ECO-FRIENDLY PEST MANAGEMENT OF GINGER SHOOT BORER, *Conogethes punctiferalis* GUENEE (PYRALIDAE: LEPIDOPTERA)

Thesis

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Doctor of Philosophy

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by

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DECLARATION

I, **K. Lalruatsangi** hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree to any other Universities/Institute.

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CERTIFICATE – I

This is to certify that the thesis entitled **"Eco-friendly pest management of ginger shoot borer, *Conogethes punctiferalis* Guenee (Pyralidae: Lepidoptera)"** submitted to Nagaland University in partial fulfilment of the requirements for the award of degree of **Doctor of Philosophy** in **Entomology** is the record of research work carried out by Ms. **K. Lalruatsangi,** Registration No. **Ph.D/ENT/00044** under my personal supervision and guidance.

The result of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN ENTOMOLOGY

This is to certify that the thesis entitled **"Eco-friendly pest management of ginger shoot borer, *Conogethes punctiferalis* Guenee (Pyralidae: Lepidoptera)"** submitted by Ms. K. LALRUATSANGI, Admission No. Ph-213/16 Registration No. Ph.D/ENT/00044 to the NAGALAND UNIVERSITY in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in Entomology has been examined by the Advisory Board and External Examiner on ……………………

The performance of the student has been found **Satisfactory/Unsatisfactory.**

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(K.LALRUATSANGI)

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LIST OF ABBREVIATIONS

/	=	Per
%	=	Per cent
@	=	At the rate of
°C	=	Degree Centigrade
a.i	=	Active Ingredients
CD	=	Critical Difference
cm	=	Centi metre
DAS	=	Days After Spraying
DAP	=	Days After Planting
Df	=	Degree of freedom
E	=	East
EC	=	Emulsifiable Concentrate
et al.	=	Et alia(and others)
Etc	=	Et cetera
Fig	=	Figure
g/gm	=	gram
ha	=	Hectare
ICAR	=	Indian Council of Agriculture Research
i.e	=	Id est (That is)
inch	=	Inches
IPM	=	Integrated Pest Management
Kg	=	Kilogram
Lit/L	=	Litre
M	=	Metre
Max.	=	Maximum
Min.	=	Minimum
Mm	=	Millimetre
MSS	=	Mean Sum of Squares
N	=	North
NEH	=	North Eastern Hill

NS	=	Non Significant
No.	=	Number
Ph	=	Potential of Hydrogen
SEm	=	Standard Error Mean
SC	=	Soluble Concentrate
R.H	=	Relative Humidity
SC	=	Soluble Concentrate
Temp	=	Temperature
Viz.	=	Namely

ABSTRACT

A field experiment was conducted at the Experimental Farm, Department of Entomology, School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema campus, entitled **"Eco-friendly pest management of ginger shoot borer, *Conogethes punctiferalis* Guenee (Pyralidae: Lepidoptera)"** with an aim to study the seasonal incidence of ginger shoot borer and its correlation with abiotic factors during 2018-2019.The results revealed that the incidence of the *C. punctiferalis* was observed from 120 DAP in D_1 (15^{th} February planting) which falls in the second week of June. The highest per cent incidence of *C. punctiferalis* was observed at 210 DAP in D_3 whereas the lowest per cent incidence was recorded at 120 DAP in D_1. Abiotic factors played an important role in the incidence of *C. punctiferalis*. Correlation with abiotic factors exhibited a significant effect on the incidence of *C. punctiferalis*. Studies on the relative abundance of natural enemies in ginger ecosystem revealed that among the natural enemies studied, the highest relative abundance was observed in spider (41.17%) while the lowest relative abundance was reported in earwig (0.91%). The relative abundance of natural enemies was higher in ecological plot as compared to botanicals/insecticides treated plot. Studies on the effect of date of planting on the incidence of ginger shoot borer revealed that late planting of ginger (D_3 *i.e.*16^{th} April planting) was effective in reducing the incidence of ginger shoot borer. The per cent reduction of *C. punctiferalis* population increased over time. The highest mean per cent reduction in the population of *C. punctiferalis* was observed in 16^{th} April planting (D_3) while the lowest mean per cent reduction was recorded on 15^{th} February planting (D_1). Studies on the effect of certain safer insecticides and botanicals on the management of ginger shoot borer revealed that all the treatments *viz.* spinosad, multineem, neem oil, imidacloprid, *Litsea citrata* and malathion had significant effect on the reduction of the pest. malathion showed the highest per cent reduction of *C. punctiferalis* and the lowest per cent reduction was recorded in *Litsea citrata*. Interaction of third date of sowing (D_3) and treatment (T_6) malathion showed highest mean per cent reduction of *C. punctiferalis* population.

Keywords: Ginger shoot borer, abiotic factors, natural enemies, seasonal incidence, botanicals, insecticides

CHAPTER 1
INTRODUCTION

INTRODUCTION

Spices are high value and export oriented commodity crops, which play an important role in Agricultural economy of the country. Among all spices, ginger is the main cash crop supporting the livelihood and improving the economic level of many ginger growers of North Eastern Indian Region (Yadav *et al*., 2004).

Ginger (*Zingiber officinale* Rosc.) which belongs to the family *Zingiberaceae* is a herbaceous perennial and an important cash crop grown for its underground rhizome which is used as a spice and for its medicinal value. It is popular not only for its use as spices and condiments but also for its use in perfumery and food flavoring and is credited with huge medicinal properties. Ginger is an important tropical horticultural plant, valued all over the world as spices , for its medicinal properties, increases flavor and taste of foods, beverages and also as herbal medicines with higher economic returns. It is rich in secondary metabolite, such as Oleoresin. Ginger is an important spice crop used either in the form of fresh rhizome or dried ground ginger. It is principally used as an ingredient in various spice blends in the food processing and beverage industries. Ginger is commercially available in various forms such as green ginger, dry ginger, ginger powder, ginger oil, ginger oleoresin and preserved ginger (Kizhakkayil and Sasikumar, 2009).

Ginger grows well in warm and humid climate and is cultivated from sea level to an altitude of 1500 m above sea level. Ginger can be grown both under rainfed and irrigated conditions. For successful cultivation of the crop, a moderate rainfall at sowing time till the rhizomes sprout, fairly heavy and well distributed showers during the growing period and dry weather for about a month before harvesting are necessary. Ginger thrives best in well drained soils like sandy loam, clay loam, red loam or lateritic loam. A friable loam with a pH of 6.0 to 6.5 rich in humus is ideal. However, being an exhausting crop it is not desirable to grow ginger in the same soil year after year. The crop performs well in a temperature range of 19°C- 28°C and a humidity of 70-90% (Jayashree *et al*., 2015).

The national area under ginger cultivation has been estimated at 132.62 thousand ha with total annual production of 655.06 thousand tones. Assam ranks first in production (122.3 thousand tones) while the productivity is highest in Gujarat (16.056 t $ha^{-1)}$ followed by Arunachal Pradesh (8.142 t ha^{-1}). In Nagaland ginger is cultivated in an area of 5.32 thousand ha with total annual production of 36.00 thousand tones (Anonymous, 2014). Ginger is the main cash crop in the North Eastern Region (NER) of India accounting 49% of India's ginger area and 72% of India's ginger production. This region is one among the highest ginger productivity area in the world (5.8 t ha^{-1} as against national average of 3.7 t ha^{-1}) and is emerging as India's organic ginger hub. Ginger produced in NER was reported to have higher oil (1.6-2.5% versus 1.5-2.0%) and oleoresin content (5.9-8.56% versus 5-8%) than from other parts of India (Rahman *et al*., 2009).

However, due to absence of proper processing units, disease and insect pests and other constraints, the ginger production in North East Region have not been benefited to the desired extend. Moreover, in spite of being a very valued crop, area under ginger has not increased much basically due to its localized and nature of cultivation. The productivity of most of the spice and condiment crops is considerably low in India due to various factors among which infestation by pests and pathogens is a major factor which causes significant yield losses (Devasahayam *et al*., 2012). Bacterial and fungal diseases, insect pests and parasitic nematodes are important as pests and diseases of ginger. Rhizome rot, bacterial wilt, phyllosticta leaf spot, and storage rots are major diseases that cause economic losses (Nada *et al*., 1996). Ginger is a herbaceous plant and many pest and diseases affect this crop

(Dohroo & Edison, 1989; Dohroo, 1997). Ginger is attacked by as many as 20 species of insect pests (Koya, 1988).

