ARS, Gangavathi, Koppal district. The experiment was laid out in randomized block design with eight treatments and three replications. The rice seedlings of popular variety BPT-5204 for Kharif and rabi-summer were transplanted in well puddled and prepared soil with 20 m ´10 m spacing with a plot size of 10 m ´ 10 m for each treatment and after every replication a gap of one-meter width path was maintained.

| Tr. No. | Treatment details |
|---|---|
| T1 | Paddy + Cowpea* |
| T2 | Paddy + Sesamum* |
| T3 | Paddy + Okra* |
| T4 | Paddy + Marigold* |
| T5 | Paddy + Sunhemp* |
| T6 | Farmer's practice (FP) |
| T7 | Recommended Plant Protection Schedule (RPP) |
| T8 | Untreated control (Paddy alone) |

* Crops grown on paddy bund

Bunds were prepared around the paddy plot for each treatment and on bunds, the flowering plants, viz., cowpea, sesamum, okra and sun hemp, were sown two days after transplanting. In addition, twenty days old marigold seedlings were planted around the bunds. The standard agronomic practices as per the recommendation of UAS Raichur (Anon., 2017) were followed except plant protection measures.

Rice + bund crops did not receive any insecticide application throughout the cropping season. The farmer practice (FP) and recommended plant protection (RPP) schedule and control plots were maintained without bund crop. Recommended plant protection schedule received management practices as per UAS Raichur package.

## OBSERVATIONS

**Incidence of yellow stemborer*Scirpophaga incertulas* (Walker)**

Observation on per cent dead heart caused by yellow stem borer (YSB) was recorded by selecting ten random hills per treatment starting from 30DAT continued at ten days intervals i.e., 30, 40, 60 and, 70 DAT. However, during the reproductive stage, the per cent white ears were recorded in each treatment.

**Leaf folder *Cnaphalocrosis medinalis* (Guen) and Natural enemies**

Observations on leaf folder incidence was recorded by counting damaged leaves on 10 randomly selected hills in each plot at 15 days interval starting from 30 DAT i.e. 45, 60, 75, 90 and 105 DAT. The per cent leaf damage worked out by dividing a number of damaged leaves by a total number of leaves.

Observations were taken on natural enemies, mainly predatory population noticed during flowering plants grown on bunds from 30 DAT. The observations were recorded at an interval of 15 days and continued till harvest.

**Stem borer egg parasitization**

The extent of egg parasitism was determined from the egg masses laid by the female moth of *S. incertulas* during two consecutive cropping seasons. The egg mass containing leaves was cut to 2 cm length, which was transferred into the glass tube and kept in the laboratory. Before transferring to a vial, the lower end of the leaf was covered with moist cotton, which was put individually in a glass tube and plugged with cotton wool. The parasitoids emerged from egg mass and first instar larvae *of S. incertulas* and un-parasitized eggs were counted for determination of the extent of egg parasitism.

The percentage of egg parasitism was calculated using the following formula.

$$\text{Per cent parasitisation} = \frac{\text{Number of parasitoids emerged}}{\text{No. of parasitoids emerged + No. of YSB larvae emerged}} \times 100$$

## RESULTS AND DISCUSSION

*A. Yellow stem borer, S. incertulas (Walker)*

From the pooled mean data of Kharif-2016 and rabi-summer 2016-17, results documented that all the bund crops showed the same influence on stem borer incidence; they did not differ statistically and were found superior to UTC. Both RPP and FP maintained superiority compared to remaining treatments.

