To study the ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame.

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

In partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE

In

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(ENTOMOLOGY)

By

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2020

CERTIFICATE – I

This is to certify that the thesis entitled **"To study the ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame."** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the **Department of Entomology** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Rotish Gour, ID. No. 180119011** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

All the assistance and help received during the course of the investigation has been acknowledged by him/her.

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This is to certify that the thesis entitled **"To study the ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame."** submitted by **Mr. ROTISH GOUR** to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the **Department of Entomology** has been, after evaluation, approved by the External Examiner and by Student's Advisory Committee after an oral examination on the same.

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I, **Rotish Gour** S/o **Omprakash Gour** certify the work embodied in the thesis entitled **"To study the ecological engineering method for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame"** is my own first time bonafide work carried out by me under the guidance of **Dr. A. K. Panday** Scientist/Assistant Professor (Entomology) at Project Coordinating Unit Sesame and Niger, College of Agriculture, JNKVV, Jabalpur (M.P) during *Kharif* season, 2019.

The matter embodied in the thesis has not been submitted for the award of any other degree/diploma. Due credit has been made to all the assistance and help.

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Place: Jabalpur

Date:…. /…/…… **(Rotish Gour)**

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LIST OF ABBREVIATION AND ERRATA

Abbreviation and Symbol	:	Stand for
@	:	At the rate of
±	:	Plus or minus
%	:	Percentage
^{0}C	:	Degree Centigrade
#	:	Numbers
T_1	:	Treatment
R_1	:	Replication
LP	:	Larval population
PD	:	Plant damage
FD	:	Flower damage
CD	:	Capsule damage
MC	:	Moisture content
RWC	:	Relative water content of flag leaf
WSD	:	Water saturation deficit
FW	:	Fresh weight
TW	:	Turgid weight
DW	:	Dry weight
SSB	:	Block sum of square
SST	:	Treatment sum of square
SSE	:	Error sum of square
SEm ±	:	Standard error of mean
CD	:	Critical difference
Cm	:	Centimeter
D	:	Days
DAS	:	Days after sowing
SW	:	Standard Week
r	:	Number of replications
t	:	't' value at 5% probability level
et al	:	Co-workers

Etc	:	et cetera
RH	:	Relative humidity
I	:	Immune
R	:	Resistant
MR	:	Moderately resistant
MS	:	Moderately Susceptible
S	:	Susceptible
HS	:	Highly susceptible
Gm/gm	:	Gram
ha^{-1}	:	Per hectare
h/Hrs/hrs	:	Hours
i.e.	:	That is
Kg/kg	:	Kilogram
L/l	:	Litre
Max.	:	Maximum
Mg/mg	:	Milligram
Min.	:	Minimum
mm	:	Millimeter
no.	:	Number
nos.	:	Numbers
NS	:	Non significant
NSKE	:	Neem seed kernel extract
Q	:	Quintal
Rs.	:	Rupees
Temp.	:	Temperature
Eve.	:	Evening
Mor.	:	Morning

INTRODUCTION

Sesame (*Sesamum indicum* L., Pedaliaceae) commonly known as 'Til, is an ancient oilseed crop and known as the "queen of oil seed. It is one of the major oilseed crop of India and grown in the entire crop growing season's *viz., kharif*, late *kharif* and *rabi*. East Africa and India are considered to be the native of sesame. It is cultivated in 78 countries belonging to many tropical countries whereas 73 per cent of global production comes from China, Ethiopia, India, Myanmar, Nigeria, Sudan and Tanzania (FAO, 2017). India ranks first in the area and production of sesame in the world. Sesame is mainly grown for its seed that contains 46 to 52 per cent oil, 20-26 per cent protein and high amount of minerals such as calcium, iron, and phosphorus (Gnanasekaran *et al*., 2010**).** Sesame oil is one of the most stable vegetable oils in the world because of the presence of some antioxidants (sesamin, sesamolin and sesamol and rich in carbohydrate, protein and minerals like calcium, iron, magnesium, manganese, phosphorus, zinc, copper, tryptophan, dietary fiber and thiamine. A hundred gram of seeds provide 592 calories. Sesame oil is not only used for edible purpose but also used in Ayurvedic medicine and as an antibacterial agent in preparation of mouthwash. Sesame seeds possess the cholesterol-lowering effect in humans and increase vitamin E supplies in animals (Chakraborthy *et al*., 2008). The most of the sesame production in the country is used for oil extraction (70-75%) and a considerable proportion is consumed as food (20-25%) in various forms and a very small quantity (2.2%) is retained for the seed every year. Sesame oil is used in the manufacture of soaps, cosmetics, perfumes, insecticides and pharmaceutical products. Sesame oil is important cooking oil in south India and substitute as the poor man's ghee. It is also used in perfumed oil as it does not itself possess any strong odour, especially after it is kept for some time and is able to absorb the fragrant essence of sweet-scented flowers. Lower grade of oil is used in soap making industries. The sesame oilcake is used as a cattle feed as well as it can also be used as manure. Sesame cake contains 6.0 to 6.2 per cent nitrogen 2.0 to 2.2 per cent phosphorous and 1.0 to 1.2 per cent potash. (Singh *et al.* 2007)

In India, Rajasthan, Madhya Pradesh, Uttar Pradesh, Gujrat, Andhra Pradesh, Karnataka, West Bengal, Maharashtra, Orissa, Punjab and Tamil Nadu are the major sesame growing areas of India (Anonymous, 2017-18). In India the area under sesame cultivation is about 715.7 thousand hectares with an annual production of 1544.9 thousand tones and an average productivity of 463 kg/ha while in Madhya Pradesh the total area is about 424 thousand ha with annual production of about 180 thousand tones and average productivity of 425 kg/ha *(*Anonymous*,* 2017-18*).* The productivity of sesame in India is low (463 kg/ha) and fluctuating.

Among various factors responsible for the low productivity levels of sesame damage caused by insect pests is one of the major constraints limiting the yield of the sesame. Twenty nine insect-pests have been reported to infest this crop at various stages of plant growth (Biswas *et al*., 2001; Kumar *et al*.**,** 2010*).* Among the 29 insect species, sesame leaf webber and capsule borer, *Antigastra catalaunalis (Duponchel*) is considered a serious pest. The leaf webber and capsule borer feeds on the tender foliage by webbing the top leaves and also bores into the shoots and pods (Sharma and Reddy, 1983; Sankar Narayanan and Nadarajan, 2005), and causing yield loss up to 68.2 per cent (Ahuja, 1990).

In a country like India, the production of sesame is already much below the expectation and therefore the damage due to insect pests are not desirable Among the various methods of insect pest management, use of insecticides forms the first line of crop protection against insect pests. Though synthetic insecticides stands first in the chain, eco-friendly method of insect pest management offers adequate level of pest control with the reduction of 3R (residue, resistance and resurgence) problems. Being an economically important crop and with changing scenario of pests in recent days, an updated list of pests attacking sesame is needed prior to planning IPM strategies. The application of ecological engineering for pest management includes 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*., 2004a). Keeping these facts in view the present investigation “To study the ecological engineering method for the

management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.)" in sesame has been taken up with following objectives:

Objective:

1. Evaluation of different ecological engineering method for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame
2. To study the succession of insect pests complex associated with sesame

REVIEW OF LITERATURE

The literature available on sesame leaf webber and capsule borer on various aspects is vast and voluminous, precisely in case of *Antigastra catalaunalis*. But keeping in mind the research work, the review of literature to the topic “To study the ecological engineering method for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame” is cited below:-

OBJECTIVE 1: Evaluation of different ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame.

Simons J. (1957) studied the effects of insecticides and physical barriers on field spread of pepper vein banding mosaic virus and reported that high, tall, barrier crops may act as mechanical barriers that impede insect colonization on the protected crop.

Root R.B. (1973) studied the organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards (*Brassica oleracea*) and reported that pests find it easier to locate host plants when grown in a monoculture versus a mixed planting. This is based on the “Resource Concentration Hypothesis” which says that plant-feeding insects are more likely to find and stay in more dense and less diverse patches of their host plants.

Gavarra and Raros (1975) found more predatory spiders and coccinellids in groundnut and maize intercropping system than in sole crop of groundnut.

Singh *et al*., (1991) studied the influence of intercropping on natural enemy complex in groundnut and reported that the groundnut main crop, when raised with sorghum as intercrop significantly reduced the thrips population by harbouring natural enemies like *Cheilomenus septumpunctata* and *C. sexmaculata.* They also concluded that the population of spiders was higher in intercropping system than that of sole crop.

Wu *et al*., (1991) reported that intercropping maize in cotton fields increased the population of Spiders, Coccinellids and Chrysopids by 62.8-115.7% compared to control fields.

Shanower *et al*., (1992) studied the effect of inter cropping on the incidence of larval parasitoids and pathogens of the groundnut leaf miner, *Aproaerema modicella* (and reported that intercropping of groundnut with pearl millet (*Pennisetum glaucum* L.) has particularly been found to increase the population of *Goniozus sp*., a parasitoid species that effectively manages leaf miner pest populations in groundnut.

Fereres A. (2000) evaluated different barrier crops as a cultural control measure of non-persistently transmitted aphid-borne viruses and reported that use of fast growing and tall cereal crops as barrier crops can be an effective crop management strategy to protect against virus infection.

Mahabaleshwar *et al*., (2003) noticed that average population of *C. carnea* and spiders were significantly high on cotton intercropped with lucerne, cowpea, and groundnut.

Midega and Khan (2003) studied the impact of a habitat management system on diversity and abundance of maize stemborer predators in western Kenya and reported that border crops increased the abundance of natural enemies like *Cheilomenes* sp. *Chrysoperala* sp, ants, ear wigs and spiders concurrently with reducing target insect pests in main crop.

Gupta (2003) studied the efficacy of neem products *viz.,* neem kernel extract in water or cow urine, neem gold, neem leaf extract in cow urine and neem oil for controlling the major pests (*Antigastra catalaunalis*) and (*Dasineura sesami*) of sesame and compared to that of endosulfan. Flower and capsule damage were lowest with the application of neem oil and endosulfan, respectively. Application of neem oil resulted in the lowest bud and flower damage (13.3%) and highest seed yield (665 Kg/ha) and net profit (Rs 2636/ha).

Ahirwar *et al.,* (2006) tested the efficacy of indigenous natural products like neem oil, neem leaf extract (NLE) ,neem seed kernel extract (NSKE), cow butter milk, Cow urine and garlic buds+ red pepper extracts in comparison to

the effects of endosulfan against the incidence of leaf roller/ capsule borer, *Antigastra catalaunalis* during *kharif* season 2003-2005.The results indicated that neem oil@10 ml/l.NLE (in cow urine) @ 30 ml/l, NSKE (in cow urine)@30ml/l, cow butter milk @ 40 ml/l, cow urine @30 ml/l and garlic buds + red pepper extracts(1:1)@ 10 ml/l were highly effective and statistically on par with endosulfan 0.07% @ 2ml/l not only in reducing larval population, percent flower and capsule damage caused by *Antigastra catalaunalis* larvae but also increasing the grain yield.

Cullen *et al*., (2008) stated that ecological engineering aims to protect crops from pest damage by maximizing natural mortality by strategic introduction of plant diversity. The practices are very useful in respect to Economics and adoption of conservation biological control.

Gurr (2009) evaluated ecological engineering methods and concluded that this approach is intended to promote natural enemy activity by providing resources to enhance their performance. These resources include alternate foods when prey or hosts are temporarily unavailable.

Bheemanna *et al*., (2010) demonstrated the effect of Bt-cotton as an ovipositional trap crop with different proportions in conventional cotton insect-pest management on American bollworm population (*Helicoverpa armigera*). The studies revealed that larval population of *H. armigera* on cotton when *Bt*-cotton was used as trap crop indicated minimum incidence in cotton IPM treatment. The minimum damage to green bolls and very low incidence of pink bollworm was registered in cotton IPM treatment. Cotton IPM package and Bt-cotton border experiments recorded maximum good opened bolls with least bad opened bolls. Trap crops also play a significant role in minimizing pest population in different agroecosystems.

Lan *et al.,* (2010) in Vietnamese field studies it was demonstrated that growing nectar plants on the bunds beside rice crops significantly increased the number and impact of natural enemies of rice planthoppers they also reported that the Parasitoid. Density Higher in Farmers' Ecological Engineering Fields and there was no difference in species biodiversity.

Rao *et al.,* (2012) conducted on farm experiments in villages of semi-arid tropical (SAT) India to identify the appropriate combination of castor (*Ricinus communis* L.) (Malpighiales: Euphorbiaceae) and intercropping in relation to pest incidence. The on-farm diversity was enhanced by introducing cluster bean, cowpea, black gram, or groundnut as intercrops in castor (1:2 ratio proportions), which was resulted in reduction of incidence of insect pests *viz.,* semilooper (*Achaea janata* L.), leaf hopper (*Empoasca flavescens* Fabricius), and shoot and capsule borer (*Conogethes punctiferalis* Guenee). It was found that the minimum incidence of *A. Janata* and *C. punctiferalis* was observed in Caster and cluster bean inter-cropping system.

Soundararajan and Chitra (2012) studied the impact of intercrops on insect pests of blackgram, *Vigna mungo* and reported that blackgram + sorghum combination, incidence of the major pod borer *Maruca vitrata* was very less. Similarly the damage in harvested blackgram pods was low in sorghum+blackgram followed by pearl millet+blackgram. They concluded that altering the cropping system either by intercrops or border crops; will significantly influences the insect rather larval feeding or oviposition by the adult insects.

Kumar *et al*.,(2012) studied the efficacy of Neem seed kernel extract @5%,Neem leaf extract @2%, Kranj seed kernel extract @5%,mahuwa oil@ 2%,Neem oil @2%,Nimbecdine @0.15% and endosulfan 35 EC @ 0.07% for the management of *A. catalaunalis* (Dup.).The efficacy of endosulfan 35EC @0.07% was highest (percent reduction in population) followed by NSKE>Neem leaf extract>Neem oil>Nimbecidine>NSKE>Mahuwa oil in decreasing order during both the years. The highest seed yield was obtained in treatment of endosulfan (7.68q/ha) followed by NSKE (6.21q/ha) and neem leaf extract.

Behera *et al*., (2013) revealed that sesamum intercropped with green gram (PDM 84-139), black gram (PU-35), pearlmillet (L-74), sorghum (SSG 59-3) and cluster bean (PNB) at 3:3 row ratio reduced the incidence of *Antigastra catalaunalis* on sesame (OSC-207). In case of sesame (sole crop) 10% capsule damage was recorded but lower incidence (6-9%) was recorded in intercropping systems. Amongst the intercrops, cluster bean gave highest

sesame equivalent yield (2198.38) followed by blackgram (777.0kg/ha).The cost benefit ratio was 5.79 and 2.85 in case of cluster bean and blackgram intercropping system respectively.