Among the several insect pests reported on ginger, the shoot borer, *Conogethes punctiferalis* Guenee, is the most severe. The larva of this species is the damaging stage, and it bore into pseudo stems and feed on the internal shoot resulting in yellowing and drying of infected pseudo stems. The presence of bore holes on the pseudo stem, through which frass is extruded, and the withered central shoot are characteristic symptoms of pest infestation. It is the most serious pest of ginger especially in India (Devasahayam & Koya, 2005). Yield losses of 25 % have been reported in castor when 23 to 24 % of pseudo stems are infested by shoot borer and the pest was reported to cause 40 per cent yield loss in Kottayam and Idukki districts in Kerala (Nybe, 2001). Studies on yield loss caused by the pest in Kerala indicated that when 50 per cent of the pseudostems in a plant are affected, there was a significant reduction of 38 g of yield per plant (Koya *et al*., 1986). Crop yield can be significantly affected when more than 45% of shoots in a clump are damaged (Devasahayam *et al*., 2010).

Several control measures have been recommended and followed to reduce the damage caused by this pest. Unfortunately chemical pesticides are preferably used by farmers for protection of ginger pests as they are regarded as the only effective method to manage this pest, which results in pesticide residues in the produce affecting human health and also causing other ecological hazards. Recent investigations have proved that the use of synthetic pesticides is hazardous to human health and have long residual effects. Beside these, the chemicals create harmful effects over the population of important natural enemies like predatory spiders, ants and coccinellid beetles etc. Since spices are high value and export-oriented commodities, levels of pesticide residues are to be kept well below tolerance limits in view of the stringent standards set by the importing countries (Devasahayam & Koya, 2005).

Moreover protective measures using different chemicals can cause adverse effects to human health, as gingers are being used as fresh vegetables in human diet. Therefore, there has been a renewed interest in developing environment-friendly pest management schedules in agriculture (Pervez *et al*., 2014).

Taking all the above cited views it is necessary to find a way out which is more eco-friendly in management of pest problems. Chemicals are indeed unavoidable in pest management but with the help of recent innovations, techniques and technologies it is possible to tackle the pests to certain extent without the use of harmful chemicals.

Cultural practices are an important component of Integrated Pest Management which is considered important in suppression of pest population. The application of this method affects the insect pest population as it manipulates the environment in such a way to render it unfavorable for the pest. This method also modifies the crop in such a way that pest infestation results in reduced injury to the crop. This may be achieved through techniques such as crop rotation or maintenance of a host-free season, intercropping, manipulation of planting dates.

The concept of pest management embodies the idea that knowledge of pest ecology is essential for appropriate control strategies. Information on incidence of ginger shoot borer at different growth stages of the crop and its relation with weather parameters will be of great help to adopt appropriate control measures. The meteorological parameters like temperature, relative humidity and rainfall play a pivotal role in the biology of any insect pest and are the most crucial abiotic factor influencing the rate of growth and development of insect pests and are important for timing of effective control measures. The study on the relationship between weather and incidence of insect pests helps to find out under what weather conditions, pest would appear, which ultimately helps to forewarn the cultivators to resort to preventive measures against such pest in time. Population density of insect pests and their natural enemies fluctuates with changing weather conditions. Seasonal incidence, population count and development rates of the pests and natural enemies are controlled by abiotic factors particularly temperature, relative humidity and rainfall. Such information is therefore essential in developing integrated pest management systems with ecological and economical balance.

Altering the planting time of the crop as a means of cultural control can result in plants escaping from damaging pest infestations. Normally, insect population fluctuates throughout the cropping season and their activities are mainly confined for a specific period, where they cause significant losses to the crop plants. Consequently, evaluating their damage at different planting dates would help in desynchronizing their emergence with vulnerable/critical stages of the crop growth (Firake *et al*., 2018). The manipulation of planting time helps to minimize pest damage by producing asynchrony between host plant and pest *i.e.* feeding stage of insect with the susceptible stage of the crop. Careful selection of the planting time enables the plant to escape damage during susceptible growth stage and it advances into tolerant stage before the pest attack occurs and reduces the number of generation of the pest. Proper planting period is an important non-monetary input in crop production. Too early or delayed planting will affect the growth, yield and performance of the crop (Yadav *et al*., 2013). The yield of ginger has been reported to vary greatly depending on cultivars, climate, planting time and maturity at harvest (Peter *et al*., 2005). Planting dates play an important role in the germination, growth, yield and quality of ginger. Optimum planting dates results in better germination of the crop which results in good growth and eventually increases the yield of ginger. Information regarding insect pests appearance, infestation and its severity of damage in relation to sowing time plays an important role in management of insect pest to a great extent. So, adjusting planting dates of ginger can sometimes help to avoid certain insect infestations and reduce the need for chemical control.

Biological control of insect pests and conservation of natural enemies by understanding them play an important role in pest management to a great extent. Many researchers have worked on the importance of natural enemies of the pest and the role they played in suppression of pest population. Most biological control agents like predators and parasitoids are naturally occurring ones, which provide excellent regulation of many pests with little or no assistance from humans. The existence of naturally occurring biological control agents is one reason that many plant-feeding insects do not ordinarily become economic pests. Biocontrol agents are being used as an alternate strategy to chemical pesticides as they are target specific and environment friendly due to their higher selectivity and biodegradable nature. Natural biological control is the most important component of pest management in crop fields. Biocontrol agents have added advantages of being self perpetuating and establishing for many years offering permanent control in the ecosystem (Seema Wahab, 2009). Parasitoids and predators naturally control the pests in the field thus maintaining a proper balance in the insect population. Exploring the parasitoids and predators which are found parasitizing and predating insect pest in the field is necessary for effective usage of them in biological control (Stanley *et al*., 2009).

Pesticides continue to be one of the most powerful tools available for the control of pests and increasing crop yield in spice crops such as ginger. Since *Conogethes punctiferalis* is one of the major pests infesting the economic produce in ginger, there is every need to evaluate efficacy of promising new groups of chemicals or reduced-risk pesticides in reducing the pest population which are safe to environment and natural enemies. Reduced-risk pesticides are pesticides that have low impact on human health and toxicity to non-target organisms and lower potential for developing pest resistance, and are thus more compatible with other integrated pest management procedures (Fishel, 2019). In spice crops a few reduced-risk pesticides have been evaluated in ginger and turmeric in recent years. The use of bio-pesticides in commercial agriculture and horticulture is being practiced since long to tackle the problems associated with indiscriminate use of harmful pesticides and are earning reputation among the researchers and growers. The bio-pesticides offer desirable alternative derived from animals, plants, bacteria and certain minerals. Bio-pesticides are less toxic to non-targeted natural enemies, generally affecting only the target pest, effective even in small quantities, decompose quickly resulting in lower exposures and are not harmful for the environment. Plant-derived pesticides are attractive alternatives to synthetic insecticides and constitute an affordable tool for insect pest management. Plant products act as antifeedants, repellents and growth regulators, and also cause mortality in insect pests. The use of botanical products *e.g.* tobacco extract, neem oil, neem seed kernal extract, *Litsea citrata* oil etc. are cheap and are easily available in rural areas and are also found promising and useful for pest control. In Nagaland and other parts of NE Indian states the approach of organic farming is being introduced with an objective of creating a viable, sustainable agricultural production system. Organic products are high in demand and fetches premium price due to its high quality. Accordingly the adoption of pest management methods without use of chemicals is the need of the day to reduce the adverse effect of the chemicals to the environment. This has promoted the necessity for the development of new, safer and biodegradable insecticides and botanicals that could be feasible and effective for insect pest management.

Though *C. punctiferalis* is an important pest on ginger, the work on this pest is limited in North East India and Nagaland in particular, it is desirable to undertake detailed investigations on the seasonal incidence of this pest and management with safer chemicals, biopesticides and botanicals. Therefore, considering the importance of the crop and to safe guard our health and environment a study was undertaken with the following objectives.