The lowest incidence of dead heart was recorded in paddy + cowpea bund crop 3.53 per cent with 34.39 per cent reduction of dead heart over UTC. The next best treatments were paddy + marigold (3.68 %) and paddy + sun hemp (3.90 %) were registered 31.60 and 27.51 per cent dead heart over UTC, respectively. Maximum dead heart incidence recorded in paddy + sesamum (4.11 %) and paddy + okra (4.27 %). Both of these treatments were registered 23.61 and 20.63 per cent reduction of dead heart over UTC. Whereas, RPP (1.26

%) and FP (1.52 %) were found significantly superior with a dead heart reduction of 76.58 and 71.75 per cent over UTC, respectively. Similarly, the influence of border crop on white ear incidence proved that, paddy + cowpea bund crop recorded the lowest white ear 5.39 per cent. Paddy + sun hemp (5.95 %) and paddy + marigold (6.11 %) were the next best treatments. The maximum white ear incidence was noticed in paddy + sesamum (7.18 %) and paddy + okra crop (7.28 %). Whereas, RPP (2.42 %) and FP (3.10 %) proved significantly the best treatments compared to different border crops. A higher level of dead heart incidence was noticed in UTC (10.55%) (Table 1).

*B. Leaf folder, C. medinals (Guen)*

The results of a field study on the impact of border crops on the leaf damage by leaf folder revealed that there was no significant variation in different border cropping. However, the pooled mean data revealed that paddy + cowpea (2.01 %), paddy + marigold (2.20 %) and paddy + sunhemp (2.21 %) recorded less per cent leaf damage. Whereas, RPP (0.78 %) and FP (0.90 %) were found significantly superior over other treatments, while UTC recorded the highest per cent leaf damage (3.33%) (Table 2). Overall per cent reduction over control revealed that paddy + cowpea, paddy + marigold and paddy + sunhemp were recorded 39.64, 33.93 and 33.63 per cent, respectively and these all three treatments performed better in reducing leaf damage. While RPP (76.58 %) and FP (72.97 %) recorded a maximum reduction of leaf damage.

*C. Natural enemies*

**Spider.** From the pooled data of Kharif-2016 and rabi-summer 2016-17, the highest mean spider population of 3.31 per hill with 101.83 per cent increase of spiders over UTC has noticed in paddy + cowpea followed by paddy + sun hemp (2.63 $hill^{-1}$ with 60.37 % increase over UTC), paddy + marigold (2.61 $hill^{-1}$ with 59.15 % increase over UTC) and Paddy + okra (2.53 $hill^{-1}$ with 54.27 % increase over UTC). However, RPP (1.23 spiders $hill^{-1}$) and FP (0.91 spiders $hill^{-1}$) recorded the lowest spider population and registered 25.00 per cent and 44.51 per cent reduction of spider population over UTC, respectively.

All the bund crops attracted natural enemies; among them, paddy + cowpea attracted significantly more number of natural enemies (Table 3).

**Carabid beetle, *Ophionea indica* (Pooled)**

Pooled results proved that, the highest mean population of *O. indica* was noticed in paddy + cowpea (2.40 $hill^{-1}$) with 118.18 per cent increased population over UTC. The next best treatments were paddy + marigold (1.86$hill^{-1}$), paddy + sunhemp (1.83$hill^{-1}$) and paddy + sesamum (1.73$hill^{-1}$) and were on par with paddy + cowpea treatment and registered 69.09, 66.36 and 57.27 per cent increase of *O. indica* population over UTC.

**Table 1: Influence of ecological engineering system on yellow stem borer, *Scirpophaga incertulas* incidence on paddy during *kharif* 2016 and *rabi* - summer 2016-17 (Pooled data).**