Degri *et al*., (2014) evaluated effect of intercropping pattern on stem borer infestation in pearl millet (*Pennisetum glaucum* L.) and reported that in addition to natural enemy effects, the pearl millet component crop as non-host plants could have further constituted a physical barrier to leaf miner pests in groundnut that possibly inhibits their movements in border cropped systems. The concluded that crop diversification through intercropping/border cropping, such as cereals with legumes, was effective in reducing insect pest damage.

Zhu *et al*., (2015) compared that different ecological engineering methods to farmer practices and reported that ecological engineering practices reduced the amount of insecticides by more than 75%, but the yields in both areas with ecological engineering and farmer practices were above 10 tons per ha. There was no significant yield loss in ecological engineering field (10.02 t/ha) compared with yields in farmer fields (10.27 t/ha), meanwhile famers obtained about 120 US$/ha extra income from sesame seeds harvested on the bound and saved about 150 US $/ha cost for insecticide application.

Sujayanand *et al*., (2015) studied the crop diversification for sustainable insect pest management in eggplant (Solanales: Solanaceae) and reported the reduction of fruit borer and leafhopper incidences in main crop brinjal, when raised with maize as border crop.

Deepika A. (2016) evaluated ecological engineering methods for enhancing entomophages and increasing pest suppression on okra and reported that okra + cowpea border cropping system registered a maximum population of dragonflies, damselflies, wasps, predatory pentatomid bugs and coccinellids on okra and border crops, and reduced the population of *Bemisia tabaci* and *Helicoverpa armigera* on okra. These border cropping system also had the highest population of ichneumonid and braconid wasps and tachinid flies on okra and trap crops. They concluded that these conditions resulted in

higher occurrence ratio of natural enemies, higher pest defender ratio, higher yield and cost benefit ratio.

Chandrasekar *et al*., (2016) studied the ecological engineering cropping method for Enhancing Predator *Coccinella septempunctata* and Suppression of Planthopper, *Nilaparvata lugens* (Stal) in Rice. And reported that rice + cowpea border cropping system registered maximum population coccinellids and rove beetle on rice and border crops and minimum population of planthoppers and leafhoppers on rice alone.

Lokesh *et al*., (2017) evaluated the different border crops *viz.,* cowpea, red gram, lablab, green gram, cluster bean and french bean separately during 2015 and 2016 to enhance activity of predatory coccinellids and to suppress aphids, *Aphis gossypii* (Glover). Blackgram + cowpea border cropping system significantly influenced maximum coccinellids on blackgram 3.72/plant) along with highest pest defender ratio (PDR) of 1: 2.4, occurrence ratio (OR) of coccinellids (1.83), minimum *A. gossypii* (3.63/terminal shoot), preference ratio (PR) of *A. gossypii* (0.94) and maximum BC ratio (1: 4.35). Blackgram and cluster bean, French bean, lablab, red gram or green gram border cropping systems also effected for higher population of coccinellids; higher PDR and OR of coccinellids; and minimum *A. gossypii* and PR.

Parthiban *et al*., (2018) Field experiment was conducted to find out cost-effective groundnut based intercropping system to enhance the activities of natural enemies *viz.,* coccinellids and green lacewings. Groundnut (*Arachis hypogaea*) when intercropped with maize (*Zea mays*) and bajra (*Pennisetum glaucum*) 4:1 ratio attracted the highest population of natural enemies like coccinellids and green lacewings, recording the population of 8.11 and 3.13 nos./10 plants and 5.94 and 2.27 nos./10 plants followed by groundnut + sorghum (Sorghum bicolor), groundnut + redgram (*Cajanus cajan*), groundnut + sesame (*Sesamum indicum*), groundnut + marigold (*Tagetes erecta*) and groundnut + onion (*Allium cepa*), while it was 5.94 and 2.27 nos./10 plants in groundnut pure crop.

Indiragandhi *et al.,* (2018) evaluated border crops and reported that among the seven combinations, border cropping of groundnut with sorghum,

pearl millet and maize recorded significantly the lowest population of thrips, leafhopper and reduced *Spodoptera litura*, *Helicoverpa armigera* and *Aproaerema modicella* damage. The incidence of Peanut Bud necrosis Disease (PBND) was reduced to the tune of 49.23-52.30% compared to control by these combinations. More number of natural enemies *viz.,* coccinellids (3.8/plant) and spider (4.2/plant) were recorded in groundnut border cropped with these cereal crops. The same combinations (T6, T5 and T7) increased the economic returns of 1:4.35, 1:4.3 and 1:3.8, respectively. It could be inferred that the fast growing and taller cereals could reduce the pests' incidence in the main crop groundnut by acting as physical/mechanical barrier despite encouraging the natural enemies population.

Parthiban, *et al*., (2018) evaluated cost-effective groundnut based inter-cropping system for the management of key insect pests. Groundnut (*Arachis hypogaea* Linnaeus; Variety: VRI II) when intercropped with bajra (*Pennisetum glaucum* L.; Variety: Co 7), maize (*Zea mays* L.; Variety; Co 6) and sorghum (*Sorghum bicolor* L.; Variety: Co 30) 4: 1 ratio harboured significantly less mean population of sucking pests *viz.* leafhopper, *Empoasca kerri* Pruthi, Aphids, *Aphis craccivora* Koch and Thrips, *Scirtothrips dorsalis* and recording 23.05, 24.81 and 25.47 nos./10 plants, 21.27, 23.52 and 22.44 nos./2.5 cm shoot and 11.15, 12.62 and 12.19 nos./5 leaflet respectively, whereas intercropping with red gram (*Cajanus cajan* L.; Variety: VBN (Rg) 3), marigold (*Tagetes erecta* L.), sesame (*Sesamum indicum*) and onion (*Allium cepa*) recorded high mean population as compared to other cropping systems while groundnut as pure crop recorded the highest mean population of 33.14 nos./10 plants, 33.22 nos./2.5 cm shoot and 19.00 nos./5 leaflet respectively.

Chaitra *et al*., (2020) evaluated nine biopesticides against insect pests of sesame and reported that among the tested biopesticides, Neem Seed Kernel Extract (NSKE) 5%, neem oil 0.3% and *B. bassiana* 0.1% effectively managed whitefly and leaf webber incidence in both the seasons and also produced higher seed yield than control viz. 56.65, 50.23 and 26.08% in plots treated with NSKE 5%, neem oil 0.3% and *B. bassiana* 0.1%, respectively

during summer. In kharif, seed yield over control was 93.27, 72.21 and 71.61% in NSKE 5%, *B. bassiana* 0.1% and neem oil 0.3%, respectively.

Jasmine *et al.,* (2020) field experiments were conducted to screen the best border crop for the management of major insect pest, *Antigastra catalaunalis* by attracting and sustaining the natural enemy population in sesame ecosystem. Treatments consisted of sesame, the main crop along with different border crops the results showed that lowest population of *Antigastra* larva (0.4/plant) was recorded in T5 (sesame + pearl millet) followed by T1 (sesame + sorghum) and T7 (sesame + castor) (0.6/plant). Damage percent was more in T8 (26.39%) (Sole sesame) followed by T6 (sesame + sunflower) (20%). T5 (sesame + pearl millet) registered the lowest capsule damage (4.17%) followed by T7 (4.95%) and T3 (5.04%). Sesame+pearl millet registered lowest leafhopper population (1.0/plant) followed by T1, T2 and T4 (1.20/plant). During rabi/summer 2017, lowest number of *Antigastra* (0.70/plant) was recorded in sesame + pearl millet followed by sesame + sorghum (0.73/plant) at vegetative stage. During flowering stage, pearl millet border cropping recorded lesser damage (14.04%) followed by sesame+sorghum (14.67%) whereas sole sesame recorded damage to the tune of 23.72%. However, sorghum border cropping recorded lowest capsule damage (4.67%) followed by sesame+pearl millet (4.93%). The same trend was observed during capsule formation stage also. During kharif 2016, predatory coccinellids population was more in black gram border cropping (1.41/plant) followed by sorghum and cowpea border cropping (1.10/plant). During rabi/summer 2017, also the coccinellids population was more in sesame border cropped with pulses like black gram (1.67/plant) and cow pea (1.33/plant) during flowering stage. With regard to spiders, highest population was recorded in sesame+pearl millet (0.73/plant) followed by sesame+sorghum (0.67/plant). Sesame+pearl millet combination recorded maximum of seed yield 547 and 636 kg/ha during kharif 2016 and rabi/summer 2017 followed by sesame+sorghum combination (528 & 612 kg/ha).

2. To study the succession of insect pests complex associated with sesame.

Thakur and Kaistha (1994) were observed that 9 insect pest causing damage to sesame in Himachal Pradesh, during different stages of its growth. the pest incidence on the crop was overlapping. Bihar hairy caterpillar attacked the crop at the vegetative growth to pod maturity stage from the 2nd week of August to 3rd week of September.

Bhadauria (2000) was noticed that 25 insect pests during *kharif* season in sesame at Gwalior, Madhya Pradesh, India from germination to harvest season (1994-97). Which includes 11 homopterous, 7 lepidopterous, 2 each of orthopterous, coleopterons and dipterous pest, out of these pests 12 insect species were observed as regular and 13 were sporadic pest.

Gupta *et al.,* (2001) observed that the occurrence of all 3 sucking pests leaf hopper (0.39/plant), mirid bug (0.52/plant) and whitefly (0.59/plant) were at peak respectively during 34th, 34th, 35th SMW.

Ahirwar *et al.,* (2009) observed that the incidence of larval / nymphal and adult populations of *Antigastra catalaunalis*, *Acherontia* styx, *Dasineura sesame, orosius albinctus, Nesidiocoris tennis* and *Bemisia tabaci* was maximum at 32nd, 34th, 36th and 37th meteorological week respectively.

Kumar *et al.,* (2009) studied pest succession in sesame and found that the incidence of til leaf webber and capsule borer occurred throughout the crop period i.e. from seedling to harvesting stage. Further they reported that whitefly, leaf hopper and sting bug were active during vegetative stage. The incidence of sesame gall fly and stink bug was reported to be from flowering to capsule stage, whereas, till hawk moth's first incidence was observed at capsule formation stage and continued till capsule maturity stage.

Kumar *et al.,* (2010) studied pest succession in sesame and noticed that the peak population of leaf hopper, whitefly, stink bug were observed that in 36th SMW.

Patidar (2010) identified whitefly, leaf hopper, til hawk moth, hairy caterpillar, mirid bug, thrips, leaf webber and capsule borer and gallfly as the major insect pests of sesame. Out of which, the whitefly, leaf hopper, til hawk moth, hairy caterpillar and mirid bug were found to occur in early flowering stage, whereas, thrips, leaf webber and capsule borer and gallfly were

observed from 3rd week of august to 2nd week of September.

Gangwar *et al*., (2014) reported that the population of shoot webber and pod borer (*Antigastra catalaunalis)* and leaf hopper *(orosius albinctus)* was first appeared in 21 to 23 days old sesame crop. Its peak population 1.13-1.17 larvae / plant and 1.33 & 1.73 leaf hopper/plant were observed at 37th and 38th standard week when the crop was 56 to 63 days old.

Mishra *et al.,* (2015) studied the seasonal incidence of insect pests of sesame and reported *Antigastra* as the first appearing insect in the week of 33rd SMW followed by leaf hopper and whitefly (in 34th SMW) and mirid bug (in 35th SMW).

Choudhary *et al.,* (2015) studied that seasonal incidence of insect pests of sesame and reported that the, sesame leaf and capsule borer, leaf hopper, white fly, and gall fly. as major insect pest of sesame crop. The populations of former 3 insect pest were recorded first during 33rd SMW (14th August) and peak population appeared during 35th SMW (28th august).

Bondre *et al.,* (2016) identified leaf webber and capsule borer *(Antigastra catanalulis* Dup), Bihar hairy caterpillar (*Spilarctia obliqua* Walker), leaf hopper (*Orosius albinctus* Distance), til hawk moth (*Acherontia styx* Westwood), whitefly (*Bemisia tabaci* Genadius), gall fly (*Ashpondia sesame* Felt) as the major pests of sesame crop. The peak activity of leaf hopper was noticed during 1st week of October which was followed by til hawk moth, Bihar hairy caterpillar, gall fly and whitefly (2nd week of Oct) and leaf webber and capsule borer (3rd week of October).

Chaitra (2016) observed that activity of whitefly and leaf hopper on sesame crop were started from 32nd SMW to 36th SMW, respectively and its peak activity were recorded in 36th SMW and 37th SMW, respectively.

Sharma (2017) noticed that the incidence of leaf roller and capsule borer, leaf hopper, white fly and Ladybird beetle in 33rd SMW (3rd week of August) on sesame crop. The mean population of leaf hopper (2.96 nymph and adult/ three leaves/plant). Mirid bug (4.92 nymph and adult/ three leaves/plant) and white fly (4.44 nymph and adult/ three leaves/plant) were recorded at higher level and considered as key pests of sesame.

Thangjam and Vastrad (2018) identified *Acherontia styx, Spilarctia oblique*, *Nezara viridula*, *Dolycoris indicus, Orosius albicinctus* and *Bemisia*

tabaci as the major pests infesting the sesame crop. The activity of til hawk moth was found to be from vegetative to maturity stage, whereas BHC, leaf hopper and whitefly occurred from vegetative to pod formation stage. Further Natural enemy i.e. Ladybird beetle was reported to occur from flowering to maturity stage.

Naveen *et al., (*2019) observed the peak population of coccinellid beetle in sesame crop in the fourth week of October (43rd standard week) and afterwards the population declined gradually.

Saritha *et al.,* (2020) noticed that incidence of aphids, leaf hoppers and thrips on sesame crop during *kharif* season has started on 25th SMW. Thrips (7.3/plant) attained peak in the 30st SMW, whereas, whitefly population reached peak during 27th SMW with population of (1.7/ plant) whereas, leaf hopper (2.8/plant) and aphid population (12.1/plant) reached peak in the 31st SMW with population.

MATERIAL AND METHODS

The present investigation entitled **"To study the ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.)**" comprised two experiments was carried out at the Experimental farm of Project Coordinating Unit Sesame and Niger (ICAR), College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh) during *Kharif* season, 2019.