1. To study the seasonal incidence of ginger shoot borer (*C. punctiferalis*) and its correlation with abiotic factor
2. To study the relative abundance of natural enemies in ginger ecosystem
3. To study the effect of date of planting on the incidence of ginger shoot borer
4. To study the efficacy of certain biopesticides and safer chemicals on the management of ginger shoot borer

CHAPTER - 2
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Studies on the “Eco-friendly pest management of ginger shoot borer, *Conogethes punctiferalis* (Pyralidae: Lepidoptera)” are reviewed under the following heads.

2.1 Seasonal incidence of ginger shoot borer, *Conogethes punctiferalis*:

Fletcher (1914) first reported shoot borer, *Conogethes punctiferalis* Guen. and *Calobata* sp. as the most important pests of ginger and turmeric. Larvae bore into the pseudostems and feed on the growing shoot resulting in yellowing and drying of the infested shoots.

Srivastava and Awasthi (1961) observed that the larvae of *C. punctiferalis* entered into a quiescent stage during December, January and first half of February and overwintering larvae resumed their activity when they are exposed to a temperature of 25°C.

Mishra and Teotia (1965) studied seasonal history of capsule borer and reported that the pest was generally active in main crop season with occurrence of all stages from March to April.

Studies conducted by Bilapate and Talati (1977) on castor showed that, the percentage of damaged plants by *C. punctiferalis* ranged from 16 to 72, peak damage to panicles and capsules occurring in September - November and withering of inflorescences ranged from 3 to 8 %. They further reported that the percentage of damaged seeds in infested plants ranged from 27 to 46 per cent, with average of 34.7 per cent. Attack on the July sown crop commenced in August and larvae and pupae reached peak numbers in November. During the off season the pest survived on perennial castor plants.

Jacob (1981a) studied the biology of *C. punctiferalis* in turmeric under field and laboratory condition and reported that, there was difference in the life cycle pattern of *C. punctiferalis* fluctuating with weather patterns in Karnataka. He observed *C. punctiferalis* from Kasargod District from late July to August on turmeric at 4 to 5 leaf stage of the crop. Jacob (1981b) observed the pest incidence of *C. punctiferalis* in ginger highest during September to October.

Koya (1984) reported that the percentage of shoots bored by *C. punctiferalis* in ginger was at the minimum of 5% in July and it steadily increased reaching a peak of 14.8% in November.

The pests of turmeric, *Curcuma longa* (Linnaeus) and ginger, *Zingiber officinale* (Rosc.) were surveyed by Patel *et al.* (1988) during 1985-86. The pyralid, *C. punctiferalis*, was considered to be a potential pest in the second fortnight of September.

Goel and Kumar (1990) reported that maximum and minimum temperature influenced positively with significant effect on per cent infestation of capsule by shoot and capsule borer, *C. punctiferalis*.

Ram *et al.* (1997) recorded *C. punctiferalis* infesting grapes for the first time in Karnataka during December 1993 to February 1994.

Asokan and Kempuchetty (2000) reported that incidence of capsule borer, *C. punctiferalis* started from November-December with 1 to 3 per cent capsule damage in the rainfed castor as intercrop. The peak period of damage was more during January-February and extended up to March - April. However, castor as pure irrigated crop (hybrid) was attacked by capsule borer even during October and 30-50 % damage was noticed in November-December.

A roving survey was conducted by Kotikal and Kulkarni (2000) during 1996-97 at three growth phases of turmeric. Results revealed that shoot borer was the predominant pest in early vegetative phase (45-60 days) and grand growth stage (100-120 days) of the crop in Raibag, Chikodi, Jamakhandi and Humanabad taluks of Karnataka, India respectively.

Singh *et al.* (2000) studied the lepidopteran larvae associated with castor capsules and found that *C. punctiferalis* was dominant over other capsule borer larvae throughout the season with peak occurrence at end of February month.

Gupta and Arora (2001) conducted a preliminary survey on the incidence of Lepidopteran fruit borers of guava in Jammu during 1999. The results revealed that severe infestation of the two borers namely *Virachola isocrates* and *C. punctiferalis* in guava orchards were observed. The pest infestation was first noticed during the second fortnight of October with 2.5% fruit infestation which subsequently reached a maximum of 23.0% in the fourth week of November and lasted to the second week of March respectively.

Kesar (2001) worked on the seasonal incidence and management of lepidopteran fruit-borer(s) on guava and he reported that the peak infestation of guava borers (*D. punctiferalis* and *V. isocrates)* was observed in the month of August. Temperature, relative humidity and rainfall had significant positive correlation with the borers' infestation and the abiotic factors were responsible to influence the infestation upto 63.2 and 62.6 % at Udheywalla and Raya respectively.

Tirupati (2002) reported that the initial incidence of the infestation of capsule by *C. punctiferalis* started in first week of February with 14.16 % and the maximum damage of capsules was observed during last week of March with 32.94 % capsule infestation. The relationship between the weather parameters and capsule infestation was significant and positive between per cent infestation of capsule and maximum temperature/minimum temperature, while negative and significant relation was found between infestation and humidity.

Kaul and Kesar (2003) documented that the highest incidence (20%) of guava fruit borers *viz*., *Virachola isocrates* (*Deudorix isocrates*) and *Dichocrosis punctiferalis* (*C. punctiferalis*) was observed in the 32nd standard week and the multiple correlation analysis of the data showed that the abiotic factors like maximum temperature, minimum temperature and relative humidity had significant and positive effect on the incidence of borers.

Thyagaraj (2003) reported that shoot and capsule borer occurs throughout the year on cardamom in Western Ghats of South India. Usually two peaks in the population were noticed in a year, *i.e*. one during April – May and the other during November- December. The population coincides with the period of less or no rainfall, *i.e*. during pre and post monsoon periods.

Kang *et al.* (2004) studied the overwintering ecology of peach pyralid moth, *C. punctiferalis* Guenee in Southern regions of Korea and they reported that overwintered generations of *C. punctiferalis* emerged from May 20 to June 28.

Madhuri (2005) reported that the activity of shoot and capsule borer was observed initially during the last week of January and capsule infestation reached peak level by first week of March. The correlation between capsule infestation and mean maximum temperature was significant and positive while relative humidity had significant negative correlation and rainfall had non significant and negative correlation.

According to Kannan and Rao (2007) maximum and minimum temperatures have negative correlation with the incidence of *C. punctiferalis* in mango.

Stanley *et al.* (2009) reported that, *C. punctiferalis* completes its life cycle in about 28 days in castor, 31 days in cardamom, and 32 days in ginger under laboratory conditions and they further reported that increasing relative humidity increases damage caused by *C. punctiferalis*.

Naik *et al.* (2010) recorded the activity of *C. punctiferalis* on castor during July to November.

Rashmi (2014) reported that infestation of capsules by *C. punctiferalis* on cardamom was observed from May till November in both the varieties (M1 and M2), and the peak per cent infestation was observed in second fortnight of November. The incidence of borer showed significant positive correlation with maximum temperature, while the relative humidity & rainfall had a negative correlation both in cardamom varieties M1 & M2. Whereas, the capsule damage had a significant correlation with the both maximum and minimum relative humidity, rainfall and had a negative correlation with the maximum temperature.

Akashe *et al.* (2015) studied the incidence of capsule borer, *C. punctiferalis* on castor and other crops in Maharashtra and found peak activity of the pest during September to December.

Patel *et al*. (2015) worked on incidence of castor capsule borer and they reported that higher activity of the pest was observed from first week of November to second week of January, with a peak level (20.04) on third week of November. The per cent capsule damage showed highly significant positive association with bright sunshine hours, whereas evaporation, wind speed, temperature and vapour pressure exhibited highly significant negative correlation with *C. punctiferalis* incidence on castor.

Momin *et al.* (2018) studied the pest complex, biology and population dynamics of insect pest of ginger in Northeast India. Rhizome fly, shoot borer, rhizome mealy bug, white grub, rhizome weevil were recorded as pest of ginger. Weather parameters, particularly temperature and rainfall were found to have significant impact on pest populations of ginger.

Gundappa *et al.* (2018) studied the seasonal incidence of guava fruit borer, *C. punctiferalis* under Lucknow (Uttar Pradesh, India) conditions and they reported the incidence of the pest varied from 7.79 % to 25.20 %. The incidence of the pest started during 28th standard meteorological week (SMW) and peak incidence (25.5%) was recorded during 31st SMW. They further reported that fruit borer incidence was significant, which negatively correlated with maximum relative humidity, rainfall, and evaporation and positively correlated with sunshine hours.