| Treatment | Per cent dead heart at different days after transplanting | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 | Mean | Reduction over UTC (%) | Per cent white ear |
| Paddy + Cowpea* | $2.95^b$ (9.85) | $4.92^b$ (12.81) | $4.80^b$ (12.64) | $3.58^c$ (10.87) | $1.41^b$ (6.80) | $3.53^b$ (10.82) | 34.39 | $5.39^c$ (13.41) |
| Paddy + Sesamum* | $3.11^b$ (10.10) | $5.62^b$ (13.71) | $5.46^b$ (13.50) | $4.69^b$ (12.51) | $1.68^b$ (7.43) | $4.11^b$ (11.68) | 23.61 | $7.18^b$ (15.54) |
| Paddy + Okra* | $3.30^b$ (10.46) | $5.90^b$ (14.06) | $5.71^b$ (13.82) | $4.74^b$ (12.56) | $1.68^b$ (7.45) | $4.27^b$ (11.91) | 20.63 | $7.28^b$ (15.65) |
| Paddy + Marigold* | $2.87^b$ (9.75) | $4.99^b$ (12.90) | $4.99^b$ (12.89) | $4.05^{bc}$ (11.59) | $1.51^b$ (7.02) | $3.68^b$ (11.02) | 31.60 | $6.11^{bc}$ (14.31) |
| Paddy + Sunhemp* | $3.10^b$ (10.13) | $5.31^b$ (13.31) | $5.24^b$ (13.22) | $4.21^{bc}$ (11.83) | $1.63^b$ (7.34) | $3.90^b$ (11.38) | 27.51 | $5.95^{bc}$ (14.11) |
| Farmer's practice | $1.44^c$ (6.85) | $1.68^c$ (7.41) | $1.88^c$ (7.88) | $1.86^d$ (7.83) | $0.73^c$ (4.90) | $1.52^c$ (7.00) | 71.75 | $3.10^d$ (10.11) |
| Recommended Plant Protection Schedule | $1.33^c$ (6.59) | $1.36^c$ (6.69) | $1.56^c$ (7.14) | $1.50^d$ (7.03) | $0.56^c$ (4.26) | $1.26^c$ (6.41) | 76.58 | $2.42^d$ (8.94) |
| Untreated control (UTC) | $4.17^a$ (11.75) | $7.32^a$ (15.65) | $7.04^a$ (15.38) | $6.19^a$ (14.38) | $2.18^a$ (8.48) | $5.38^a$ (13.41) | - | $10.55^a$ (18.88) |
| **S. Em (±)** | 0.39 | 0.48 | 0.44 | 0.44 | 0.26 | 0.44 | | 0.57 |
| **CD (≤0.05)** | 1.21 | 1.48 | 1.38 | 1.38 | 0.81 | 1.37 | | 1.77 |
| **CV (%)** | 7.25 | 6.93 | 6.43 | 7.01 | 6.85 | 7.37 | | 7.17 |

* Crops grown on paddy bund.

Figures in the parentheses are angular transformed values;

Means followed by same alphabet do not differ significantly by DMRT (≤0.05)

**Table 2: Influence of ecological engineering system on leaf folder, *Cnaphalocrocis medinalis* incidence on paddy during *kharif* 2016 and *rabi* -summer 2016-17 (Pooled data).**