Geographical location and climatic:

Jabalpur is situated between 22^0 49" and 24^0 8" North latitude and 78^0 21" and 80^0 58" East longitude and at an altitude of 411.78 m above the mean sea level. The climate of the region is typically semi-humid and sub-tropical. Jabalpur falls under the agro-climatic zone VII, Kymore Plateau and Satpura Hills. It lies in rice-wheat crop zone of the state. The mean annual rainfall is nearly 1423 mm, which received mostly between mid-June to mid-September. The mean maximum temperature during the hottest months of May and June varies from 41.8 to 44.4^0C. January is the coldest month with maximum and minimum temperatures of 25^0C and 3.1^0C, respectively. The weather conditions during the course of studies *i.e*. from July to November, 2019 mentioned in (Table number 1)**.**

Table 1: Meteorological data during the *Kharif* season 2019.

Average weekly meteorological data									
SMW	**Temp.(°C)**		**RH (%)**		**Rainfall (mm)**	**Rainy Days (hrs)**	**Sun Shine (hrs)**	**Wind Speed (km/hrs)**	**Evaporation (mm)**
	Max.	**Min.**	**Morn.**	**Even.**					
32	29.6	23.5	92	81	210.0	4	2.7	3.3	2.8
33	28.6	22.9	91	83	302.1	4	2.9	3.2	1.9
34	29.2	22.5	97	83	212.9	7	1.4	2.1	4.9
35	30.9	23.4	93	75	57.2	4	3.3	0.7	3.2
36	31.6	23.4	94	79	185.0	5	3.8	1.8	4.9
37	28.5	23.4	93	83	101.4	5	1.2	1.9	2.5
38	31.7	22.7	91	78	53.1	3	4.5	1.1	3.5
39	29.5	22.1	93	78	77.6	4	2.5	1.6	2.7

SMW = Standard Meteorological Week

General details of experiments:

The experiment was laid out in two sets.

1. Evaluation of different ecological engineering method for the management of leaf Webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame.
2. To study the succession of insect pests complex associated with sesame.

Experiment No. 1: Evaluation of different ecological engineering method for the management of leaf Webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame.

Table 2: Details of experiment

Crop	Sesame
Variety	TKG-21
No. of plots	30
Net plot size	20 m x 10 m (200m^2)
Spacing row to row	30 cm
Spacing plant to plant	10cm
Total no. of Replication	3×10
Date of sowing	28 July,2019

Table 3: Treatment details (10)

Tr.	Seed treatment	Border crop	Soil application at the time of sowing	Foliar spray
T_1	*Trichoderma viride* @ 10g/kg seed and *Pseudomonas florescence* @10g/kg seed	Pearl millet	Neem cake@ 250 kg/ha	Neem oil @ 10 ml/l
T_2	do	Pearl millet	Vermicompost @ 1.0 t/ha	Vermiwash @ 5%
T_3	do	Pearl millet	Poultry manure @ 1.0 t/ha	NSKE @ 5%
T_4	do	Sorghum	Neem cake@ 250 kg/ha	Neem oil @ 10 ml/l
T_5	do	Sorghum	Vermicompost @ 1.0 t/ha	Vermiwash @ 5%
T_6	do	Sorghum	Poultry manure @ 1.0 t/ha	NSKE @ 5%
T_7	do	Maize	Neem cake@ 250 kg/ha	Neem oil @ 10 ml/l
T_8	do	Maize	Vermicompost @ 1.0 t/ha	Vermiwash @ 5%
T_9	do	Maize	Poultry manure @ 1.0 t/ha	NSKE @ 5%
T_{10}	Control			

Observation Schedule:

Different ecological engineering methods were evaluated against the major insect pests of sesame**.** The observations were started from one week after germination and continued till maturity of the crop. The population of Lepidopterion insect pests **(**leaf webber and capsule borer, Bihar hairy caterpillar) were recorded by counting the number of larvae/plant while the population of sucking insect pests were (leafhopper, whitefly and mirid bug) recorded at weekly intervals by counting the number of nymphs and adults per six leaves/plant (2 leaves each from top, middle and bottom) on five random selected plants from each plot. However foliar spray of treatments should be imposed based on ETL. Capsule damage and seed yield were recorded at harvest and cost benefit ratio was worked out.

Plant damage (%):

The percent plant damage caused by leaf webber and capsule borer in different varieties of sesame was recorded by counting the total no of damage and healthy plants/plot at 30 DAS and estimated by using the following formula:

$$\text{Plant damaged \%} \quad \frac{\text{Number of damaged plants}}{\text{Total number of plants}} \text{ x100}$$

Flower damage (%):

Percent flower damage at 45 DAS from each variety were recorded separately by counting the total number of damaged and healthy flowers on five randomly selected plants from each replications. The percent flower damage was worked out by using following formula.

$$\text{Flower damage (\%):} \quad \frac{\text{Number of damaged flower}}{\text{Total number of flower}} \text{ x100}$$

Capsule damage (%):

Percent capsule damage at 70 DAS from each variety were recorded separately by counting the total number of damaged and healthy capsules on five randomly selected plants from each replications. The percent capsule damage was worked out by using following formula.

$$\text{Capsule damage (\%):} \quad \frac{\text{Number of damaged capsule}}{\text{Total number of capsule}} \times 100$$

Statistical analysis:

Table 4: Analysis of variance following analysis of variance table was used: Skeleton of analysis of variance (ANOVA)

Source of variation	D.F.	SS	MSS	F cal.	F tab.
Replication	(R-1) = r				
Treatment (T)	(T-1) = t				
Period (P)	(P-1) = p				
T x P	(t x p) = n				
Error	x - (r+t+p+n)				
Total	(x-1) = x				

The significance among different treatment means was judged by critical difference (C.D) at 5% level of significance for comparison among the treatments, for which the marginal means of each treatment was considered. The following formula was used for various estimations:

Standard error for observation mean:

i. SEm± for (T) $= \sqrt{\frac{EMS}{rXP}}$

ii. SEm± for (P) $= \sqrt{\frac{EMS}{rXT}}$

iii. SEm± for (T x P) $= \sqrt{\frac{EMS}{r}}$

Critical difference (CD)

i. CD between treatment = $\sqrt{2}$ x SEm± (T) x t (5%) at error degree of fredom.

i. CD between periods of observation = $\sqrt{2}$ x SEm± (P) x t (5%) at error degree of fredom.

ii. CD between treatment x periods of observation = x SEm± (TxP) x t (5%) at error degree of fredom.

where,

EMS = Error mean sum of square.

r = number of replications.

T = number of treatment.

P = number of periods.

t = 't' Table value at 0.5% and 0.1% probability level.

SEm± = Standard error of mean.

CD = Critical difference.

(4) Seed yield

Seed yield was calculated under different treatments as per formula

$$\text{Yield kg/ha} = \text{Factor} \times \text{seed yield / plot}$$

where,

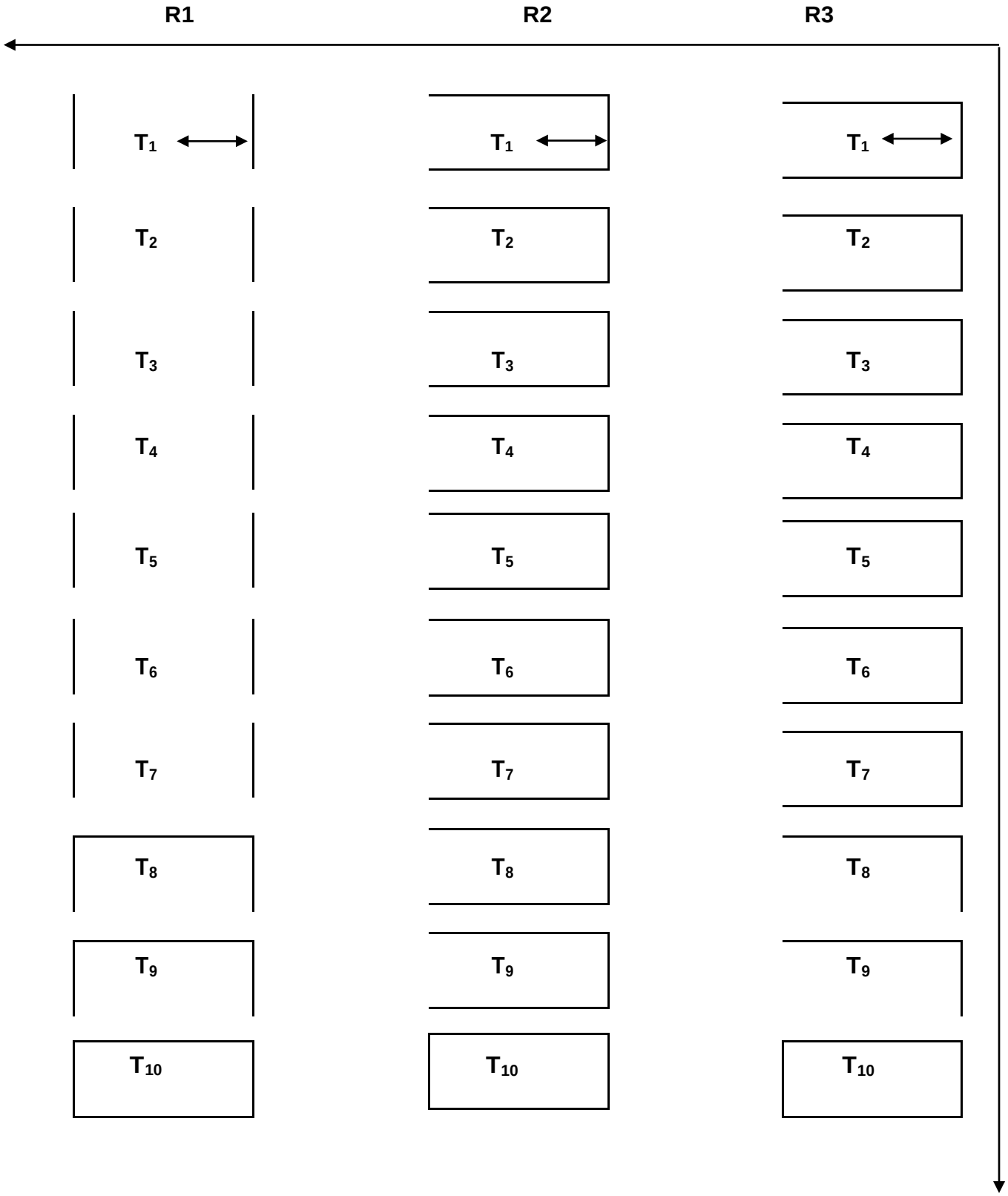
$$\text{Factor} = \frac{10000}{\text{Net plot size}} \text{ in sq. m.}$$

(5) B: C Ratio

B: C ratio was calculated under different treatments as per formula

$$\text{B:C Ratio} = \frac{\text{Net profit}}{\text{Cost of treatment}}$$

Fig. 01 - Layout plan of experiment area:-



Experiment No. 2:

Table 5: To study the succession of insect pests complex associated with sesame.

Experimental details:

Variety	Prachi
No of plots	1(Untreated)
Distance between rows	30 cm
Distance between plants	10 cm
Size of plot	20m×10m
Date of sowing	28 July, 2019

(I) Observation schedule:

To study the succession of insect pests, the crop was kept free from insecticide application. Weekly observations on different insect pests were recorded on 10 randomly selected plants starting from one week after germination and continued till the availability or maturity of the crop. The population of sucking insect pests (leaf hopper, white fly and mirid bug) was recorded by counting the number of nymphs and adults/six leaves/plant (2 leaves each from top, middle and bottom). The population of leaf webber and capsule borer, hawk moth and Bihar hairy caterpillar were recorded by counting the number of larvae larvae/plant on ten randomly selected plants. For gall fly the observations were recorded on ten randomly selected plants by counting the number of maggots/galls and averaged as per plant basis.

RESULTS

The findings of the experiment "**To study the ecological engineering method for management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame"** was recorded as per methodology and data is duly analyzed and described in this chapter under respective objectives.

Evaluation of different ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame.

The experiment "**Evaluation of different ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame**" was laid out with sesame variety TKG-21 in RBD with three replications consisting of nine treatments. In each treatment seed treatment with *Trichoderma viride* @ 10g/kg seed and *Pseudomonas florescence* @10 g/kg seed was common except control. Treatment T_1 to T_3 were laid with border crop of Pearl millet, in treatment T_4 to T_6 border crop maize had been taken while in treatment T_7 to T_9 border crop of sorghum had been taken. Each treatment having different border crops were evaluated by adding different fertilizers and bio-pesticides combinations.

Evaluation of different ecological engineering methods on the basis of percent damages at different stages of plant growths

For the management of leaf webber and capsule borer in sesame nine ecological engineering methods were evaluated. The percent damages due to leaf webber and capsule borer at different stages of plant growths (vegetative flowering and capsule maturity stages) were recorded.

a) Percent plant damage:

The results revealed that all the ecological engineering methods were found significantly superior over control to record the lowest percent plant damage. Among the treatment the lowest percent plant damage (6.88%) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (8.33%) T_1 (seed treatment + soil application of neem cake 250

kg/ha + border crop with pearl millet + two foliar spray of neem oi) and (8.43) T_4 (seed treatment + soil application of neem cake + border crop with sorghum + two foliar spray of neem oi). However the highest percent plant damage (14.79%) was recorded from the control T_{10} followed by (10.83) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash) and followed by (10.63%) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash). The treatments T_7 (6.88%), T_1 (8.33%), T_4 (8.43%) and T_6 (8.75%) were found at par to each other in respect to record the lowest percent plant damage. Similarly the treatment T_1 (8.33%), T_2 (10.11%), T_3 (10.00%), T_4 (8.43%), T_6 (8.75%), T_8 (10.63%) and T_9 (9.42%) were found at par to each other in respect to record the lowest percent plant damage.

b) Percent flower damage:

The results revealed that all the ecological engineering methods were found significantly superior over control to record the lowest percent flower damage. Among the treatment the lowest percent flower damage (10.22%) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (10.93%) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and (11.0%) T_4 (seed treatment + soil application of neem cake + border crop with sorghum + two foliar spray of neem oi). However the highest percent flower damage (19.57%) was recorded from the control T_{10}, and followed by (14.28%) T_2(seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash).followed by (13.61) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash) and followed by (13.56%) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash). The treatments T7 (10.22%), T1 (10.93%), T4 (11.00%) and T6 (11.61%) were found at par to each other in respect to record the lowest percent flower damage. Similarly, the treatment T1 (10.93%), T2 (14.28%), T3 (12.28%), T4 (11.00%), T6 (12.00%), T8 (13.56%) and T9 (11.61%) were found at par to each other in respect to record the lowest percent flower damage.

c) Percent capsule damage:

The results revealed that all the ecological engineering methods were found significantly superior over control to record the lowest percent capsule damage. Among the treatment the lowest percent capsule damage (8.34%) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (8.55%) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and (9.02%) T_9 (seed treatment + soil application of poultry manure + border crop with maize + two foliar spray of NSKE).However the highest percent capsule damage (20.04%) was recorded from the controlT_{10} followed by (12.05%) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) and followed by (12.01%) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash). The treatments T_7 (8.34%), T_1 (8.55%), T_9 (9.02%) and T_6 (9.14%) were found at par to each other in respect to record the lowest percent capsule damage. Similarly the treatment T_1 (8.55%), T_2 (12.01%), T_3 (9.52%), T_4 (10.58%), T_6 (9.14%), T_8 (12.05%) and T_9 (9.02%) were found at par to each other in respect to record the lowest percent capsule damage.