Kasareddy *et al*. (2018) conducted a research on the influence of weather parameters on incidence of cardamom shoot and capsule borer, (*C. punctiferalis* Guenee) on cardamom and they reported that the peak population was recorded in the month of second fortnight of May on both M-1 and M-2 varieties of cardamom (per cent shoot damage of 24.93 and 26.06 respectively). Whereas, the peak infestation on capsules was recorded in the month of November on both M-1 and M-2 varieties of cardamom (15.0 and 15.8 respectively). The correlation studies indicated that there was a significant positive correlation with relative humidity and rainfall with per cent shoot damage in M-1 and M-2 varieties of cardamom.

Manjunatha *et al*. (2019) studied the population dynamics of pests infesting castor and their natural enemies in Southern Karnataka and they observed the shoot borer, *C. punctiferalis* incidence from the maturity stage of the crop (during the second fortnight of October) and continued till the end of the growing period of crop, with a peak capsule infestation (15.50%) during the second fortnight of November.

Devi *et al*. (2021) studied the seasonal incidence of fruit borers *C. punctiferalis* in guava cv. Taiwan white and they reported that the peak larval population of fruit borer, *C. punctiferalis* (4.50 larvae per tree) and its fruit infestation (32.79%) was found in 9^{th} Standard mean week of 2020.They further reported that the maximum and minimum temperature was negatively correlated and Relative humidity is having positively correlation with the incidence of fruit borers whereas, rainfall was negatively correlated with the incidence of *C. punctiferalis* respectively.

2.2 Natural enemies in ginger ecosystem:

Rodrigo (1941) reported *Dolichurus* sp. (Sphegidae), *Xanthopimpla* sp. (Ichneumonidae), and *Phanerotoma hendecasisella* Cam. (Braconidae) as parasitoids of shoot borer from Sri Lanka.

Angitia trochanterata Morl. (Ichneumonidae), *Theromia inareolata* (Braconidae), *Bracon brevicornis* West., *Apanteles* sp. (Braconidae) and *Brachymeria euploeae* West. (Chalcidae) were documented by David *et al*. (1964) as natural enemies of shoot borer infesting castor.

Brachymeria nosatoi Habu and *B. lasus* West. were recorded as parasitoids of *Conogethes punctiferalis* by Joseph *et al*. (1973).

According to Mayse *et al*. (1978) relative abundance is the percent composition of an organism of a particular kind relative to the total number of organism in the area.

Mermithid nematode (Mermithidae), *Myosoma* sp. (Braconidae), *Xanthopimpla australis* Kr. and general predators such as dermapteran [*Euborellia stali* Dohrn (Carcinophoridae)], asilid flies (*Philodicus* sp. and *Heligmoneura* sp.) (Asilidae), and spiders (*Araneus* sp., *Micaria* sp., and *Thyene* sp.) have been recorded by Jacob (1981b) on the shoot borer infesting turmeric in Kerala.

The natural enemies recorded by Jacob (1986) on rhizome scale at Kasaragod (Kerala, India) include *Physcus* (*Cocobius*) *comperei* Hayat (Aphelinidae), *Adelencyrtus moderatus* Howard (Encyrtidae) and two species of mites. Parasitization by *P. comperei* brought down the population of rhizome scale by about 80 per cent in three months.

Seasonal incidence of natural enemies of ginger shoot borer was studied by Devasahayam and Koya (1994) at Peruvannamuzhi and they reported that *Hexamermis* sp. parasitized larva of shoot borer during July to November with a peak parasitisation of 72 % during August. The hymenopterous parasites

(*Bracon* sp. and *Apanteles taragamme*) were observed during October to December with a peak parasitisation of 28 % during November.

Choo *et al*. (1995) evaluated the pathogenecity of entomopathogenic nematodes against the shoot borer, *C. punctiferalis* and they reported that *Steinernema* sp. and *Heterorhabditis* sp. caused 90 and 100 % mortality respectively of test insects in the laboratory when 20 nematodes per larva were inoculated.

Murphy *et al*. (1995) recorded *Dichocrocis punctiferalis* NPV (Baculoviridae) as the only virus infecting shoot borer.

Varadarasan (1995) recorded various parasitoids on the shoot borer infesting cardamom and they include *Palexorista parachrysops* (Tachinidae), *Agrypon* sp., *Apechthis copulifera*, *Eriborus trochanteratus* (Morl.), *Friona* sp., *Gotra* sp., *Nythobia* sp., *Scambus persimilis*, *Temeluca* sp., *Theronia inareolata*, *Xanthopimpla australis* Kr., *Xanthopimpla kandiensis* Cram. (Ichneumonidae), *B. brevicornis* West., *Microbracon hebator, Apanteles* sp., *Phanerotoma hendecasisella* Cram. (Braconidae), *Synopiensis* sp., *Brachymeria* sp. nr. *australis* Kr. and *B. obscurata* (Chalcidae).

At Peruvannamuzhi, Kerala, India apart from *Caccobius* sp., a predatory beetle and ant were observed by Devasahayam (1996) to predate on the rhizome scale.

Huang *et al*. (2000) recorded *Apanteles* sp. (Braconidae), *Brachymeria lasus* West. (Chalcidae), and *Temelucha* sp. (Ichneumonidae) as parasitoids of shoot borer infesting longan (*Dimocarpus longan* Lour.) in China.

In Australia, a tachnid parasitoid *Argyrophylax proclinata* Crosskey is reported to parasitise *C. punctiferalis* up to 40 % by Pena *et al*. (2002). Two peak periods were noticed on the parasitization of *C. punctiferalis i.e*., during first week of June (55%) and first week of November (40%).

The efficacies of eight native entomopathogenic nematodes (EPNs) *Heterorhabditis* sp. (IISR 01), *Steinernema* sp. (IISR 02), *Steinernema* sp.

(IISR 03), *S. carpocapsae* (Weiser) and *Oscheius* spp. (IISR 04, 05, 07 and 08) were tested by Pervez *et al.* (2012) against larvae of hairy caterpillar, *Euproctis* sp., and larvae and pupae of the shoot borer, *C. punctiferalis,* and their multiplication was assessed. Among the tested EPN isolates, *Heterorhabditis* sp. (IISR 01), *Steinernema* sp. (IISR 02) and *Oscheius* sp. (IISR 07 and 08) caused 100 % mortality to shoot borer larvae, while *Steinernema* sp. (IISR 03) and *Oscheius* spp. (IISR 04 and 05) caused 92 % and *S. carpocapsae* 83 % mortality.

Ansar Ali *et al*. (2014) reported that the per cent natural parasitism on *C. punctiferalis* in cardamom by larval parasitoids ranged from 3.36 to 43.31% and pupal parasitoids ranged from 0.23 to 1.23 %. The per cent damage on shoots by cardamom shoot borer was reduced from 23.21 to 10.23% by the natural occurrence of larval parasitoids respectively.

Choudhury *et al*. (2016) studied the relative abundance of different insect pests and their natural enemies in brinjal ecosystem and they reported that spiders were the most abundant natural enemies (4.13%) (79.90 individuals) observed as predator in brinjal ecosystem followed by black ant, *Camponotus compressus* Fab. (2.89%) (56.40 Individuals) respectively.

Infectivity of *Heterorhabditis indica* (NBAII Hi 01) and *Steinernema abbasi* (NBAII Sa 01) were tested against larvae and pupae of the shoot borer, *C. punctiferalis* and their multiplication in the hosts were assessed by Pervez *et al*. (2016). Both species of tested EPNs were found pathogenic against shoot borer larvae and it brought about cent per cent mortality within 72 h. However, *H. indica* (NBAII Hi 01) was the most virulent isolate against the shoot borer pupae, causing 33% mortality, followed by 17% mortality by *S. abbasi* (NBAII Sa 01).

Ponnusamy *et al.* (2019) recorded two natural parasitoids *viz*., larval parasitoid, *Apanteles taragamae* Vierick (Hymenoptera: Braconidae) and larval-pupal parasitoid, *Agrypon* sp. (Hymenoptera: Ichneumonidae) from cardamom hill reserve, Kerala. *Apanteles taragamae* parasitism was high on the *Conogethes* population found on capsules (1.01 to 16.79%) than shoots (0.13 to 0.54%) and panicles (0.03%) and they also noticed first time in shoots and panicles. They further recorded that *Agrypon* sp. was high on the *Conogethes* population found on shoots only (5.46 to 9.63%) and this species do not parasitized on *Conogethes* in panicles and capsules.