| Treatment | Per cent damaged leaves at different days after transplanting | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 | 45 | 60 | 75 | 90 | 105 | Mean | Reduction over UTC (%) |
| Paddy + Cowpea* | $0.53^{b}$ (4.10) | $2.41^{c}$ (8.91) | $4.02^{b}$ (11.50) | $3.09^{c}$ (10.09) | $0.94^{c}$ (5.52) | $0.16^{c}$ (2.28) | $2.01^{c}$ (8.14) | 39.64 |
| Paddy + Sesamum* | $0.60^{b}$ (4.44) | $3.15^{b}$ (10.21) | $4.96^{b}$ (12.86) | $3.76^{bc}$ (11.17) | $1.31^{b}$ (6.57) | $0.23^{b}$ (2.72) | $2.52^{b}$ (9.13) | 24.32 |
| Paddy + Okra* | $0.67^{b}$ (4.69) | $3.22^{b}$ (10.32) | $4.95^{b}$ (12.85) | $3.82^{b}$ (11.26) | $1.37^{b}$ (6.70) | $0.22^{b}$ (2.57) | $2.57^{b}$ (9.18) | 22.82 |
| Paddy + Marigold* | $0.56^{b}$ (4.26) | $2.60^{bc}$ (9.28) | $4.28^{b}$ (11.93) | $3.49^{bc}$ (10.76) | $1.10^{bc}$ (6.01) | $0.21^{bc}$ (2.20) | $2.20^{bc}$ (8.53) | 33.93 |
| Paddy + Sunhemp* | $0.53^{b}$ (4.17) | $2.41^{c}$ (8.93) | $4.36^{b}$ (12.02) | $3.63^{bc}$ (10.97) | $1.13^{bc}$ (6.10) | $0.19^{bc}$ (2.21) | $2.21^{bc}$ (8.55) | 33.63 |
| Farmers' practice | $0.35^{c}$ (3.37) | $1.16^{d}$ (6.17) | $1.61^{c}$ (7.25) | $1.13^{d}$ (6.09) | $0.61^{d}$ (4.46) | $0.09^{d}$ (0.90) | $0.90^{d}$ (5.43) | 72.97 |
| Recommended Plant Protection Schedule | $0.28^{c}$ (3.01) | $1.18^{d}$ (6.23) | $1.33^{c}$ (6.61) | $0.88^{d}$ (5.34) | $0.57^{d}$ (4.32) | $0.06^{e}$ (0.78) | $0.78^{d}$ (5.05) | 76.58 |
| Untreated control (UTC) | $1.07^{a}$ (5.94) | $4.19^{a}$ (11.79) | $6.10^{a}$ (14.30) | $4.83^{a}$ (12.67) | $1.94^{a}$ (8.00) | $0.29^{a}$ (3.33) | $3.33^{a}$ (10.51) | - |
| **S. Em (±)** | 0.21 | 0.34 | 0.45 | 0.37 | 0.25 | 0.11 | 0.29 | |
| **CD (≤0.05)** | 0.67 | 1.07 | 1.39 | 1.15 | 0.78 | 0.35 | 0.91 | |
| **CV (%)** | 8.92 | 6.71 | 7.00 | 6.64 | 7.38 | 8.39 | 6.38 | |

* Crops grown on paddy bund
Figures in the parentheses are angular transformed values
Means followed by same alphabet do not differ significantly by DMRT (≤0.05)

**Table 3: Influence of ecological engineering system on population of spiders on paddy during *kharif* 2016 and *rabi*-summer 2016-17 (Pooled data).**