Table 6: Effect of different ecological engineering methods on the damage caused by leaf webber and capsule borer at different stages of plant growths

Treatments	(%) damage due to leaf webber and capsule borer at different stages of plant growth		
	Plant (30DAS)	Flower (45DAS)	Capsule (70DAS)
T_1 – ST with *Trichoderma viride*@ 10g/kg seed +border crop with Pearl millet+soil application of Neem cake@ 250kg/ha+ two foliar spray of Neem oil @ 10 ml/l	**8.33 (16.75)**	**10.93 (19.29)**	**8.55 (17.00)**
T_2 – ST with *Trichoderma viride*@ 10g/kg seed +border crop with Pearl millet+soil application of vermicompost@ 1.0t/ha+ two foliar spray of vermiwash @ 5%.	**10.11 (18.54)**	**14.28 (22.20)**	**12.01 (20.27)**
T_3– ST with *Trichoderma viride*@ 10g/kg seed +border crop with Pearl millet +soil application of poultry manure@ 1.0 t/ha+ two foliar spray of NSKE @ 5%.	**10.00 (18.43)**	**12.28 (20.51)**	**9.52 (17.95)**
T_4– ST with*Trichoderma viride*@ 10g/kg seed +border crop with Sorghum+soil application of Neem cake@ 250 kg/ha+ two foliar spray of Neem oil @ 10 ml/l	**8.43 (16.71)**	**11.00 (19.37)**	**10.58 (18.98)**
T_5 – ST with *Trichoderma viride*@ 10g/kg seed +border crop with Sorghum+soil application of vermicompost@ 1.0 t/ha+ two foliar spray of vermiwash @ 5%.	**10.83 (19.17)**	**13.61 (21.62)**	**11.17 (19.53)**
T_6– ST with *Trichoderma viride*@ 10g/kg seed +border crop with Sorghum+soil application of poultry manure@ 1.0 t/ha+ two foliar spray of NSKE @ 5%.	**8.75 (17.18)**	**12.00 (20.26)**	**9.14 (17.60)**
T_7– ST with*Trichoderma viride*@ 10g/kg seed +border crop with Maize+soil application of Neem cake@ 250 kg/ha+ two foliar spray of Neem oil @ 10 ml/l	**6.88 (15.19)**	**10.22 (18.64)**	**8.34 (16.78)**
T_8– ST with *Trichoderma viride*@ 10g/kg seed +border crop With maize+soil application of vermicompost@ 1.0 t/ha+ two foliar spray of vermiwash @ 5%.	**10.63 (19.01)**	**13.56 (21.60)**	**12.05 (20.31)**
T_9– ST with *Trichoderma viride*@ 10g/kg seed +border crop with Maize +soil application of poultry manure@ 1.0 t/ha+ two foliar spray of NSKE @ 5%.	**9.42 (17.85)**	**11.61 (19.92)**	**9.02 (17.46)**
T_{10} (Control)	**14.79 (22.61)**	**19.57 (26.25)**	**20.04 (26.59)**
SEm ±	**0.84**	**0.44**	**0.29**
C. D. (P = 0.05)	**2.50**	**1.30**	**0.85**

***Figures within parentheses are arcsine transformed values**

Impact of different ecological engineering methods on the incidence of major insect pests and their natural enemies

All the ecological engineering methods were also assessed on the basis number of insect pests and presence of natural enemies per plant. The observations of on number of insect pests and their natural enemies were recorded at weekly intervals. The seed yield and cost benefit ratio of each ecological engineering methods were also calculated.

a) Leaf webber and capsule borer [*Antigastra catalaunalis* (Dup.)]

The results presented in table (7) revealed that all the ecological engineering methods (treatments) were found significantly superior over control to reduce the larval population of leaf webber and capsule borer. Among the treatments the lowest mean larval population (0.35 larvae/plant) was recorded in treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.31 larvae/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and T_6 (seed treatment + soil application of poultry manure + border crop with sorghum + two foliar spray of NSKE 5%). The highest mean larval population (1.76 larvae/plant) was recorded in treatment T_{10} (control) followed by (0.82 larvae/plant) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) and T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash). The treatments T_7 (0.35 larvae/plant), T_1 (0.39 larvae/plant), T_3 (0.46 larvae/plant) T_4 (0.45 larvae/plant) and T_6 (0.44 larvae/plant) were found at par to each other in respect to record the lowest larval population per plant.

Table 7: Evaluation of different ecological engineering methods against leaf webber and capsule borer in sesame

Treatment	Mean larval population of leaf webber and capsule borer/plant (Days after sowing)									Mean
	14	21	28	35	42	49	56	63	70	
T_1	0.20 (0.84)	0.40 (0.95)	0.60 (1.05)	0.30 (0.89)	0.67 (1.08)	0.00 (0.71)	0.47 (0.98)	0.20 (0.83)	0.70 (1.09)	**0.39**
T_2	0.50 (1.00)	0.70 (1.05)	0.90 (1.18)	0.53 (1.01)	1.03 (1.24)	0.30 (0.89)	0.80 (1.14)	0.53 (1.01)	1.10 (1.26)	**0.71**
T_3	0.23 (0.86)	0.50 (1.00)	0.70 (1.09)	0.40 (0.94)	0.80 (1.14)	0.07 (0.75)	0.53 (1.02)	0.27 (0.87)	0.60 (1.05)	**0.46**
T_4	0.30 (0.89)	0.50 (1.00)	0.70 (1.09)	0.37 (1.92)	0.57 (1.03)	0.00 (0.71)	0.53 (1.02)	0.27 (0.87)	0.83 (1.15)	**0.45**
T_5	0.50 (1.00)	0.77 (1.12)	0.97 (1.21)	0.53 (1.01)	1.20 (1.30)	0.20 (0.84)	0.67 (1.08)	0.40 (0.94)	1.13 (1.28)	**0.71**
T_6	0.40 (0.95)	0.60 (1.05)	0.80 (1.14)	0.30 (0.87)	0.83 (1.15)	0.00 (0.71)	0.47 (0.98)	0.20 (0.83)	0.40 (0.95)	**0.44**
T_7	0.10 (0.77)	0.30 (0.89)	0.50 (1.00)	0.23 (0.84)	0.83 (1.15)	0.00 (0.71)	0.43 (0.97)	0.17 (0.81)	0.60 (1.05)	**0.35**
T_8	0.63 (1.06)	0.83 (1.15)	1.03 (1.24)	0.60 (1.04)	1.20 (1.30)	0.40 (0.95)	0.87 (1.17)	0.60 (1.04)	1.23 (1.32)	**0.82**
T_9	0.37 (0.93)	0.60 (1.05)	0.80 (1.14)	0.50 (0.99)	0.73 (1.11)	0.10 (0.77)	0.57 (1.03)	0.30 (0.89)	0.67 (1.08)	**0.52**
T_{10}	1.10 (1.26)	1.30 (1.34)	1.50 (1.41)	1.70 (1.48)	1.80 (1.52)	1.90 (1.55)	2.00 (1.58)	2.17 (1.63)	2.37 (1.69)	**1.76**
SEm ±	**0.05**	**0.06**	**0.05**	**0.04**	**0.07**	**0.04**	**0.06**	**0.04**	**0.07**	**0.05**
C. D. (P = 0.05)	**0.15**	**0.17**	**0.13**	**0.11**	**0.22**	**0.12**	**0.17**	**0.13**	**0.22**	**0.16**

***Figures within parentheses are squire root transformed values**

b) Leafhopper (*Orocious albicinctus* (Distance)

The results presented in table (8) revealed that all the ecological engineering methods (treatments) were found significantly superior over control to reduce the population of leafhopper. Among the treatments the lowest mean population (0..27 leafhopper/three leaves/plant) was recorded in treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.28 leafhopper/three leaves/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and (0.38 leafhopper/three leaves/plant) T_6 (seed treatment + soil application of poultry manure + border crop with sorghum + two foliar spray of NSKE 5%). The highest mean population of leafhopper (1.25 leafhopper/three leaves/plant) was recorded in treatment T_{10} (control) followed by (0.60 leafhopper/three leaves/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash) and (0.55 leafhopper/three leaves/plant) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash). The treatments T_7 (0.27 leafhopper/three leaves/plant), T_1(0.28 leafhopper/three leaves/plant), T_4 (0.28 leafhopper/three leaves/plant), T_6 (0.38 leafhopper/three leaves/plant) and T_3 (0.41 leafhopper/three leaves/plant) were found at par to each other in respect to record the lowest population of leafhopper.

Table 8: Evaluation of different ecological engineering methods against leafhopper in sesame

Treatment	Leafhopper population/three leaves/plant (Days after sowing)									Mean
	14	21	28	35	42	49	56	63	70	
T_1	0.10 (0.77)	0.20 (0.84)	0.30 (0.89)	0.13 (0.80)	0.50 (1.00)	0.17 (0.89)	0.60 (1.05)	0.03 (0.73)	0.50 (1.00)	**0.28**
T_2	0.47 (0.98)	0.57 (1.03)	0.70 (1.09)	0.47 (0.98)	0.93 (1.20)	0.40 (0.95)	0.80 (1.14)	0.23 (0.86)	0.80 (1.14)	**0.60**
T_3	0.40 (0.95)	0.50 (1.00)	0.60 (1.05)	0.23 (0.85)	0.63 (1.06)	0.17 (0.82)	0.50 (1.00)	0.07 (0.75)	0.60 (1.04)	**0.41**
T_4	0.20 (0.84)	0.30 (0.89)	0.30 (0.89)	0.13 (0.79)	0.40 (0.95)	0.17 (0.82)	0.60 (1.05)	0.03 (0.73)	0.37 (0.93)	**0.28**
T_5	0.53 (1.01)	0.63 (1.06)	0.70 (1.09)	0.33 (0.91)	0.97 (1.21)	0.30 (0.89)	0.70 (1.09)	0.17 (0.82)	0.83 (1.15)	**0.57**
T_6	0.40 (0.95)	0.50 (1.00)	0.60 (1.05)	0.10 (0.77)	0.63 (1.06)	0.10 (0.77)	0.40 (0.95)	0.07 (0.75)	0.60 (1.04)	**0.38**
T_7	0.13 (0.80)	0.23 (0.86)	0.27 (0.88)	0.07 (0.75)	0.53 (1.02)	0.07 (0.75)	0.57 (1.03)	0.03 (0.73)	0.57 (1.03)	**0.27**
T_8	0.50 (1.00)	0.60 (1.05)	0.70 (1.09)	0.53 (1.02)	0.83 (1.15)	0.37 (0.93)	0.83 (1.15)	0.20 (0.84)	0.70 (1.09)	**0.58**
T_9	0.43 (0.96)	0.53 (1.02)	0.60 (1.05)	0.30 (0.89)	0.57 (1.03)	0.17 (0.82)	0.57 (1.03)	0.10 (0.77)	0.57 (1.03)	**0.43**
T_{10}	0.77 (1.12)	0.87 (1.17)	1.03 (1.24)	1.37 (1.37)	1.50 (1.41)	1.70 (1.48)	1.30 (1.34)	1.40 (1.38)	1.30 (1.34)	**1.25**
SEm ±	**0.04**	**0.05**	**0.06**	**0.07**	**0.11**	**0.06**	**0.08**	**0.06**	**0.11**	**0.07**
C. D. (P = 0.05)	**0.11**	**0.16**	**0.19**	**0.22**	**0.34**	**0.18**	**0.23**	**0.17**	**0.34**	**0.22**

***Figures within parentheses are squire root transformed values**

c) Whitefly (*Bemisia tabaci* (Genadius))

The results presented in table (9) revealed that all the ecological engineering methods (treatments) were found significantly superior over control to reduce the population of whitefly. Among the treatments the lowest mean population of whitefly (0.88 whitefly/three leaves/plant) was recorded in treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.96 whitefly/three leaves/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and (1.03 whitefly/three leaves/plant) T_4 (seed treatment + soil application of neem cake + border crop with sorghum + two foliar spray of neem oi). The highest mean population of whitefly (2.61 whitefly/three leaves/plant) was recorded in treatment T_{10} (control) followed by (1.49 whitefly/three leaves/plant) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) and (1.48 whitefly/three leaves/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash).The treatments T_7 (0.88 whitefly/three leaves/plant), T_1 (0.96 whitefly/three leaves/plant), T_4 (1.03 whitefly/three leaves/plant) T_6 (1.09 whitefly/three leaves/plant) and T_3 (1.12 whitefly/three leaves/plant) were found at par to each other in respect to record the lowest larval population of white fly per three leaves per plant.