Gayatri *et al.* (2020) studied the virulence of entomopathogenic nematode against late instar larvae of castor capsule borer, *C. punctiferalis* and they reported that late instar larvae were highly susceptible at all six infecting juvenile (IJ) concentration (30,60,60,120,150 and 200 IJ $larva^{-1}$) of the EPN evaluated. At 48 hr post infection, complete larval mortality was observed in *C. punctiferalis.* LC_{50} values of 570 IJ $larva^{-1}$ for capsule borer were observed with *Heterorhabditis bacteriophora* and *H. indica* respectively at 24 hr exposure. These values indicated the highly virulent nature of EPN's.

2.3 Effect of date of planting on the incidence of ginger shoot borer:

Mohanty *et al.* (1990) reported that the best time of planting ginger for obtaining maximum yield is the first fortnight of April, while planting by end of May resulted in poor yield.

Sarma (1994) mentioned that since the crop season varies at different places and the ideal time of planting also vary accordingly.

Pruthi (1998) stated that ginger is mainly grown as a monsoon crop from April to December in South India but it is grown as an irrigated crop in North and Central India, though early planting is advisable. In Eastern India planting is done in March. In trials conducted at Ambalavayal Kerala it was noticed that the local practice of planting is May or June. The observation has also been confirmed by the trials carried out at Naya bungalow in Assam. In trials at Dadohoo, Himachal Pradesh, it was observed that the Himalayas at an altitude of 1050m, 13% to 65% higher yield is produced in April. In lower elevation the period of planting could however be extended up to May to June.

Peter *et al*. (2005) reported that the yield of ginger vary greatly depending on cultivars, climate, planting time and maturity at harvest.

Temjentoshi (2008) worked on the effect of dates of planting and ginger cultivars on the infestation of ginger shoot borer in Nagaland and he reported that of all the three different dates of planting (31st March, 15th April and 30th April), the 15th April planting recorded the maximum infestation throughout the observation period and minimum infestation was recorded on 30th April planting. The date of planting has a significant effect on the incidence of ginger shoot borer.

Yadav *et al*. (2013) studied the effect of dates of planting and spacing on growth and yield characteristics of ginger (*Zingiber officinale* Rosc.) var. IISR Mahima and they reported that dates of planting had significant effect on almost all the characters under study. Planting of rhizomes on 15th April showed better growth, yield and yield attributing characters. Among the various treatment combinations planting on 15th April and spacing of 25 cm × 15 cm exhibited higher plant height, yield of green (40.16 t ha^{-1}) and dry ginger (8.58 t ha^{-1}).

Rekha *et al*. (2016) reported planting of ginger in March or April with varieties like Maran and Himachal helps in overcoming the rhizome rot disease in ginger and realizing higher yields.

Jalgaonkar *et al.* (2020) studied the effect of sowing date in relation to incidence of shoot and fruit borer on okra and the results revealed that the maximum shoot and fruit borer infestation of 33.70 % was recorded in 9th week after sowing in late sown crop whereas minimum infestation recorded was 8.61 % on 4th week in early sown crop. The infestation of the pest increased with the delay in sowing of the crop.

2.3.1 Other cultural control:

Devasahayam and Koya (2004) reported that the best management method of *C. punctiferalis* is integrated management including cultural methods, such as pruning of freshly infested shoots at the initial stage of infestation and spraying of insecticide when high population density of the pest is recorded.

Studies on the combined efficacy of proven management strategies against oriental fruit fly, *Bactrocera dorsalis* conducted at Ludhiana by Gill and Mann (2008) revealed that, the practices significantly reduced the incidence of castor capsule borer, *C. punctiferalis*. The per cent fruit infestation ranged from 0 to 16.67 per cent in IPM treatment compared to 76.67 per cent in the untreated control. Overall, the mean infestation was significantly lower in IPM (4.00 %) compared to the control (19.39 %).

Patel and Patel (2009) revealed that, lowest infestation (34.18 %) of capsule borer, *C. punctiferalis* was recorded in castor inter cropped with cow pea (1:2) and maximum seed yield of castor was obtained from green gram (1:1) inter crop, but it was not differed from sesame (1:1) or (1:2) inter crop. Overall results revealed that, green gram and sesame were profitable by achieving higher seed yield and reducing the infestation of capsule borer.

2.4 Efficacy of certain biopesticides and safer chemicals against ginger shoot borer:

2.4.1 Spinosad:

Field experiment was undertaken for two cropping seasons during September - December, 2006 and September - December, 2007 by Ghosh *et al*. (2010) to find out the efficacy of spinosad 45% SC against tomato fruit borer (*Helicoverpa armigera* Hub.) at Nadia, West-Bengal, India. It was found that spinosad was effective against *H. armigera* on tomato at 73 to 84 gm a.i./ha moreover spinosad at 73 to 84 g a.i./ha was very safe to three important predators recorded in tomato field that is, *Menochilus sexmaculaus., Syrphus corollae* and *Chrysoperla carnea* respectively.

Nine insecticides and a natural product were evaluated for their efficacy against shoot borer (*Conogethes punctiferalis*), a serious insect pest of ginger (*Zingiber officinale*) for two years at Experimental Farm of ICAR-Indian Institute of Spices Research at Peruvannamuzhi by Senthil Kumar *et al*. (2017). Pooled analysis of two years data indicated that chlorantraniliprole 0.01% was the best treatment with mean pseudostem damage of 2.6% which was on par with flubendiamide 0.02% (4.1%), spinosad 0.0225% (6.5%) and cyantraniliprole 0.005% (8.8%), when sprayed at 15 days interval during the second fortnight of July to the first fortnight of November. The trials indicated that that these low-risk insecticides and the natural product can be utilized for the management of *C. punctiferalis* in ginger with reduced risk to the environment.

Kayalvizhi *et al*. (2018) studied the field efficacy of newer insecticides for management of annual moringa leaf webber, *Noorda blitealis* Walker (Lepidoptera: Crambidae). Analysis of pooled data from two locations indicated that two rounds of foliar application of spinosad 45 SC @ 56g a.i./ha at fortnightly interval, starting from new flush period was effective in reducing the leaf damage to 8.57% which was significantly superior over profenophos 50 EC 2250 g a.i./ha (11.23% leaf damage) and flubendiamide 20 WG @ 250g a.i./ha (11.42% leaf damage). All the treatments being significantly superior over untreated control.

Senthil Kumar *et al.* (2019) worked on the efficacy of nine insecticides and a natural product for the management of shoot borer (*Conogethes punctiferalis*), a major insect pest on turmeric (*Curcuma longa*) in the field at Peruvannamuzhi (Kerala). Pooled analysis of data for two years showed that chlorantraniliprole 0.01% treatment had the lowest mean pseudostem damage

(0.3%) that was on par with lambda-cyhalothrin 0.01% (1.0%) and flubendiamide 0.02% (1.8%) respectively. Though the insecticide treatments were significantly superior to spinosad 0.0225%, the yield of fresh rhizomes in spinosad-treated plots was on par with the insecticide treatments.

Khare and Sneha (2021) studied the efficacy and economics of spinosad for controlling brinjal shoot and fruit borer and the result of the experiment confirms that the naturally derived insecticide spinosad 45% SC perform better than the locally used insecticide against brinjal shoot and fruit borer. They further reported that the shoot infestation was lowest in the spinosad treated field and the yield was also higher with its application over control and other treatments.

Prevalence of insect pests in large cardamom (*Amomum subulatum* Roxb.) and evaluation of bio-rationals for the management of major pests under organic agro-ecosystem of Sikkim was conducted by Raj *et al.* (2021) and the result revealed that among all the treatments, application of spinosad 45 SC @ 0.3 ml L^{-1} was found effective followed by neem-based oil (Azadirachtin 0.15% EC) 150ppm @ 3 ml L^{-1} at three different time intervals against all the test insects *i.e.* stem borer, shootfly , leaf eating caterpillar and tea mosquito bug respectively.