| Treatment | Population of spiders $hill^{-1}$ on paddy at different days after transplanting | | | | | | | Increase Over UTC (%) |
|---|---|---|---|---|---|---|---|---|
| | 30 | 45 | 60 | 75 | 90 | 105 | Mean | |
| Paddy + Cowpea* | $1.71^{a}$ (1.64) | $2.81^{a}$ (1.94) | $4.34^{a}$ (2.29) | $4.38^{a}$ (2.32) | $3.82^{a}$ (2.19) | $2.79^{a}$ (1.94) | $3.31^{a}$ (2.06) | 101.83 |
| Paddy + Sesamum* | $0.95^{b}$ (1.39) | $1.51^{bc}$ (1.58) | $2.73^{bcd}$ (1.93) | $2.62^{bc}$ (1.90) | $2.78^{a}$ (1.94) | $2.10^{ab}$ (1.76) | $2.12^{bc}$ (1.76) | 29.27 |
| Paddy + Okra* | $1.00^{b}$ (1.42) | $2.25^{a}$ (1.80) | $3.33^{ab}$ (2.08) | $3.46^{ab}$ (2.10) | $2.72^{a}$ (1.93) | $2.43^{a}$ (1.85) | $2.53^{ab}$ (1.88) | 54.27 |
| Paddy + Marigold* | $1.16^{ab}$ (1.47) | $2.05^{ab}$ (1.75) | $3.23^{abc}$ (2.05) | $3.39^{ab}$ (2.10) | $3.26^{a}$ (2.05) | $2.55^{a}$ (1.88) | $2.61^{ab}$ (1.90) | 59.15 |
| Paddy + Sunhemp* | $1.00^{b}$ (1.41) | $2.11^{ab}$ (1.76) | $3.35^{ab}$ (2.08) | $3.76^{a}$ (2.18) | $3.09^{a}$ (2.02) | $2.47^{a}$ (1.86) | $2.63^{ab}$ (1.90) | 60.37 |
| Farmer's practice | $0.25^{d}$ (1.12) | $0.84^{d}$ (1.35) | $1.24^{e}$ (1.50) | $1.35^{d}$ (1.53) | $0.84^{b}$ (1.36) | $0.96^{c}$ (1.70) | $0.91^{e}$ (1.38) | -44.51 |
| Recommended Plant Protection Schedule | $0.40^{cd}$ (1.18) | $0.96^{d}$ (1.40) | $1.86^{de}$ (1.69) | $1.80^{cd}$ (1.67) | $1.14^{b}$ (1.46) | $1.21^{c}$ (1.49) | $1.23^{de}$ (1.49) | -25.00 |
| Untreated control (UTC) | $0.75^{bc}$ (1.32) | $1.28^{cd}$ (1.51) | $2.32^{cd}$ (1.82) | $2.56^{bc}$ (1.89) | $1.43^{b}$ (1.56) | $1.52^{bc}$ (1.58) | $1.64^{cd}$ (1.62) | - |
| **S. Em (±)** | 0.05 | 0.06 | 0.08 | 0.07 | 0.08 | 0.07 | 0.08 | |
| **CD (≤0.05)** | 0.17 | 0.20 | 0.25 | 0.23 | 0.25 | 0.22 | 0.23 | |
| **CV (%)** | 7.44 | 7.16 | 7.70 | 7.01 | 8.06 | 7.51 | 7.94 | |

* Crops grown on paddy bund
Figures in the parentheses are $(\sqrt{x}+1)$ transformed values
Means followed by same alphabet do not differ significantly by DMRT (≤0.05)

**Table 4: Influence of ecological engineering system on population of *Ophionea indica* on paddy during *kharif* 2016 and *rabi*-summer 2016-17 (Pooled data).**