Table 9: Evaluation of different ecological engineering methods against whitefly in sesame

Treatment	Whitefly population/three leaves/plant (Days after sowing)									Mean
	14	21	28	35	42	49	56	63	70	
T_1	1.13 (1.28)	1.37 (1.37)	1.50 (1.41)	0.20 (0.84)	1.53 (1.43)	0.10 (0.77)	1.50 (1.41)	0.03 (0.73)	1.30 (1.34)	**0.96**
T_2	1.83 (1.53)	2.13 (1.62)	2.40 (1.70)	0.40 (0.95)	2.70 (1.79)	0.40 (0.95)	1.60 (1.45)	0.30 (0.89)	1.60 (1.44)	**1.48**
T_3	1.33 (1.35)	1.53 (1.43)	1.90 (1.55)	0.30 (0.89)	2.10 (1.61)	0.23 (0.86)	1.20 (1.30)	0.13 (0.80)	1.40 (1.37)	**1.12**
T_4	1.13 (1.28)	1.33 (1.35)	1.70 (1.48)	0.20 (0.84)	1.97 (1.56)	0.23 (0.85)	1.40 (1.38)	0.13 (0.79)	1.20 (1.30)	**1.03**
T_5	1.53 (1.43)	1.83 (1.53)	2.10 (1.61)	0.30 (0.89)	2.37 (1.69)	0.30 (0.89)	1.70 (1.48)	0.20 (0.84)	1.70 (1.48)	**1.34**
T_6	1.43 (1.39)	1.63 (1.46)	2.00 (1.58)	0.13 (0.80)	1.97 (1.57)	0.13 (0.80)	1.10 (1.26)	0.03 (0.73)	1.40 (1.37)	**1.09**
T_7	0.93 (1.20)	1.13 (1.28)	1.43 (1.39)	0.10 (0.77)	1.70 (1.48)	0.10 (0.77)	1.40 (1.38)	0.03 (0.73)	1.10 (1.26)	**0.88**
T_8	1.83 (1.53)	2.17 (1.63)	2.10 (1.61)	0.43 (0.97)	2.40 (1.70)	0.37 (0.93)	1.90 (1.55)	0.27 (0.88)	1.90 (1.54)	**1.49**
T_9	1.93 (1.56)	2.20 (1.64)	2.00 (1.58)	0.30 (0.89)	1.67 (1.47)	0.20 (0.84)	1.30 (1.34)	0.10 (0.77)	1.50 (1.41)	**1.24**
T_{10}	2.33 (1.68)	2.70 (1.79)	2.90 (1.84)	2.60 (1.76)	3.20 (1.92)	2.73 (1.80)	2.30 (1.67)	2.47 (1.72)	2.30 (1.67)	**2.61**
SEm ±	**0.08**	**0.09**	**0.10**	**0.09**	**0.11**	**0.09**	**0.08**	**0.05**	**0.09**	**0.09**
C. D. (P = 0.05)	**0.24**	**0.27**	**0.29**	**0.25**	**0.33**	**0.26**	**0.24**	**0.15**	**0.27**	**0.26**

***Figures within parentheses are squire root transformed values**

d) Mirid bug

The results presented in table (10) revealed that all the ecological engineering methods (treatments) were found significantly superior over control to reduce the population of mirid bug. Among the treatments the lowest mean population of mirid bug (0.26 mirid bug/three leaves/plant) was recorded in treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.29 mirid bug/three leaves/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and (0.30 mirid bug/three leaves/plant) T_4(seed treatment + soil application of neem cake + border crop with sorghum + two foliar spray of neem oi). The significantly highest mean population of mirid bug (1.43 mirid bug/three leaves/plant) was recorded in treatment T_{10} (control) followed by (0.71 mirid bug/three leaves/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash) and (0.70 mirid bug/three leaves/plant) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash).The treatments T_7 (0.26 mirid bug/three leaves/plant), T_1 (0.29 mirid bug/three leaves/plant), T_4 (0.30 mirid bug/three leaves/plant) T_6 (0.40 mirid bug/three leaves/plant) and T_3 (0.43 mirid bug/three leaves/plant) were found at par to each other in respect to record the lowest population of mirid bug per three leaves per plant.

Table 10: Evaluation of different ecological engineering methods against mirid bug in sesame

Treatment	Mirid bug population/three leaves/plant (Days after sowing)									Mean
	14	21	28	35	42	49	56	63	70	
T_1	0.10 (0.77)	0.30 (0.89)	0.43 (0.97)	0.07 (0.75)	0.63 (1.06)	0.20 (0.84)	0.43 (0.97)	0.07 (0.75)	0.40 (0.94)	**0.29**
T_2	0.37 (0.93)	0.60 (1.05)	0.83 (1.15)	0.30 (0.89)	1.23 (1.32)	0.43 (0.97)	1.20 (1.30)	0.23 (0.86)	1.20 (1.30)	**0.71**
T_3	0.27 (0.88)	0.47 (0.98)	0.73 (1.11)	0.20 (0.84)	0.53 (1.01)	0.33 (0.91)	0.57 (1.03)	0.13 (0.80)	0.63 (1.06)	**0.43**
T_4	0.07 (0.75)	0.27 (0.88)	0.40 (0.95)	0.03 (0.73)	0.50 (1.00)	0.17 (0.81)	0.63 (1.06)	0.03 (0.73)	0.57 (1.03)	**0.30**
T_5	0.37 (0.93)	0.57 (1.03)	0.83 (1.15)	0.30 (0.89)	1.20 (1.30)	0.43 (0.97)	1.20 (1.30)	0.23 (0.86)	1.20 (1.30)	**0.70**
T_6	0.27 (0.88)	0.43 (0.96)	0.73 (1.11)	0.20 (0.84)	0.67 (1.08)	0.33 (0.91)	0.40 (0.95)	0.13 (0.80)	0.43 (0.96)	**0.40**
T_7	0.10 (0.77)	0.33 (0.91)	0.40 (0.95)	0.07 (0.75)	0.43 (0.96)	0.20 (0.84)	0.40 (0.94)	0.03 (0.73)	0.40 (0.94)	**0.26**
T_8	0.30 (0.89)	0.50 (1.00)	0.83 (1.15)	0.23 (0.86)	1.17 (1.29)	0.37 (0.93)	1.30 (1.34)	0.17 (0.82)	1.30 (1.34)	**0.69**
T_9	0.33 (0.91)	0.50 (1.00)	0.70 (1.09)	0.27 (0.88)	0.60 (1.05)	0.43 (0.97)	0.70 (1.09)	0.23 (0.85)	0.70 (1.09)	**0.50**
T_{10}	0.80 (1.14)	1.03 (1.24)	1.30 (1.34)	0.97 (1.21)	2.07 (1.60)	1.17 (1.29)	2.30 (1.67)	0.97 (1.21)	2.30 (1.67)	**1.43**
SEm ±	**0.09**	**0.08**	**0.07**	**0.08**	**0.12**	**0.11**	**0.13**	**0.07**	**0.08**	**0.09**
C. D. (P = 0.05)	**0.26**	**0.25**	**0.22**	**0.24**	**0.35**	**0.32**	**0.39**	**0.20**	**0.25**	**0.28**

***Figures within parentheses are squire root transformed values**

Impact of different ecological engineering methods on the incidence of ladybird beetle, seed yield and BC ratio.

a) Ladybird beetle population after 30 day after sowing:

The results revealed that all the ecological engineering methods were differed significantly to each other in respect to record the population of Ladybird beetle. Among the treatments at 30 DAS the highest population of Ladybird beetle was recorded in treatments having border crop of maize (T_7, T_8 and T_9) followed by treatments having border crop of sorghum (T_1, T_2 and T_3). However among 3 treatments with border crop of maize significant highest population of Ladybird beetle (1.83 beetle/plant) was recorded in treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) followed by (1.70 beetle/plant) T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) and T_9 (soil application of poultry manure @1.0t/ha + border crop with maize + two foliar spray of NSKE). However significantly lowest Ladybird population (1.30 beetle/plant) was recorded from the control plot (T_{10}) followed by (1.43 beetle/plant) T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil) and (1.47 beetle/plant) T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil). The treatments T_{10} (1.30 beetle/plant), T_4 (1.43 beetle/plant), T_1 (1.47 beetle/plant) and T_3 (1.50 beetle/plant) were found at par to each other in respect to record the lowest Ladybird beetle population after 30 day after sowing.

b) Ladybird beetle population after 45 day after sowing:

The results revealed that all the ecological engineering methods were differed significantly to each other in respect to record the population of Ladybird beetle at 45 DAS. Among the treatments the highest population of Ladybird beetle (2.33 beetle/plant) was recorded from the T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) followed by (2.20 beetle/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of

vermiwash) and (1.83 beetle/plant) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash). However significantly lowest Ladybird population (1.60 beetle/plant) was recorded from the treatment T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil) followed by (1.67 beetle/plant) T_{10} (control) and (1.70 beetle/plant) T_3 (seed treatment + soil application of poultry manure + border crop with pearl millet + two foliar spray of NSKE). The treatments T_1 (1.73 beetle/plant), T_3 (1.70 beetle/plant), T_4 (1.60 beetle/plant), T_6 (1.77 beetle/plant), T_7 (1.70 beetle/plant) and T_{10} (1.67 beetle/plant) were found at par to each other in respect to record the Ladybird beetle population after 45 day after sowing.

c) Ladybird beetle population after 70 day after sowing:

All the ecological engineering methods were differed significantly to each other in respect to record the population of Ladybird beetle. Among the treatments at 70 DAS the highest Ladybird beetle population (2.90 beetle/plant) was recorded from the treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) followed by (2.70 beetle/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash) and (2.50 beetle/plant) T_9 (soil application of poultry manure @1.0t/ha + border crop with maize + two foliar spray of NSKE). The significantly lowest Ladybird population (1.90 beetle/plant) was recorded from the control T_{10} followed by (2.07 beetle/plant) T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil) and (2.27 beetle/plant) T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil). The treatments T_{10} (1.90 beetle/plant) and T_4 (2.07 beetle/plant), T_1 (2.27 beetle/plant) and T_6 (2.30 beetle/plant), T_2 (2.70 beetle/plant) T_5 (2.57 beetle/plant) were found at par to each other in their respect group to record the Ladybird beetle population after 70 day after sowing.

Table 11: Impact of different ecological engineering methods on the incidence of Ladybird beetle, seed yield and B:C ratio.

Treatments	Ladybird beetle/plant				Seed yield (kg/ha)	BC ratio
	30 DAS	45 DAS	70 DAS	Mean		
T_1	1.47 (1.40)	1.73 (1.49)	2.27 (1.66)	1.82	1018	**3.77**
T_2	1.53 (1.43)	2.20 (1.64)	2.70 (1.79)	2.14	877	**3.14**
T_3	1.50 (1.41)	1.70 (1.48)	2.33 (1.68)	1.84	990	**3.12**
T_4	1.43 (1.39)	1.60 (1.45)	2.07 (1.60)	1.7	947	**3.33**
T_5	1.50 (1.41)	1.83 (1.53)	2.57 (1.75)	1.96	817	**2.73**
T_6	1.57 (1.44)	1.77 (1.50)	2.30 (1.67)	1.88	950	**2.90**
T_7	1.70 (1.48)	1.70 (1.48)	2.47 (1.72)	1.95	1088	**4.21**
T_8	1.83 (1.53)	2.33 (1.68)	2.90 (1.84)	2.35	863	**3.05**
T_9	1.70 (1.48)	1.83 (1.53)	2.50 (1.73)	2.01	1015	**3.25**
T_{10} **(Control)**	1.30 (1.34)	1.67 (1.47)	1.90 (1.55)	1.62	412	**-**
SEm ±	**0.08**	**0.06**	**0.05**		**4.57**	**-**
C. D. (P = 0.05)	**0.25**	**0.19**	**0.15**		**13.58**	**-**

***Figures within parentheses are squire root transformed values**

d) Evaluation of different ecological engineering methods on the basis of seed yield (kg/ha) and B:C ratio:

The seed yield of each treatment from each replication were recorded separately and converted into kg/ha. All the treatments (ecological engineering methods) were found significantly superior over control to record the higher seed yield. The significantly highest seed yield (1088 kg/ha) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (1018 kg/ha) treatment T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil) and (1015 kg/ha) T_9 (soil application of poultry manure @1.0t/ha + border crop with maize + two foliar spray of NSKE). The significantly lowest seed yield (412 kg/ha) was recorded from the treatment T_{10} (control plot) followed by (817 kg/ha) the treatment T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash) and (863 kg/ha) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash). The treatment T_7 and T_1 in which soil application of neem cake and foliar spray of neem oil were applied were found superior to others in respect to record higher seed yield.

e) B:C ratio

The benefit cost ratio of each treatment was recorded separately. Among the treatment the highest BC ratio was recorded from the treatment the highest BC ratio (4.21) was recorded in treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (3.77) T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil) and (3.33) T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil). However the lowest benefit cost ratio was found in treatment (2.73) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash) followed by (2.90) T_6 (soil application of poultry manure @1.0t/ha + border crop with sorghum + two foliar spray of NSKE) and (3.05) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray

of vermiwash). The treatment T_7 and T_1 in which soil application of neem cake and foliar spray of neem oil were applied were found superior to others in respect to record higher benefit cost ratio.

To study the succession of insect pests complex associated with sesame

To study the succession of insect pests on sesame

To study the succession of insect pests, the crop was kept free from insecticide application. Weekly observations on different insect pests were recorded on 10 randomly selected plants starting from one week after germination and continued till the availability or maturity of the crop *i.e.* August, 2019 to October, 2019. During the course of study, following insect pests were recorded.

I. The incidence of leaf webber and capsule borer was observed from the seedling stage *i.e* 7 days old crop age at this stage they infesting the plants by forming the leaf webs of terminal leaves. The Incidence of this insect pest was noticed one week after germination to till the Maturity of the crop.

II. The incidence of Bihar hairy caterpillar was observed from seedling stage and incidence was continued till the capsule formation stage of the crop (20 August to 07 October, 2019). This insect pest was active from crop age of 14 to 63 days.

III. Til hawk moth was appeared during the seedling stage of the crop growth and their incidence was continued till capsule maturity stage of the crop (14 August to 21 October, 2019). This pest was active from crop age of 14 to 77 days.

IV. The incidence of whitefly and leafhopper was noticed from one week after germination of the crop and continued till capsule formation stage of the crop. The activity of both the insect pests were noticed from 7 days old stage and continued to crop age of 56 days (13 August, 2019 to 30 September, 2019).