2.4.2 Botanicals:

Rajkumar *et al.* (2003) reported that among the biorationals evaluated *viz.* Fish Oil Insecticidal Soap (Na) 2.5%, FOIS (K-based) 2.5%, FOIS (K) + tobacco extract (2.5%), FOIS (Na) + tobacco extract (2.5%), nimbecidine (0.2%), garlic extract (2.5%) + nimbecidine (0.2%) and quinalphos (0.05%). None of the treatments were effective for the control of shoot and capsule borer infestation in cardamom.

According to Naik *et al.* (2004) amongst the neem products experimented in the field, Neemgold® (3%) and NO (3%) were found promising for the management of shoot and capsule borer (*C. punctiferalis* Guen.).

The efficacy of neemgold (0.03%), neem seed cake (0.5 kg/plant), NSKE (4.0%), neem oil (0.03%), Econeem plus (0.03%) and monocrotophos (0.05%) against capsule borer (*C. punctiferalis*) on small cardamom (cv. M-2) was evaluated by Naik *et al.* (2006) in Mudigere and they found out that there were least number of capsule borer population when sprayed with Neem oil.

Mhonchumo (2007) worked on the management of *C. punctiferalis* in ginger in Nagaland and he suggested spraying quinalphos 0.05% + Ozoneem 1500 ppm (3 ml l^{-1}) for the management of *C. punctiferalis* in ginger.

Moanaro (2007) evaluted plant extracts against rice leaf folder in Nagaland and reported significant increase in yield over control, the highest being neem oil followed by *Litsea citrata* acetone extract.

Lalnuntluanga and Singh (2008) studied the performance of pesticides and neem formulations against ginger shoot borer, *C. punctiferalis* infesting ginger in Nagaland and the treatment comprises of neem oil (seed treatment), chlorpyriphos (seed treatment), mulching (mahaneem leaves), phorate (soil application), neem seed cake (whorl application), neem oil (foliar spraying), achook (foliar spraying) and quinalphos (foliar spraying). Among treatments mulching of neem leaves @ 10 t ha^{-1} and spraying with NSKE (5%) during high pest incidence resulted in an increase in yield by 50 to72 % (164.68 q ha^{-1}) and this treatment was as effective as quinalphos (0.05%) in controlling the shoot borer (*C. punctiferalis* Guen.).

Ganesh (2011) revealed that Acephate 75 SP was the next best treatment for *C. punctiferalis* with 39.46 and 24.13 % reduction in capsule damage and larval number of 3.82 and 4.06 larvae/ plant after first and second spray, respectively with seed yield of 10.95 q/ha. However, NSKE 5% was on par with acephate which recorded 50.37 and 30.03 % reduction in capsule damage. Whereas, spinosad 25EC spared a per cent reduction of capsule damage of 47.15 and 15.92 with larval population of 1.91 and 3.15 larvae/plant after first and second spray respectively with seed yield of 9.73q/ha.

Rajabaskar and Regupathy (2013) conducted a research on neem based IPM Modules for control of *Sciothrips cardamom* Ramk and *Conogethes punctiferalis* Guenee in small cardamom and they found out that sequential application of neem oil 0.03%, profenofos 50EC 0.05%, diafenthiuron 50WP 0.06%, neem oil 0.03%, profenofos 50EC 0.05% at 21 days interval was most effective in controlling *C. punctiferalis* infestation. Field evaluation of neem formulation showed that the greatest reduction of *S. cardamom* and *C. punctiferalis* damages were reported in Neemazal 5% treated plot followed by TNAU neem 0.03% EC respectively.

Ganesha *et al.* (2014) recorded chlorpyriphos 50 EC (2 ml/lit.) as the best treatment for the management of castor capsule borer, *C. punctiferalis* Guenee in castor which was at par with neem oil (3 ml/lit.).

Shitiri *et al.* (2014) tested 3 plant extracts *viz.*, stem of *Costus speciosus* (J. Konig.), seed of *Litsea citrata* (Bl.Bijdr) and seed of *Chenopodium ambrosioides* L. against the insect pests of lowland rice. Among the botanical treatments, *Litsea citrata* seed extract @ 20ml/litre of water was found to give effective control against stem borer, leaf folder and ear head bug almost at par monocrotophos.

Chethan *et al*. (2016) conducted a study on the evaluation of insecticide molecules against shoot borer, *Conogethes punctiferalis* Guenee (Lepidoptera: Pyralidae). All the tested insecticides were effective in suppressing the incidence of *C. punctiferalis.* Larval population was significantly less on all the treated plots than control. They further reported that the botanical pesticide nimbicidine was also effective in controlling the pest and recorded significantly lower larval mortality over control.

Sathe *et al*. (2016) stated 0.1% Azadirachtin as effective eco-friendly management for lepidopteran pests.

Singh *et al*. (2016) studied the efficacy of insecticides against shoot borer on turmeric crop in North-East India and they found out that carbofuran 3G @ 1.0 kg a.i./ha was most effective in controlling the pest (73.61 mean per cent reduction) and was at par with cartap hydrochloride 4G @ 0.75 kg a.i. /ha (68.33%). Regent (Fipronil) 5 SC @ 0.05 kg a.i. /ha (60.83%) was also significantly effective in reducing the pest infestation which was at par with malathion 50 EC 0.1% kg a.i. /ha (57.78%), Neukil (Ethofenprox) 10 EC 0.07 kg a.i. /ha. (56.39%), neem oil @ 2.0% (45.56%) and NSKE @ 5.0% (38.33 %) solution were also found effective to check the pest infestation over control.

Chethan *et al*. (2017) worked on the evaluation of insecticide molecules against turmeric shoot borer, *Conogethes punctiferalis* Gueene (Lepidoptera: Pyralidae) and they reported that all the tested insecticides lamda cyhalothrin, chloropyripos, carbofuron, phorate, imidacloprid, fipronil, chlorontronilprole and nimbicidine were effective in suppressing the incidence of *C. punctiferalis*. The higher mean larval mortality was observed in lamda cyhalothrin (59.30 %), followed by carbofuron (56.63 %) and chloropyripos (53.19 %) respectively. The botanical pesticide nimbicidine was also effective in reducing the pest.

Pandey and Thakur (2017) studied the bioefficacy of some plant product against brinjal shoot and fruit borer *Leucinodes orbonalis.* Neem leaf extract 0.5%, NSKE 2.5%, garlic extract 5%, pongamia extract 5%, tobacco leaf extract 1%, leaf extract of *Lantana camara* 1%, cypermethrin 25 EC were evaluated against *L. orbonalis* infesting brinjal. The observations on infestation of *L. orbonalis* 24 hours before (Pre-treatment) and 3, 7 and 14 days after treatment (Post-treatment) revealed that insecticide cypermethrin 0.2% was the most effective treatment followed by neem leaf extract 0.5%, Pongamia 5%, NSKE 2.5%, garlic extract 5%, tobacco leaf extract 1.0%, *Lantana camara* Leaf extract 5% respectively.

Berani *et al*. (2018) reported that among the different botanicals tested for their bio-efficacy against lepidopteran insect pest infesting black gram Azadirachtin 0.15 EC 0.0006 %, Neem Seed Kernel Extract (NSKE) 5 %, neem oil 0.3 % and Neem Leaf Extract (NLE) 10 % were found highly effective in managing Bihar hairy caterpillar, *Spilosoma obliqua* Walker and spotted pod borer, *Maruca testulalis* (Geyer) in black gram.

2.4.3 Imidacloprid:

Effectiveness of different treatments with imidacloprid 200 SL was evaluated against leaf folder (*Cnaphalocrosis medinalis* Guenee) and stem borer (*Scirpophaga incertulus* Walker) incidence in rice by Ramesh *et al*. (2000). Sprouted seed soaking at 0.05% for 3hr before sowing offered good protection against leaf folder than other treatments. Foliar application 5 days before pulling @ 25g a.i./ha was found effective up to 30 days after transplanting in reducing stem borer incidence.

Maurya *et al.* (2016) worked on the efficacy of acephate 50% + imidacloprid 1.8% SP against sucking pest and fruit borer of okra and they found out that application of acephate 50% + imidacloprid 1.8% SP @ 1000 and 1200g/ha were most effective in controlling fruit borer, *Helicoverpa armigera,* jassids and whitefly populations as compared to the standard check and untreated control. They were also found to be safer to predatory coccinellids and spider population.