| Treatment | Population of *O. indica* hill$^{-1}$ on paddy at different days after transplanting | | | | | | | Increase Over UTC (%) |
|---|---|---|---|---|---|---|---|---|
| | 30 | 45 | 60 | 75 | 90 | 105 | Mean | |
| Paddy + Cowpea* | 0.59$^{a}$ (1.25) | 2.31$^{a}$ (1.80) | 3.21$^{a}$ (2.05) | 3.62$^{a}$ (2.15) | 2.56$^{a}$ (1.87) | 2.09$^{a}$ (1.76) | 2.40$^{a}$ (1.83) | 118.18 |
| Paddy + Sesamum* | 0.48$^{ab}$ (1.21) | 1.54$^{b}$ (1.59) | 2.22$^{bc}$ (1.77) | 2.70$^{ab}$ (1.92) | 1.87$^{ab}$ (1.69) | 1.58$^{ab}$ (1.61) | 1.73$^{a}$ (1.65) | 57.27 |
| Paddy + Okra* | 0.47$^{ab}$ (1.21) | 1.60$^{ab}$ (1.61) | 2.12$^{bc}$ (1.77) | 2.50$^{bc}$ (1.87) | 1.79$^{ab}$ (1.67) | 1.53$^{ab}$ (1.59) | 1.67$^{ab}$ (1.63) | 51.82 |
| Paddy + Marigold* | 0.54$^{ab}$ (1.23) | 1.53$^{b}$ (1.59) | 2.25$^{ab}$ (1.80) | 2.81$^{ab}$ (1.95) | 2.22$^{a}$ (1.79) | 1.82$^{a}$ (1.67) | 1.86$^{a}$ (1.68) | 69.09 |
| Paddy + Sunhemp* | 0.44$^{bc}$ (1.20) | 1.62$^{ab}$ (1.62) | 2.22$^{ab}$ (1.79) | 2.76$^{ab}$ (1.94) | 2.14$^{a}$ (1.77) | 1.80$^{a}$ (1.66) | 1.83$^{a}$ (1.68) | 66.36 |
| Farmer's practice | 0.22$^{e}$ (1.11) | 0.48$^{d}$ (1.22) | 0.72$^{d}$ (1.31) | 0.95$^{e}$ (1.39) | 0.73$^{d}$ (1.31) | 0.50$^{d}$ (1.22) | 0.60$^{d}$ (1.26) | -45.45 |
| Recommended Plant Protection Schedule | 0.32$^{cd}$ (1.15) | 0.70$^{cd}$ (1.30) | 1.20$^{d}$ (1.48) | 1.38$^{de}$ (1.54) | 1.10$^{cd}$ (1.45) | 0.81$^{cd}$ (1.34) | 0.92$^{cd}$ (1.38) | -16.36 |
| Untreated control (UTC) | 0.30$^{d}$ (1.14) | 0.89$^{c}$ (1.37) | 1.31$^{cd}$ (1.52) | 1.73$^{cd}$ (1.65) | 1.29$^{bc}$ (1.51) | 1.09$^{bc}$ (1.44) | 1.10$^{bc}$ (1.45) | - |
| **S. Em (±)** | 0.04 | 0.06 | 0.08 | 0.07 | 0.07 | 0.06 | 0.06 | |
| **CD (≤0.05)** | 0.14 | 0.18 | 0.25 | 0.21 | 0.21 | 0.20 | 0.19 | |
| **CV (%)** | 7.03 | 7.24 | 8.96 | 7.03 | 7.75 | 7.58 | 7.31 | |

*Crops grown on paddy bund

Figures in the parentheses are ($\sqrt{x}+1$) transformed values

Means followed by same alphabet do not differ significantly by DMRT (≤0.05)

While FP and RPP recorded 0.60 and 0.92 *O. indica* per hill along with 45.45 and 16.36 per cent reduction of *O. indica* over UTC, respectively (Table 4).

**Influence of ecological engineering system on egg mass parasitization and extent of egg parasitization of yellow stem borer**

The pooled data results revealed that, egg mass parasitization ranged from 38.40 per cent in paddy + sunhemp to 24.30 per cent in paddy + okra treatment. The treatment of paddy + marigold (31.60 %) egg mass parasitisation was statistically on par with paddy + sun hemp. RPP and UTC registered 16.70 and 17.90 per cent egg mass parasitisation, respectively and found statistically superior to farmer's practice (9.40%) (Table 5).

**Grain yield.** The pooled data on grain yield of paddy revealed that paddy + cowpea was the best ecological engineered crop which recorded a maximum yield of 45.92 q ha$^{-1}$and was statistically on par with paddy + sunhemp (43.34 q ha$^{-1}$) and paddy + marigold (42.94 q ha$^{-1}$). However, the recommended plant protection schedule and farmer's practice were superior to the remaining treatments and recorded 71.86 and 67.44 q ha$^{-1}$, respectively, as against UTC (31.99 q ha$^{-1}$) (Table 6).