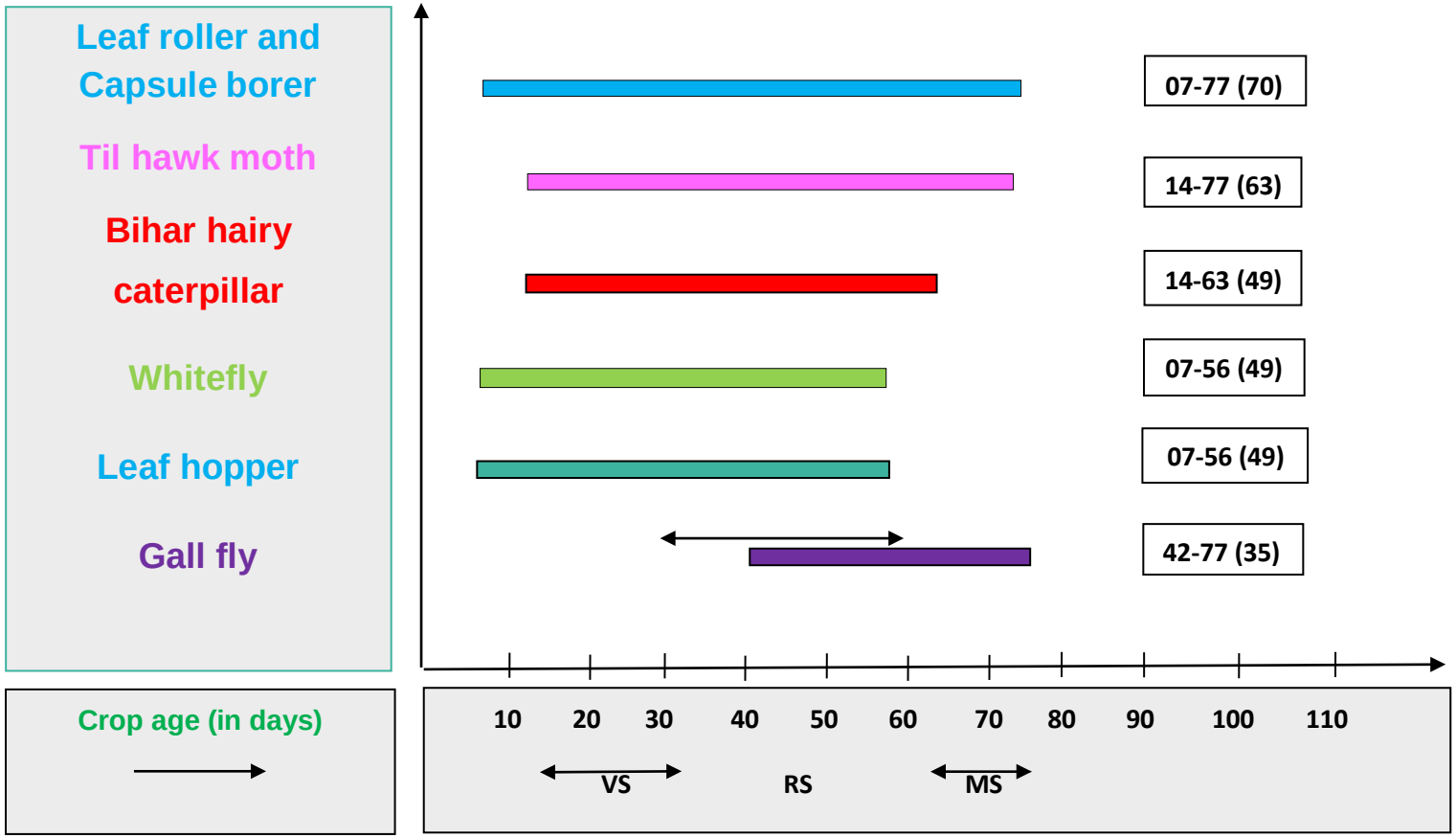
V. The incidence of mirid bug was noticed from vegetative stage of the crop

and continued till capsule maturity stage of the crop. The activity of mirid bug was noticed from 21 days old crop stage and continued to 70 days old crop stage (27 August, 2019 to 14 October, 2019).

VI. The incidence of gall fly was noticed from flowering stage of the crop growth to capsule maturity stage of the crop. This pest was active from 42 days after germination and continued till the maturity of the crop. (16 September to 21 October,2019).

Table 12 List of insect pests observed on Sesame at Jabalpur during 2019-2020.

S. No.	Common name	Scientific name	Order	Family	Nature of damage
1	Leaf webber and Capsule borer	*Antigastra catalaunalis* (Duponchel)	Lepidoptera	Crambidae	In early stage caterpillars feed on tender leaves and remain inside the leaf web. At flowering, larvae feed inside the flowers and on capsule formation, larvae bore into capsules and feed on developing seed
2	Til hawk moth	*Acherontia styx* (West wood)	Lepidoptera	Sphingidae	Larva is robust feeder. They feed on leaves and defoliate the plants and cut the tender portion of the plant.
3	Bihar hairy caterpillar	*Spilosoma obliqua* (Walker)	Lepidoptera	Arctiidae	Early stage larvae are gregarious feeders, they scraped the green portion of the leaves, affected leaves were turn in to white paper like structure. Mature caterpillars migrate to other plants and feed voraciously leaving only the stem.
4	Whitefly	*Bemisia tabaci* (Genadius)	Hemiptera	Aleyrodidae	Nymph & Adult suck the cell sap from the leaves.
5	Leafhopper	*Orocious albicinctus* (Distance)	Hemiptera	Cicadellidae.	Nymph and Adult suck the cell sap from the tender parts of the plants. They are also act as a vector to transmit the sesame phyllody disease.
6	Gall fly	*Asphondylia sesami* (Felt.)	Diptera	Cecidomylidae	Maggots feed inside the floral bud leading to formation of gall like structure which do not develop into capsule**.**
7	Mirid Bug	*Nesidiocoris tenuis* (Reuter)	Heteroptera	Miridae	Nymph and Adult suck the cell sap from the tender parts of the plants.



Crop stage: VS= Vegetative stage, RS=Reproductive stage (Flowering / Fruiting stage), MS=Maturity stage

Fig. 2. To study the succession of insect pests complex associated with sesame.

Table 13 Succession of major insect pests on sesame at Jabalpur during *Kharif* (2019-2020).

Date of Observation	Crop		Insects and pests	
	stage	age (days)	Scientific name	Damaging stage
13 Aug, 2019	Seedling	7	*Antigastra catalaunalis* (Dup.)	Larvae
			Bemisia tabaci (Genadius)	Nymph and adult
			Orocious albicinctus (Distance)	
20 Aug,2019	Seedling	14	*A. catalaunalis*	Larvae
			S. oblique (Walker)	
			Acherontia styx (West Wood)	
			B. tabaci	Nymph and adult
			O. albicinctus	
27 Aug, 2019	Vegetative	21	*A. catalaunalis*	Larvae
			S. oblique	
			A. styx	
			B. tabaci	Nymph and adult
			O. albicinctus	
			Nesidiocoris tenuis	
02 Sep, 2019	Vegetative	28	*A. catalaunalis*	Larvae
			S. oblique	
			A. styx	
			B. tabaci	Nymph and adult
			O. albicinctus	
			N. tenuis	
09 Sep,2019	Vegetative	35	*A. catalaunalis*	Larvae
			S. oblique	
			A. styx	
			B. tabaci	Nymph and adult
			O. albicinctus	
			N. tenuis	
16 Sep, 2019	Flowering	42	*A.catalaunalis*	Larvae
			S. oblique	
			A. styx	
			O. albicinctus	Nymph and adult
			B. tabaci	
			N. tenuis	
			Asphondylia sesami	Maggot
23 Sep, 2019	Flowering and Capsule formation	49	*A. catalaunalis*	Larvae
			S. oblique	
			A. styx	
			O. albicinctus	Nymph and adult
			B. tabaci	
			N. tenuis	
			A. sesami	Maggot
30 Sep, 2019	Capsule formation	56	*A. catalaunalis*	Larvae
			S. oblique	
			A. styx	
			O. albicinctus	Nymph and adult
			B. tabaci	
			N. tenuis	
			A. sesami	Maggot
07 Oct, 2019	Capsule formation	63	*A. catalaunalis*	Larvae
			S. oblique	
			A. styx	
			N. tenuis	Nymph and adult
			A. sesami	Maggot
14 Oct,2019	Capsule Maturity	70	*A. catalaunalis*	Larvae
			A. styx	
			N. tenuis	Nymph and adult
			A. sesami	Maggot
21 Oct, 2019	Capsule Maturity	77	*A. catalaunalis*	Larvae
			A. styx	
			A. sesami	Maggot

Among the recorded insect pests the longest succession period 77 and 70 days were recorded respectively in *A. catalaunalis* and *A. styx* thèse insect pests were active from seedling stage of the crop growth to capsule maturity stage of the crop. The succession of *S. oblique, B. tabaci and O. albicinctus* were recorded 56 days. The incidence of *S. oblique, B. tabaci* and *O. albicinctus* were noticed from seedling stage to capsule formation stage of the crop growth. The succession of mirid bug was recorded 63 days and the activity of this pests was recorded from vegetative stage to capsule maturity stage of the crop growth (21 days after germination to 70 days after germination). The shortest succession period of 42 days was recorded in case of *A. sesame* which was active from flowering stages to capsule maturity stage of the crop growth.



A. Sesame border crop with pearl millet



B. Sesame border crop with maize



C. Til hawk moth larva



D. Larva of Bihar hairy caterpillar



E. Mirid bug



F. Lady bird beetle



G. **Leaf webbing by *Antigastra catalaunalis***



G. Capsule damage by *Antigastra catalaunalis*



H. Leaf hopper



I. Whitefly

DISCUSSION

The results of investigation "**To study the ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame** have been presented in preceding chapter. The findings of investigation have been discussed in the light of previously available information and important conclusion.

Evaluation of different ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame.

The experiment "Evaluation of different ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame " was laid out with sesame variety TKG-21 in RBD with three replications consisting of nine treatments. In each treatment seed treatment with *Trichoderma viride* @ 10g/kg seed and *Pseudomonas florescence* @10g/kg seed was common except control. Treatment T_1 to T_3 were laid with border crop of pearl millet, in treatment T_4 to T_6 border crop of maize had been taken while in treatment T_7 to T_9 border crop of sorghum had been taken. Each treatment having different border crops were evaluated by adding different fertilizers and bio-pesticides combinations.

Evaluation of different ecological engineering methods on the basis of percent damages at different stages of plant growths

For the management of leaf webber and capsule borer in sesame nine ecological engineering methods were evaluated. The percent damages due to leaf webber and capsule borer at different stages of plant growths (vegetative flowering and capsule maturity stages) were recorded.

Percent plant damage:

The results revealed that all the ecological engineering methods were found significantly superior over control to record the lowest percent plant, flower and capsule damage. Among the treatment the lowest percent plant (6.88%), flower (10.22%) and capsule (8.34%) damage were recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil). Treatment T_1 (seed

treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) was the next better treatment in respect to record the lowest damages and recorded 8.33%, 10.93% and 8.55% plant flower and capsule damages respectively. The highest percent plant (14.79%), flower (19.57%) and capsule damage (20.04%) was recorded from the (T_{10}) control plot. Among the ecological engineering treatment, T_2 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash) was the least effective treatment in respect to record the lowest percent plant damage while in case of percent flower and capsule damage treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) was found the least effective with 10.83% and 13.61% flower and capsule damages respectively. Present findings are corroborated with the findings of Jasmine *et al*., (2020) they evaluated the different ecological engineering methods against major insect pests of sesame and reported during flowering stage, pearl millet border cropping recorded lesser damage (14.04%) followed by sesame+sorghum (14.67%) whereas sole sesame recorded damage to the tune of 23.72%. However, sorghum border cropping recorded lowest capsule damage (4.67%) followed by sesame+pearl millet (4.93%). The observed the same trend during the capsule formation stage also. Present findings are also supported by the findings of Behera *et al*., (2013) they evaluated the sesamum intercropped with green gram (PDM 84-139), black gram (PU-35), pearl millet (L-74), sorghum (SSG 59-3) and cluster bean (PNB) at 3:3 row ratio and reported that the capsule damage due to *A. catalaunalis* was more (10%) in case of sesame (sole crop) as compare to lower damage (6-9%) was recorded in intercropping systems.

Impact of different ecological engineering methods on the incidence of major insect pests and their natural enemies

All the ecological engineering methods were also assessed on the basis number of insect pests and presence of natural enemies per plant. The observations of on number of insect pests and their natural enemies were recorded at weekly intervals. The seed yield and cost benefit ratio of each ecological engineering methods were also calculated.

Leaf webber and capsule borer [*Antigastra catalaunalis* (Dup.)]

The results presented in table revealed that all the ecological engineering methods (treatments) were found significantly superior over control to record the lowest larval population of leaf webber and capsule borer. Among the treatments the lowest mean larval population (0.35 larvae/plant) was recorded in treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.31 larvae/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and T_6 (seed treatment + soil application of poultry manure + border crop with sorghum + two foliar spray of NSKE 5%). Present findings are in agreement with the findings of Jasmine *et al*., (2020) they conducted a field experiments to screen the best border crop for the management of major insect pest of sesame and reported that the lowest population of *Antigastra* larva (0.4/plant) was recorded in sesame + pearl millet combination followed by T_1 (sesame + sorghum) and T_7 (sesame + castor) (0.6/plant). Present findings are also supported by the findings of Behera *et al*., (2013) revealed that sesamum intercropped with green gram (PDM 84-139), black gram (PU-35), pearl millet (L-74), sorghum (SSG 59-3) and cluster bean (PNB) at 3:3 row ratio reduced the incidence of *A. catalaunalis* on sesame (OSC-207). In case of sesame (sole crop) 10% capsule damage was recorded but lower incidence (6-9%) was recorded in intercropping systems. The highest mean larval population (1.76 larvae/plant) was recorded in treatment T_{10} (control) followed by (0.82 larvae/plant) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) and T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash). Present findings are in confirmity with the findings of Chaitra *et al*., (2020) they evaluated nine biopesticides against insect pests of sesame and reported that among the tested biopesticides, Neem Seed Kernel Extract (NSKE) 5%, neem oil 0.3% and *B. bassiana* 0.1% effectively managed whitefly and leaf webber incidence in both the seasons.

Leaf hopper:

The results revealed that all the ecological engineering methods were found significantly superior over control to reduce the population of leafhopper. Among the treatments the lowest mean population (0.27 leafhopper/three leaves/plant) of leafhopper was recorded in treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.28 leafhopper/three leaves/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and (0.38 leafhopper/three leaves/plant) however the highest mean population of leafhopper (1.25 leafhopper/three leaves/plant) was recorded from treatment (T_{10}) control plot followed by (0.60 leafhopper/three leaves/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash) and (0.55 leafhopper/three leaves/plant). Present findings are supported by the findings of Indiragandhi *et al* (2018) they evaluated different border crops and reported that among the seven combinations, border cropping of groundnut with sorghum, pearl millet and maize recorded significantly the lowest population of thrips, leafhopper and reduced the damage caused by *Spodoptera litura*, *Helicoverpa armigera* and *Aproaerema modicella*e. Present findings are also in confirmity with the findings of Sujayanand *et al* (2015) they studied the crop diversification for sustainable insect pest management in eggplant (Solanales: Solanaceae) and reported the reduction of fruit borer and leafhopper incidences in main crop brinjal, when raised with maize as border crop.