2.4.4 Malathion:

Kumaresan *et al*. (1978) reported the effectiveness of 10 insecticides, applied in sprays at 0.1% for the control of *C. punctiferalis* on cardamom. All compounds significantly reduced infestation and over 70 per cent reduction was afforded by monocrotophos 36SL, a mixture of carbaryl 80S with molasses (sevimol), phosalone 35 EC, endosulfan 35 EC, dichlorvos 76 EC

(DDVP), quinalphos 25 EC and dimethoate 30 EC. The destruction of badly infested cardamom pseudostems and also of any wild castor plants nearby was recommended in order to keep down the pest population. Further they also reported that, sprays of malathion (0.1 %), parathion (0.04 %), endrin (0.04 %), phosphamidon (0.03 %) and carbaryl (0.25 %) were effective in reducing infestation of the pest.

Mandal *et al.* (1978) suggested that, four sprays of carbaryl (0.25%) at 21 day interval commencing at the time of flowering proved most effective and can be recommended for the control of *C. punctiferalis* in cardamom ecosystem.

Varadarasan and Kumaresan (1987) suggested that, chemical control was unsatisfactory as it reached only the early larval instars, correct timing of pesticide application based on adult emergence was not always possible and *C. punctiferalis* also attacked a number of other crops. The use of light traps, pheromones and hand picking were suggested as possible alternative means of control.

Two commercial products of *Bacillus thuringiensis* namely, biosap (0.25%, 0.50% and 0.75%) and dipel (*B. thuringiensis kurstaki*) (0.1%, 0.2% and 0.3%) were evaluated along with malathion (0.1%) by Devasahayam (2000) at Kerala, against shoot borer (*C. punctiferalis*) on ginger. All the treatments were effective in reducing the damage compared to the control. Five sprays of dipel 0.3%, at 21 days intervals during July - October was the most effective treatment resulted in significant lower percentage of infested shoots on the crop.

A field experiment was conducted by Singh and Sharma (2005) to assess the efficacy of bioagents and neem products in relation to malathion against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee on brinjal. The study revealed that the bioagents and neem products were not superior to the Malathion 50 EC (0.05%), however, *Bacillus thuringiensis* subs, kurstaki (Dipel 8L @ 2.5ml/lit water) provided sufficient control of the pest.

The effectiveness of profenofos was tested by Renuka *et al*. (2006) in laboratory and field condition in cardamom against *C. punctiferalis* and they reported that profenofos is found effective in controlling *C. punctiferalis* and is a good alternative to conventional insecticides and less persistent in cured cardamom. Among the different concentrations used profenofos at 0.05% was cost effective.

Devasahayam *et al.* (2010) reported that monthly spraying of malathion (0.1%) during July - October or by integrating mechanical pruning and destruction of freshly damaged shoots during July- August and monthly spraying of malathion (0.1 %) during September- October effectively suppressed shoot borers in ginger ecosystem.

Diafenthiuron, a novel insecticide was found to be effective against *Conogethes punctiferalis* in field trials conducted at Nedukandam, Idukki district, Kerala with the cardamom cultivars, Njellani (Green gold) by Aravind *et al.* (2017). They reported that diafenthiuron 50 WP (NS) as foliar application at 1600, 800 and 400 g a.i. ha^{-1} effected 77.07, 79.23 and 72.71 per cent reduction in capsule damage, and 77.86, 77.63 and 67.19 per cent reduction in shoot damage respectively, thirty days after three applications.

Stanley *et al*. (2019) worked on the management of cardamom borer, *Conogethes punctiferalis* Guenee and thrips, *Sciothrips cardamomi* Ramk using diafenthiuron and its residues in fresh and cured cardamom capsules and they reported that diafenthiuron 50 WP @ 300 g a.i ha^{-1} was found effective in managing both the cardamom shoot and capsule borer, *C. punctiferalis* Guenee and thrips, *S.cardamomi* Ramk and thus can be recommended for pest management. The diafenthiuron residue was below the detectable levels of 0.05 µg g^{-1} in the harvested produce (both fresh and cured) after twelve and fourteen days of spray. So, capsules can be harvested safely without any risk of insecticide residues 12 days after spraying of diafenthiuron and thus can be recommended for usage in cardamom plantations.

CHAPTER – 3
MATERALS AND METHODS

MATERIALS AND METHODS

The present research entitled "Eco-friendly pest management of ginger shoot borer, *Conogthes punctiferalis* Guenee (Pyralidae:Lepiodoptera)" was carried out in the Experimental Farm, Department of Entomology, School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema campus. The details of the different materials used and methods adopted during the research are presented below.

3.1 Description of ginger shoot borer:

Scientific name: *Conogethes punctiferalis* (Guenee)

Order : Lepidoptera

Family : Pyralidae

The adult is a medium sized moth with a wingspan of about 20 mm; the wings and body are pale straw yellow with minute black spot. The freshly laid eggs are pale yellow and oval in outline. The first instar larvae are minute, light brown in colour. The sclerites of the body are dark brown in color. As the caterpillar completed its first moult, it grew in size and the abdomen became more or less cylindrical in shape. The second instar larvae are light brown with eye spots and dark mandibles. The freshly formed pupae are greenish with brown compound eyes. Later the pupa turned light brown with dark brown compound eyes.

3.2 Geographical location of the experimental site:

The experimental site is situated at 25º 45' 53'' N latitude and 93º 53' 04'' E longitudes at an elevation of 310 meters above mean sea level.

Plate 3.1 General view of the experimental plots

Plate 3.1 General view of the experimental plot

3.3 Climatic conditions and soil status:

The experimental farm lies in humid sub-tropical region with an average rainfall ranging from 2000-2500 mm annually. The mean temperature ranges from 21^0C during summer and rarely goes below 8^0C in winter due to high atmospheric humidity. The soil is sandy loam in texture, acidic in nature with pH ranging from 4.5-6.5.

3.4 Meteorological data:

The meteorological data during the period of study was obtained from ICAR-Research Complex for NEH Region, Jharnapani, Nagaland. The different abiotic factors were correlated with incidence of the target pest for significant effect.

3.5 Cultivation practices:

3.5.1 Field preparation and raising of host plant:

The soil was ploughed 4-5 times to attain fine tilt. During land preparation weeds and stubbles of the previous crop were removed. Raised bed of 1m width, 15 cm height and 1.8m length were prepared, which were kept ready for planting.

3.5.2 Planting and intercultural operations:

Healthy ginger rhizomes cultivar Nadia were collected from ICAR Research Complex for NEH Region, Umiam, Meghalaya and these rhizomes were planted in the field at a spacing of 30 cm between plant and 30 cm between rows. Important intercultural operations like manuring, mulching, irrigation and other agronomical practices were followed.

3.6 Description of ginger cultivar (Nadia)

Nadia is the high yielding variety from West Bengal and can be grown throughout ginger growing areas in India. Size of the rhizome is medium to bold, yellowish in colour, moderately pungent, mild flavored and less fibrous comparatively. The green production is about 49 tones per ha. However, dry ginger recovery is 22.40 per cent with crude fiber of 8.13 per cent. The volatile oil content (oleoresin) in dry ginger powder of this variety varies between 3.6-4.8 per cent. The essential oil content is 1.4 per cent. It is suitable for both fresh and dry ginger. It takes 200 days for maturity.

3.7 Ecological plot:

An ecological plot (14.5x2.8 m^2) with Nadia cultivar was maintained 10 m away from the main plot, which was replicated 3 times and ginger was planted based on three different assigned dates of planting. Ecological plot was maintained to study the seasonal incidence of ginger shoot borer, natural enemies of ginger shoot borer and effect of abiotic factors on the incidence of ginger shoot borer.