Among all ecological engineering bund crops, paddy + cowpea was the best treatment which influenced on higher predator population *viz.*, spiders and carabid beetle present in the paddy + cowpea treatment. This may be the reason for the reduction of the pest problem. Stem borer parasitoids like *Trichogramma* sp. *Telenomous* sp. were recorded in cowpea bund crop were played a significant role in the reduction of stem borer and leaf folder population. These findings of the influence of bund crops on stem borer, leaf folder, and natural enemy population are in close confirmatory with results of Parasappa (2014), who observed minimum insect pests in sesamum and cowpea grown on bunds compared to rice fields free from flowering plants (Prabhu, 2015). Who reported the ecological engineering for pest management to help farmers maintain the biodiversity and keep pests under control. Analysis showed that natural enemies were able to maintain the pest population infesting the paddy crop; similarly, there was more predators attracted towards the leaves and flowers of cowpea overtime followed by leaves and flowers of sunflower and coriander (Deepika, 2016). Cowpea attracted more natural enemies, which may be due to cowpea is having two alcohols, ten alkane, one alkene and six acid compounds which may attract the predatory population to cowpea (Chandrashekar *et al.*, 2017). The population of spiders on paddy crop raised with sesamum bund crop attracted more number of spiders like *Lycosa pseudoannulata*, *Oxyopes Germanicus*, *Oxyopes salticus*, *Tetragnatha maxillosa* and *Tetragnatha mandibulate* (Parasappa, 2014).

**Table 5: Extent of egg parasitism of yellow stem borer in ecological engineering based paddy ecosystem during *kharif* 2016 and *rabi*- summer 2016-17 (Pooled data).**

| Treatment | *Kharif* 2016 | | | | *Rabi*-summer 2016-17 | | | | Pooled | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of egg masses collected | Number of egg masses parasitozed | Egg parasitized (%) | Extent of parasitization | Number of egg masses collected | Number of egg masses from parasitoids emerged | Egg masses parasitized (%) | Extent of parasitization | Egg masses parasitized (%) | Extent of parasitization |
| Paddy + Cowpea* | 17 | 5 | 29.41[bc] (32.66) | 26.47[a] (30.94) | 19 | 5 | 26.31[a] (30.76) | 22.50[ab] (28.30) | 27.9[b] (31.51) | 24.5[a] (29.65) |
| Paddy + Sesamum* | 21 | 8 | 33.33[b] (35.26) | 18.42[b] (25.41) | 21 | 4 | 19.04[bc] (25.87) | 20.00[b] (26.55) | 26.20[b] (30.78) | 19.2[b] (25.99) |
| Paddy + Okra* | 19 | 4 | 26.31[c] (30.86) | 20.68[b] (27.03) | 18 | 4 | 22.22[b] (28.12) | 17.14[bc] (24.45) | 24.3[bc] (29.51) | 18.9[b] (25.77) |
| Paddy + Marigold* | 23 | 9 | 39.13[a] (38.72) | 25.64[a] (30.41) | 25 | 6 | 24.00[b] (29.31) | 23.25[ab] (28.81) | 31.6[ab] (34.18) | 24.5[a] (29.54) |
| Paddy + Sunhemp* | 20 | 9 | 45.00[a] (42.13) | 27.27[a] (31.47) | 22 | 7 | 31.81[a] (34.31) | 26.19[a] (30.76) | 38.4[a] (38.29) | 26.7[a] (31.12) |
| Farmer's practice | 17 | 2 | 11.75[e] (20.02) | 12.00[c] (20.23) | 14 | 1 | 7.14[d] (15.48) | 13.79[bc] (21.76) | 9.4[e] (17.89) | 12.9[c] (21.04) |
| Recommended Plant Protection Schedule | 15 | 3 | 20.00[d] (26.55) | 16.66[b] (24.02) | 15 | 2 | 13.33[c] (21.40) | 14.63[bc] (22.42) | 16.7[d] (24.09) | 15.7[bc] (23.25) |
| Untreated control (UTC) | 11 | 2 | 18.18e (25.19) | 17.77[b] (24.89) | 17 | 3 | 17.64c (24.81) | 15.38[bc] (23.03) | 17.9[bcd] (25.01) | 16.6[bc] (24.02) |
| **S. Em (±)** | | | 1.41 | 1.07 | | | 1.18 | 1.07 | 1.64 | 0.98 |
| **CD (≤0.05)** | | | 4.35 | 3.31 | | | 3.65 | 3.31 | 5.05 | 3.03 |
| **CV (%)** | | | 7.78 | 6.95 | | | 7.83 | 7.23 | 9.83 | 6.49 |