Whitefly (*Bemisia tabaci* (Genadius)

Among the treatments the lowest mean population of whitefly (0.88 whitefly/three leaves/plant) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.96 whitefly/three leaves/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and T_4 (seed treatment + soil application of neem cake + border crop with sorghum + two foliar spray of neem oi) while the highest population of whitefly (2.61 whitefly/three

leaves/plant) was recorded from the treatment T_{10} (control) followed by (1.49 whitefly/three leaves/plant) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) and (1.48 whitefly/three leaves/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash). Present findings are corroborated with the findings of Chaitra *et al*., (2020) they evaluated nine biopesticides against insect pests of sesame and reported that among the tested biopesticides, Neem Seed Kernel Extract (NSKE) 5%, neem oil 0.3% and *B. bassiana* 0.1% effectively managed the population of whitefly. Present findings are supported by the findings of Deepika A. (2016) they evaluated ecological engineering methods for enhancing entomophages and increasing pest suppression on okra and reported that okra + cowpea border cropping system registered a maximum population of dragonflies, damselflies, wasps, predatory pentatomid bugs and coccinellids on okra and border crops, and reduced the population of *Bemisia tabaci* and *Helicoverpa armigera* on okra.

Mirid bug

The lowest mean population of mirid bug (0.26 mirid bug/three leaves/plant) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (0.29 mirid bug/three leaves/plant) T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) and T_4 (seed treatment + soil application of neem cake + border crop with sorghum + two foliar spray of neem oi). The significantly highest mean population of mirid bug (1.43 mirid bug/three leaves/plant) was recorded in treatment T_{10} (control) followed by (0.71 mirid bug/three leaves/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash) and T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash).

Impact of different ecological engineering methods on the incidence of ladybird beetle, seed yield and BC ratio.

The activity of natural enemies was also recorded at different stages of plant growths. Different natural enemies were recorded during the course of study but their population was very low. Among the natural enemies the population of ladybird beetle was more so its population was recorded at different stages of plant growths.

Ladybird beetle population after 30 day after sowing :

The results revealed that all the ecological engineering methods were differed significantly to each other in respect to record the population of ladybird beetle. Among the treatments at the highest population of ladybird beetle was recorded in treatments having border crop of maize (T_7, T_8 and T_9) followed by treatments having border crop of sorghum (T_1, T_2 and T_3). However among 3 treatments with border crop of maize significant highest population of ladybird beetle (1.83 beetle/plant) was recorded in treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) followed by (1.70 beetle/plant) T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil). Present findings are supported by the findings of Wu *et al*. (1991) they reported that intercropping with maize in cotton fields increased the population of spiders, Coccinellids and Chrysopids by 62.8 to 115.7% compared to control fields.

The significantly lowest population of ladybird beetle (1.30 beetle/plant) was recorded from the control plot (T_{10}) followed by (1.43 beetle/plant) T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil) and (1.47 beetle/plant) T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil).

Ladybird beetle population after 45 day after sowing :

Among the treatments at 45 DAS the highest population of ladybird beetle (2.33 beetle/plant) was recorded from the treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray

of vermiwash) followed by (2.20 beetle/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash) however significantly lowest population (1.60 beetle/plant) of beetle was recorded from the treatment T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil) followed by (1.67 beetle/plant) T_{10} (control) and (1.70 beetle/plant) T_3 (seed treatment + soil application of poultry manure + border crop with pearl millet + two foliar spray of NSKE). Present findings are in conformity with the findings of Chandrasekar *et al* (2016) they studied the ecological engineering cropping method for enhancing predator *Coccinella septempunctata* and suppression of planthopper, *Nilaparvata lugens* (Stal) in rice and reported that rice + cowpea border cropping system registered maximum population of coccinellids and rove beetle and minimum population of planthoppers and leafhoppers. Present findings are also supported by the findings of Parthiban *et al* (2018) they reported that groundnut (*Arachis hypogaea*) when intercropped with maize (*Zea mays*) and bajra (*Pennisetum glaucum*) 4:1 ratio attracted the highest population of natural enemies like coccinellids and green lacewings, recording the population of 8.11 and 3.13 nos./10 plants followed by groundnut + sorghum (*Sorghum bicolor*) while it was 5.94 and 2.27 nos./10 plants in groundnut pure crop.

Ladybird beetle population after 70 day after sowing:

At 70 DAS the highest population of ladybird beetle (2.90 beetle/plant) was recorded from the treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) followed by (2.70 beetle/plant) T_2 (seed treatment + soil application of vermicompost + border crop with pearl millet + two foliar spray of vermiwash) and (2.50 beetle/plant) T_9 (soil application of poultry manure @1.0t/ha + border crop with maize + two foliar spray of NSKE) while the significantly lowest population (1.90 beetle/plant) of ladybird beetle was recorded from the control T_{10} followed by (2.07 beetle/plant) T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil) and (2.27 beetle/plant) T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil). Present findings

are supported by the findings of Lokesh *et al* (2017) They reported that blackgram + cowpea border cropping system significantly influenced maximum coccinellids on blackgram 3.72/plant) along with highest pest defender ratio (PDR) of 1: 2.4, occurrence ratio (OR) of coccinellids (1.83), minimum *A. gossypii* (3.63/terminal shoot), preference ratio (PR) of *A. gossypii* (0.94) and maximum BC ratio (1: 4.35). Present findings are also supported by the findings of Indiragandhi *et al* (2018) they evaluated border crops and reported that among the seven combinations, border cropping of groundnut with sorghum, pearl millet and maize recorded significantly the more number of natural enemies *viz.,* coccinellids (3.8/plant) and spider (4.2/plant). They concluded that the fast growing and taller cereals could reduce the pests' incidence in the main crop groundnut by acting as physical/mechanical barrier despite encouraging the natural enemies population.

Evaluation of different ecological engineering methods on the basis of seed yield (kg/ha) and BC ratio:

The results revealed that all the ecological engineering methods were found significantly superior over control to record the higher seed yield. The significantly highest seed yield (1088 kg/ha) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (1018 kg/ha) treatment T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil) while the significantly lowest seed yield (412 kg/ha) was recorded from the treatment T_{10} (control plot) followed by (817 kg/ha) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash) and (863 kg/ha) T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash). Present findings are corroborated with the findings of Jasmine *et al*., (2020) they conducted a field experiments to screen the best border crop for the management of major insect pest of sesame by attracting and sustaining the natural enemy population. They reported Sesame+pearl millet combination recorded lowest insect pests population and maximum of seed yield 547 and 636 kg/ha during kharif 2016 and rabi/summer 2017 followed by sesame+sorghum combination (528 & 612

kg/ha). Present findings are also supported by the findings of Chaitra *et al*., (2020) they evaluated nine biopesticides against insect pests of sesame and reported that among the tested biopesticides, Neem Seed Kernel Extract (NSKE) 5%, neem oil 0.3% and *B. bassiana* 0.1% effectively managed whitefly and leaf webber incidence in both the seasons and also produced higher seed yield than control viz. 56.65, 50.23 and 26.08% in plots treated with NSKE 5%, neem oil 0.3% and *B. bassiana* 0.1%, respectively during summer. In kharif, seed yield over control was 93.27, 72.21 and 71.61% in NSKE 5%, *B. bassiana* 0.1% and neem oil 0.3%, respectively.

BC ratio

The benefit cost ratio of each treatment was recorded separately and result revealed that the highest BC ratio (4.21) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (3.77) T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil) and (3.33) T_4 (seed treatment + soil application of neem cake 250 kg/ha + border crop with sorghum + two foliar spray of neem oil). Among the ecological engineering methods the lowest benefit cost ratio was recorded from the treatment (2.73) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash) followed by (2.90) T_6 (soil application of poultry manure @1.0t/ha + border crop with sorghum + two foliar spray of NSKE) and (3.05). The treatment T_7 and T_1 in which soil application of neem cake and foliar spray of neem oil were applied were found superior to others in respect to record higher benefit cost ratio. Present findings are in confirmity with the findings of Indiragandhi *et al* (2018) they evaluated different border crops and reported that among the seven combinations, border cropping of groundnut with sorghum, pearl millet and maize recorded significantly the lowest insect pests population, percent damages and higher population of natural enemies. They found the same border crop combinations increased the economic returns of 1:4.35, 1:4.3 and 1:3.8, respectively.

To study the succession of insect pests on sesame

For the study of the pest succession, weekly observations were recorded from the seedling stage of crop to maturity *i.e.* August, 2019 to October, 2019. During the course of study, the leaf webber and capsule borer appeared during the seedling stage *i.e* 7 days old crop and incidence continued till Maturity of the crop. Bihar hairy caterpillar appeared during the seedling stage and continued till the capsule formation stage (20 Aug, to 07 October, 2019). Til hawk moth appeared during the seedling stage of the crop growth and damage the crop till maturity stage (20 August to 21 October, 2019). Whitefly and leafhopper appeared in the seedling stage of crop *i.e.* on the 7 days old crop and continued till capsule formation stage of the crop (7 to 56 days). The incidence of mirid bug was noticed from vegetative stage of the crop and continued till capsule maturity stage of the crop while gall fly appeared during the flowering stage (42 days after germination) and their incidence was noticed till the maturity of the crop. (21 October, 2019). Present findings are supported by the findings of Kumar *et al*. (2009) they studied pest succession in sesame and found that the incidence of til leaf webber and capsule borer occurred throughout the crop period i.e. from seedling to harvesting stage. Further they reported that whitefly, leaf hopper and sting bug were active during vegetative stage. The incidence of sesame gall fly and stink bug was reported to be from flowering to capsule stage, whereas, till hawk moth's first incidence was observed at capsule formation stage and continued till capsule maturity stage.

Among the recorded insect pests the longest succession period 77 and 70 days were recorded respectively in *A. catalaunalis* and *A. styx* thèse insect pests were active from seedling stage of the crop growth to capsule maturity stage of the crop. The succession of *S. oblique, B. tabaci and O. albicinctus* were recorded 56 days. The incidence of *S. oblique, B. tabaci* and *O. albicinctus* were noticed from seedling stage to capsule formation stage of the crop growth. Present findings are supported by the findings of Gangwar *et al*. (2014) they studied the succession of insect pests of sesame and reported that the population of shoot webber and pod borer (*Antigastra catalaunalis)* and leaf hopper *(Orosius albinctus)* was first appeared in 21 to 23 days old

sesame crop. The succession of mirid bug was recorded 63 days and the activity of this pests was recorded from vegetative stage to capsule maturity stage of the crop growth (21 days after germination to 70 days after germination). The shortest succession period of 42 days was recorded in case of *A. sesame* which activity was noticed from flowering stages to capsule maturity stage of the crop growth.

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

Summary

The results revealed that all the ecological engineering methods were found significantly superior over control to record the lowest percent plant, flower and capsule damage. Among the treatment the lowest percent plant (6.88%), flower (10.22%) and capsule (8.34%) damage was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil). Treatment T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) was the next better treatment in respect to record the lowest damages and recorded 8.33%, 10.93% and 8.55% plant flower and capsule damages respectively. The highest percent plant (14.79%), flower (19.57%) and capsule damage (20.04%) was recorded from the (T_{10}) control plot.

Impact of different ecological engineering methods on the incidence of major insect pests and their natural enemies

The results revealed that all the ecological engineering methods (treatments) were found significantly superior over control to record the lowest insect pests population. Among the treatments the lowest mean population of leaf webber and capsule borer (0.35 larvae/plant), leafhopper (0.27 leafhopper/three leaves/plant), whitefly (0.96 whitefly/three leaves/plant) and mirid bug (0.26 mirid bug/three leaves/plant) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil). Treatment T_1 (seed treatment + soil application of neem cake 250 kg/ha + border crop with pearl millet + two foliar spray of neem oi) was the next better treatment in respect to record the lowest population of leaf webber and capsule borer (0.31 larvae/plant), leafhopper (0.28 leafhopper/three leaves/plant), whitefly (0.96 whitefly/three leaves/plant) and mirid bug (0.29 mirid bug/three leaves/plant). The highest mean population of leaf webber and capsule borer (1.76 larvae/plant), leafhopper (1.25 leafhopper/three leaves/plant) whitefly (2.61 whitefly/three leaves/plant) and

mirid bug (1.43 mirid bug/three leaves/plant) was recorded from the treatment T_{10} (control). Among the ecological engineering methods the treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) was the least effective treatment which recorded the highest population of insect pests after control.

Impact of different ecological engineering methods on the incidence of ladybird beetle, seed yield and BC ratio.

The results revealed that all the ecological engineering methods were differed significantly to each other in respect to record the population of Ladybird beetle. Among the treatments at the highest population of Ladybird beetle was recorded in treatments having border crop of maize (T_7, T_8 and T_9) followed by treatments having border crop of sorghum (T_1, T_2 and T_3). However among 3 treatments with border crop of maize significantly highest population of Ladybird beetle 1.83, 2.20 and 2.90 beetle/plant at 30, 45 and 70 DAS respectively was recorded from the treatment T_8 (seed treatment + soil application of vermicompost + border crop with maize + two foliar spray of vermiwash) however the significantly lowest population of Ladybird beetle 1.30, 1.67 and 1.90 beetle/plant at 30, 45, and 70 DAS respectively was recorded from the (T_{10}) control plot.

The results revealed that all the ecological engineering methods were found significantly superior over control to record the higher seed yield. The significantly highest seed yield and BC ratio (1088 kg/ha seed yield and 4.21 BC ratio) was recorded from the treatment T_7 (seed treatment + soil application of neem cake 250 kg/ha + border crop with maize + two foliar spray of neem oil) followed by (1018 kg/ha seed yield and 3.77 BC ratio) treatment T_1 (seed treatment + soil application of neem cake + border crop with pearl millet + two foliar spray of neem oil) while the significantly lowest seed yield (412 kg/ha) was recorded from the treatment T_{10} (control plot) followed by (817 kg/ha seed yield and 2.73 BC ratio) T_5 (seed treatment + soil application of vermicompost + border crop with sorghum + two foliar spray of vermiwash).

To study the succession of insect pests on sesame

Among the recorded insect pests the longest succession period 77 and 70 days were recorded respectively in *A. catalaunalis* and *A. styx* thèse insect pests were active from seedling stage of the crop growth to capsule maturity stage of the crop. The succession of *S. oblique, B. tabaci and O. albicinctus* were recorded 56 days. The incidence of *S. oblique, B. tabaci* and *O. albicinctus* were noticed from seedling stage to capsule formation stage of the crop growth. The succession of mirid bug was recorded 63 days and the activity of this pests was recorded from vegetative stage to capsule maturity stage of the crop growth (21 days after germination to 70 days after germination). The shortest succession period of 42 days was recorded in case of *A. sesame* which activity was noticed from flowering stages to capsule maturity stage of the crop growth.

Conclusion

From the above result it can be concluded that the lowest insect pests population, percent damage caused by leaf webber and capsule borer at different stages of plant growths, highest seed yield and BC ratio was recorded from the treatment T_7 (Seed treatment with *Trichoderma viride* @ 10g/kg) + border crop with maize + soil application of neem cake@ 250 kg/ha + foliar spraying of Neem oil @ 10 ml/l) followed by T_1 (Seed treatment with *Trichoderma viride* @ 10g/kg + border crop with pearl millet + soil application of neem cake@ 250 kg/ha + foliar spraying of neem oil @ 10 ml/l).

The highest population of Ladybird beetle was recorded from the treatment T_8 (Seed treatment with *Trichoderma viride* @ 10g/kg) + border crop with maize + soil application of Vermicompost @ 1.0 t/ha + foliar sprayings of vermiwash 5%) followed by T_2 (Seed treatment with *Trichoderma viride* @ 10g/kg) + border crop with pearl millet + soil application of vermicompost @ 1.0 t/ha + foliar sprayings of vermiwash 5%).

Among the recorded insect pests the longest succession period 77 and 70 days were recorded respectively in *A. catalaunalis* and *A. styx* thèse insect pests were active from seedling stage to maturity stage of the crop while the

shortest succession period of 42 days was recorded in case of *A. sesame* which was active from flowering to maturity stage of the crop.

The succession of *S. oblique, B. tabaci and O. albicinctus* were recorded 56 days while the incidence of *S. oblique, B. tabaci* and *O. albicinctus* were noticed from seedling stage to capsule formation stage of the crop growth.

The succession of mirid bug was recorded 63 days and the activity of this pests was recorded from vegetative stage to capsule maturity stage of the crop growth (21 days after germination to 70 days after germination).

Suggestions for further Work

- Large scale trials for the confirmation of effect of ecological aspects for the management of leaf webber and capsule borer should be conducted.
- Effect of different border crop on the incidence of insect pests and associated natural enemies may be studied.
- Biochemical assay study may be conducted on the mechanism of resistance development in plants due to the application of organic amendments.
- Detail studies on integration of organic soils amendments (neem cake application, neem seed kernel extract and ecofriendly insecticides) in the management of major insect pests of sesame may be conducted.
- Development of IPM modules comprising the combination of most effective organic amendments and indigenous sprays.

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APPENDICES

Evaluation of different ecological engineering methods for the management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup.) in sesame.

1) Effect of different ecological engineering methods on the damage caused by leaf webber and capsule borer at different stages of plant growths

ANOVA 1: Plant (At 30 DAS)

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	1.26	0.63	0.30	3.55	NS
Treatment	9	107.28	11.92	5.62	2.46	Significant
Error	18	38.17	2.12			
Total	29	146.71				
SEm± = 0.84			**C.D. (at 5%)** = 2.50			

ANOVA 2: Flower (At 45 DAS)

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	0.01	3.55	NS
Treatment	9	128.53	14.28	25.35	2.46	Significant
Error	18	10.14	0.56			
Total	29	138.68				
SEm± = 0.44			**C.D. (at 5%)** = 1.30			

ANOVA 3: Capsule (At 70 DAS)

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	1.84	0.92	3.72	3.55	Significant
Treatment	9	225.05	25.01	101.12	2.46	Significant
Error	18	4.45	0.25			
Total	29	231.35				
SEm± = 0.29			**C.D. (at 5%)** = 0.85			

2) Evaluation of different ecological engineering methods against leaf webber and capsule borer in sesame

ANOVA 1: 14 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	3.71	3.55	Significant
Treatment	9	0.52	0.06	27.54	2.46	Significant
Error	18	0.04	0.00			
Total	29	0.57				
SEm± = 0.05			**C.D. (at 5%)** = 0.15			

ANOVA 2: 21 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.03	0.02	16.19	3.55	Significant
Treatment	9	0.42	0.05	45.84	2.46	Significant
Error	18	0.02	0.00			
Total	29	0.48				
SEm± = 0.06			**C.D. (at 5%)** = 0.17			

ANOVA 3: 28 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.03	0.01	16.08	3.55	Significant
Treatment	9	0.36	0.04	46.37	2.46	Significant
Error	18	0.02	0.00			
Total	29	0.41				
SEm± = 0.05			**C.D. (at 5%)** = 0.13			

ANOVA 4: 35 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.43	0.21	56.12	3.55	Significant
Treatment	9	0.89	0.10	26.19	2.46	Significant
Error	18	0.07	0.00			
Total	29	1.39				
SEm± = 0.04			**C.D. (at 5%)** = 0.11			

ANOVA 5: 42 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.24	3.55	NS
Treatment	9	0.54	0.06	24.32	2.46	Significant
Error	18	0.04	0.00			
Total	29	0.59				
SEm± = 0.07			**C.D. (at 5%)** = 0.22			

ANOVA 6: 49 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	3.01	3.55	NS
Treatment	9	1.79	0.20	281.36	2.46	Significant
Error	18	0.01	0.00			
Total	29	1.81				
SEm± = 0.04			**C.D. (at 5%)** = 0.12			

ANOVA 7: 56 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square		Mean Sum of Square	F Cal	F Tab at 5%
Replication	2	0.05		0.03	20.20	3.55
Treatment	9	0.91		0.10	80.86	2.46
Error	18	0.02		0.00		
Total	29	0.98				
SEm± = 0.06			**C.D. (at 5%)** = 0.17			

ANOVA 8: 63 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.26	0.13	53.38	3.55	Significant
Treatment	9	1.61	0.18	73.26	2.46	Significant
Error	18	0.04	0.00			
Total	29	1.91				
SEm± = 0.04			**C.D. (at 5%)** = 0.13			

ANOVA 9: 70 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.00	1.42	3.55	NS
Treatment	9	1.21	0.13	55.13	2.46	Significant
Error	18	0.04	0.00			
Total	29	1.26				
SEm± = 0.07			**C.D. (at 5%)** = 0.22			

3) Evaluation of different ecological engineering methods against leafhopper in sesame

ANOVA 1: 14 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	24.97	3.55	Significant
Treatment	9	0.32	0.04	40.05	2.46	Significant
Error	18	0.02	0.00			
Total	29	0.38				
SEm± = 0.04			**C.D. (at 5%)** = 0.11			

ANOVA 2: 21 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	24.63	3.55	Significant
Treatment	9	0.28	0.03	39.62	2.46	Significant
Error	18	0.01	0.00			
Total	29	0.34				
SEm± = 0.05			**C.D. (at 5%)** = 0.16			

ANOVA 3: 28 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	8.83	3.55	Significant
Treatment	9	0.35	0.04	30.88	2.46	Significant
Error	18	0.02	0.00			
Total	29	0.40				
SEm± = 0.06			**C.D. (at 5%)** = 0.19			

ANOVA 4: 35 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.05	0.02	29.01	3.55	Significant
Treatment	9	0.89	0.10	127.70	2.46	Significant
Error	18	0.01	0.00			
Total	29	0.95				
SEm± = 0.07			**C.D. (at 5%)** = 0.22			

ANOVA 5: 42 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	1.71	3.55	NS
Treatment	9	0.51	0.06	16.68	2.46	Significant
Error	18	0.06	0.00			
Total	29	0.58				
SEm± = 0.11			**C.D. (at 5%)** = 0.34			

ANOVA 6: 49 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	5.25	3.55	Significant
Treatment	9	1.23	0.14	102.86	2.46	Significant
Error	18	0.02	0.00			
Total	29	1.27				
SEm± = 0.06			**C.D. (at 5%)** = 0.18			

ANOVA 7: 56 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	6.12	3.55	Significant
Treatment	9	0.32	0.04	31.18	2.46	Significant
Error	18	0.02	0.00			
Total	29	0.36				
SEm± = 0.08			**C.D. (at 5%)** = 0.23			

ANOVA 8: 63 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.21	3.55	NS
Treatment	9	1.04	0.12	68.62	2.46	Significant
Error	18	0.03	0.00			
Total	29	1.07				
SEm± = 0.06			**C.D. (at 5%)** = 0.17			

ANOVA 9: 70 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.05	0.02	3.96	3.55	Significant
Treatment	9	0.33	0.04	6.15	2.46	Significant
Error	18	0.11	0.01			
Total	29	0.49				
SEm± = 0.11			**C.D. (at 5%)** = 0.34			

4) Evaluation of different ecological engineering methods against whitefly in sesame

ANOVA 1: 14 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	1.13	3.55	NS
Treatment	9	0.62	0.07	56.91	2.46	Significant
Error	18	0.02	0.00			
Total	29	0.65				
SEm± = 0.08			**C.D. (at 5%)** = 0.24			

ANOVA 2: 21 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.68	3.55	NS
Treatment	9	0.70	0.08	87.16	2.46	Significant
Error	18	0.02	0.00			
Total	29	0.71				
SEm± = 0.09			**C.D. (at 5%)** = 0.27			

ANOVA 3: 28 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	1.90	3.55	NS
Treatment	9	0.49	0.05	12.10	2.46	Significant
Error	18	0.08	0.00			
Total	29	0.58				
SEm± = 0.10			**C.D. (at 5%)** = 0.29			

ANOVA 4: 35 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	18.42	3.55	Significant
Treatment	9	2.24	0.25	257.39	2.46	Significant
Error	18	0.02	0.00			
Total	29	2.30				
SEm± = 0.09			**C.D. (at 5%)** = 0.25			

ANOVA 5: 42 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.00	0.30	3.55	NS
Treatment	9	0.65	0.07	8.16	2.46	Significant
Error	18	0.16	0.01			
Total	29	0.82				
SEm± = 0.11			**C.D. (at 5%)** = 0.33			

ANOVA 6: 49 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	2.81	3.55	NS
Treatment	9	2.52	0.28	76.70	2.46	Significant
Error	18	0.07	0.00			
Total	29	2.61				
SEm± = 0.09			**C.D. (at 5%)** = 0.26			

ANOVA 7: 56 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	32.46	3.55	Significant
Treatment	9	0.40	0.04	146.10	2.46	Significant
Error	18	0.01	0.00			
Total	29	0.42				
SEm± = 0.08			**C.D. (at 5%)** = 0.24			

ANOVA 8: 63 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	3.89	3.55	Significant
Treatment	9	2.42	0.27	84.53	2.46	Significant
Error	18	0.06	0.00			
Total	29	2.50				
SEm± = 0.05			**C.D. (at 5%)** = 0.15			

ANOVA 9: 70 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	5.14	3.55	Significant
Treatment	9	1.85	0.21	59.24	2.46	Significant
Error	18	0.06	0.00			
Total	29	1.95				
SEm± = 0.09			**C.D. (at 5%)** = 0.27			

5) Evaluation of different ecological engineering methods against mirid bug in sesame

ANOVA 1: 14 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.00	5.67	3.55	Significant
Treatment	9	0.34	0.04	46.63	2.46	Significant
Error	18	0.01	0.00			
Total	29	0.36				
SEm± = 0.09			**C.D. (at 5%)** = 0.26			

ANOVA 2: 21 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.07	0.04	22.26	3.55	Significant
Treatment	9	0.29	0.03	19.56	2.46	Significant
Error	18	0.03	0.00			
Total	29	0.39				
SEm± = 0.08			**C.D. (at 5%)** = 0.25			

ANOVA 3: 28 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	14.09	3.55	Significant
Treatment	9	0.39	0.04	29.10	2.46	Significant
Error	18	0.03	0.00			
Total	29	0.46				
SEm± = 0.07			**C.D. (at 5%)** = 0.22			

ANOVA 4: 35 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.64	3.55	NS
Treatment	9	0.49	0.05	29.70	2.46	Significant
Error	18	0.03	0.00			
Total	29	0.53				
SEm± = 0.08			**C.D. (at 5%)** = 0.24			

ANOVA 5: 42 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	1.46	3.55	NS
Treatment	9	1.12	0.12	16.48	2.46	Significant
Error	18	0.14	0.01			
Total	29	1.28				
SEm± = 0.12			**C.D. (at 5%)** = 0.35			

ANOVA 6: 49 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	2.91	3.55	NS
Treatment	9	0.49	0.05	23.70	2.46	Significant
Error	18	0.04	0.00			
Total	29	0.54				
SEm± = 0.11			**C.D. (at 5%)** = 0.32			

ANOVA 7: 56 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.04	3.55	NS
Treatment	9	1.49	0.17	41.85	2.46	Significant
Error	18	0.07	0.00			
Total	29	1.56				
SEm± = 0.13			**C.D. (at 5%)** = 0.39			

ANOVA 8: 63 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.00	1.93	3.55	NS
Treatment	9	0.52	0.06	23.78	2.46	Significant
Error	18	0.04	0.00			
Total	29	0.57				
SEm± = 0.07			**C.D. (at 5%)** = 0.20			

ANOVA 9: 70 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	5.83	3.55	Significant
Treatment	9	0.61	0.07	40.66	2.46	Significant
Error	18	0.03	0.00			
Total	29	0.66				
SEm± = 0.08			**C.D. (at 5%)** = 0.25			

6) Impact of different ecological engineering methods on the incidence of lady bird beetle, seed yield and BC ratio.

ANOVA 1: 30 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	1.06	3.55	NS
Treatment	9	0.08	0.01	0.44	2.46	NS
Error	18	0.37	0.02			
Total	29	0.50				
SEm± = 0.08			**C.D. (at 5%)** = 0.25			

ANOVA 2: 45 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	1.69	3.55	NS
Treatment	9	0.16	0.02	1.44	2.46	NS
Error	18	0.22	0.01			
Total	29	0.42				
SEm± = 0.06			**C.D. (at 5%)** = 0.19			

ANOVA 3: 70 Days after sowing

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	0.12	0.06	7.84	3.55	Significant
Treatment	9	0.20	0.02	2.91	2.46	Significant
Error	18	0.14	0.01			
Total	29	0.46				
SEm± = 0.05			**C.D. (at 5%)** = 0.15			

ANOVA 4: Seed yield

Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	296.47	148.23	2.37	3.55	NS
Treatment	9	968170.00	107574.44	1716.31	2.46	Significant
Error	18	1128.20	62.68			
Total	29	969594.67				
SEm± = 4.57			**C.D. (at 5%)** = 13.58			

CURRICULUM VITAE



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S. No.	Institutions	Degrees awarded	Year	Percent
1.	Adarsh higher secondary school (M.P.)	10th Class	2010	78.0%
2.	Adarsh higher secondary school (M.P.)	12th Class	2012	83.0%
3.	JNKVV, COA, Rewa (M.P.)	B. Sc. (Ag.)	2014	77.0%

For the partial fulfilment of the master's degree program he choice a research problem on **"To study the ecological engineering methods for management of leaf webber and capsule borer, *Antigastra catalaunalis* (Dup) in sesame."** This was successfully conducted by him and being submitted in the form of the thesis.

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