* Crops grown on paddy bund
Figures in the parentheses are angular transformed values
Means followed by same alphabet do not differ significantly by DMRT (≤0.05)

**Table 6: Influence of ecological engineering system on grain yield of paddy.**

| Treatment | Grain yield (q $ha^{-1}$) | | |
|---|---|---|---|
| | ***Kharif* 2016** | ***Rabi*-summer 2016-17** | **(Pooled)** |
| Paddy + Cowpea* | 45.36$^{b}$ | 46.47$^{b}$ | 45.92$^{b}$ |
| Paddy + Sesamum* | 38.25$^{c}$ | 40.30$^{c}$ | 39.28$^{c}$ |
| Paddy + Okra* | 37.36$^{c}$ | 41.68$^{bc}$ | 39.52$^{c}$ |
| Paddy + Marigold* | 41.89$^{bc}$ | 43.98$^{bc}$ | 42.94$^{bc}$ |
| Paddy + Sunhemp* | 42.35$^{bc}$ | 44.33$^{bc}$ | 43.34$^{bc}$ |
| Farmer's practice | 66.35$^{a}$ | 68.53$^{a}$ | 67.44$^{a}$ |
| Recommended Plant Protection Schedule | 71.50$^{a}$ | 72.21$^{a}$ | 71.86$^{a}$ |
| Untreated control (UTC) | 31.58$^{d}$ | 32.40$^{d}$ | 31.99$^{d}$ |
| **S. Em (±)** | 2.31 | 1.91 | 1.90 |
| **CD (≤0.05)** | 5.71 | 5.73 | 5.74 |
| **CV (%)** | 6.96 | 6.71 | 6.86 |

* Crops grown on paddy bund

Means followed by same alphabet do not differ significantly by DMRT (≤0.05)

Wolf spider is considered an important predator because it feeds on the larvae and adults of stem borer, larvae of leaf folder and the nymphs and adults of *N. lugens* and *C. medinalis* (Fahad *et al.*, 2015). Sesame is unlikely to promote the longevities of key Lepidoptera pests, pink stem borer, yellow stem borer and rice leaf folders, although it does benefit the parasitoids (Zhu *et al.*, 2012; Zhu *et al.*, 2015). Zhongxian Lu *et al.* (2015) noticed that ecological engineering practices reduced the number of insecticides by more than 75 percent, but the yields in both areas with ecological engineering and farmers practices were above 10 tons per ha. There was no significant yield loss in the ecological engineering field (10.02 t $ha^{-1}$) compared with yields in farmer fields (10.27 t $ha^{-1}$). Vijayaraghavendra (2019) also recorded the significantly highest yield of 5568.77 kg per ha in paddy + sunhemp treatment with the highest B.C ratio of 1.63 followed by paddy + cowpea and paddy + okra with 4908.6 kg per ha and 4428.76 kg per ha yield, respectively and they were significantly on par with each other with B.C ratios of 1.43 and 1.29, respectively.

## CONCLUSION

In conclusion the experimental results with respect to the experiment conducted among the ecological engineering crops grown on paddy bunds paddy with cowpea recorded lowest stem borer incidence followed by paddy + marigold and paddy + sunhemp which recorded 34.39, 31.60 and 27.51 per cent reduction of dead heart over UTC, respectively. Similar trend was noticed in leaf damage caused by leaf folder paddy + cowpea, paddy + marigold and paddy + sunhemp which recorded lowest 39.64, 33.93 and 33.63 per cent reduction of leaf damage over control, respectively. Significantly highest yield of 45.92 q $ha^{-1}$ was obtained in paddy+cowpea treatment, followed by paddy+sunhemp (43.94q $ha^{-1}$) and paddy+marigold (42.94q$ha^{-1}$). The result reveals that the adoption of ecological engineering practices in paddy cultivation reduces the pest infestation and improves the productivity in an eco-friendly manner.

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