Table 3.1: Meteorological observations during the period of study (June to December 2018)

Sl. No.	Month	Temperature (ºC)		Relative humidity (%)		Rainfall (mm)
		Max.	Min.	Max.	Min.	
1	June	33.40	24.20	94.00	73.00	354.70
2	July	33.20	24.90	92.00	72.00	240.00
3	August	33.50	24.90	94.00	71.00	302.80
4	September	33.60	23.90	94.00	67.00	115.70
5	October	29.90	20.10	96.00	67.00	64.00
6	November	28.20	14.10	97.00	54.00	13.30
7	December	24.60	11.00	96.00	56.00	50.00

Table 3.2: Meteorological observations during the period of study (June to December 2019)

Sl. No	Month	Temperature (ºC)		Relative humidity (%)		Rainfall (mm)
		Max.	Min.	Max.	Min.	
1	June	33.50	24.10	91.00	69.00	195.00
2	July	33.00	24.90	93.00	72.00	271.30
3	August	34.10	24.90	93.00	73.00	274.50
4	September	32.70	23.90	94.00	72.00	173.40
5	October	30.30	21.70	95.00	73.00	244.80
6	November	28.80	16.30	97.00	64.00	52.90
7	December	24.80	12.00	96.00	57.00	15.00

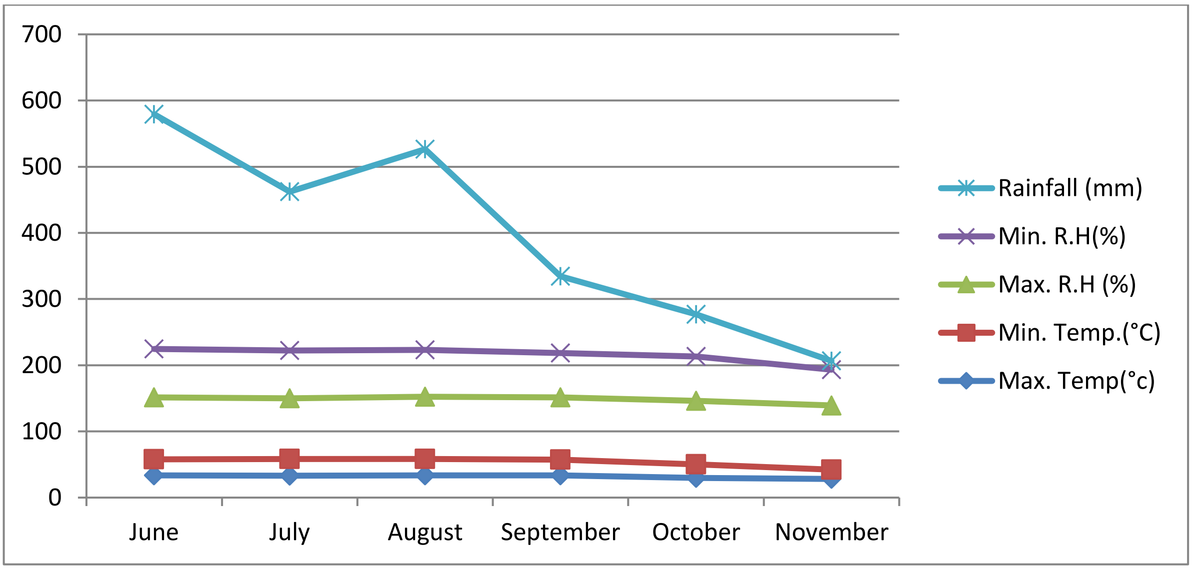

Fig.3.1 Graphical representation of the meteorological data during the period of investigation, 2018

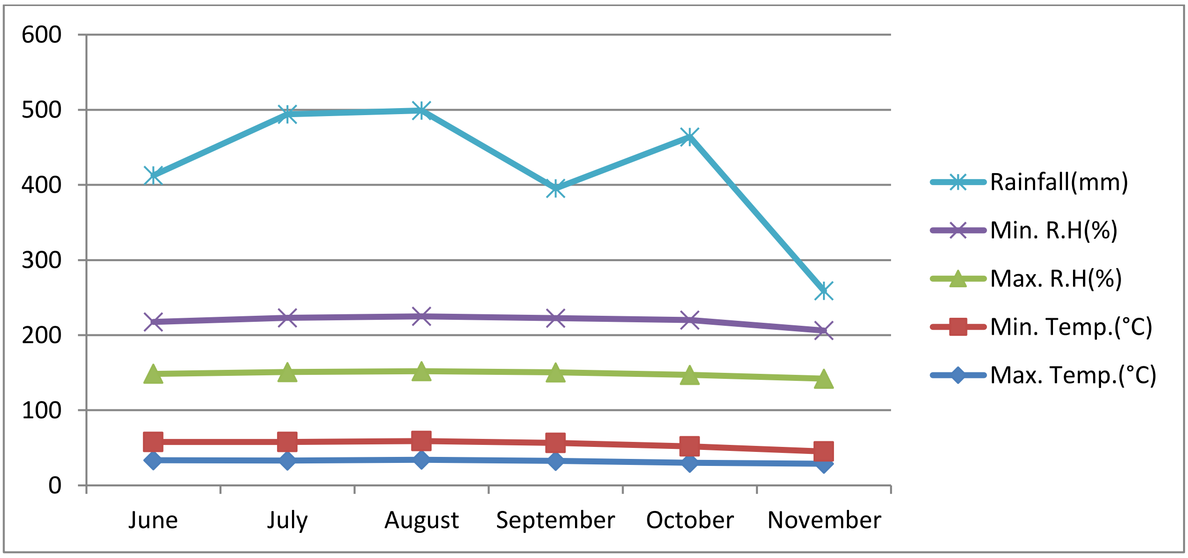

Fig.3.2 Graphical representation of the meteorological data during the period of investigation, 2019

Plate 3.2 Ecological plot

Plate 3.3 Ginger cultivar Nadia

3.8 Study on the seasonal incidence of ginger shoot borer:

9 (nine) ecological plots of 14.5 m x 2.8 m size was maintained 10 m away from the treated plots in order to study the seasonal incidence of ginger shoot borer under natural condition. For this purpose, five numbers of plants were selected randomly from each plot and tagged to assess the incidence of insect pests during the course of crop growth.

The extent of incidence of the pest was recorded by counting the number of infested shoots to the total number of shoots on the 5 randomly selected plants at fortnightly intervals and expressed as percentage with the following formula:

$$\text{Per cent shoot infestation (\%)} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

(Simple linear correlation analysis was performed to find out the relationship of weather parameters like temperature, relative humidity and rainfall with the incidence of ginger shoot borer).

The status of the pest was considered based on number of insects occurring on the plant. To study the instantaneous effect of major abiotic factors *viz.,* maximum temperature, minimum temperature, morning and afternoon relative humidity, rainfall and sun shine hours on pest infestation, a correlation coefficient and multiple linear regression was worked out taking fortnightly larval population as dependent variable with the standard week mean meteorological data as independent variables.

3.9 Relative abundance of natural enemies in ginger ecosystem and the effect of treatments.

The relative abundance of natural enemies in ginger ecosystem was carried out both in the Ecological plot and the Experimental plots at fortnightly interval from 1st August till harvesting of the crop. The collected natural enemies were brought to the Laboratory of the Department of Entomology, SASRD and the specimens were preserved under dry preservation method and abundance of the collected natural enemies were quantified through visual assessment in the field. The collected samples were identified by careful comparision with the samples from the Insect Museum, Department of Entomology and their relative abundance were worked out which were compared between the treated and untreated plots. Relative abundance of natural enemies population were calculated using the following equation (Rahman *et al*., 2014).

$$\text{Relative abundance (\%)} = \frac{\text{Total number of individuals of each species}}{\text{Total number of individuals of all species}} \times 100$$

3.10 Details of the experiments:

3.10.1 Experimental design and layout:

The present study was carried out in split plot design with three replications, keeping planting dates in the main plot and treatments in the sub-plot. Ginger rhizomes were planted in the field with 3 different dates of planting with 3 replications starting from 15th February 2018, with an interval of 30 days. The detailed layout is presented below.

Crop: Ginger (*Gingiber officinalis*)

Variety: Nadia

Design: Split plot design

Main factor: 3 dates of planting

Sub factor: 7 treatments

Number of replications: 3

Number of treatments: 21

Total number of plots: 63

Spacing:-

a. Row to Row:30cm
b. Plant to plant:30cm
c. Interspacing between blocks: 1m
d. Interspacing between main plots:1m
e. Interspacing between sub plots:0.5m

Number of main plots:9
Size of main plots:14.5mx2.8m

Number of plants in main plot:210

Number of sub plots:63

Size of sub-plots:1.8mx1.5m

Number of plants/sub-plot:30

Total number of sub-plots/main plot:7

Total number of plants: 1890

3.11 Effect of date of planting on the incidence of ginger shoot borer (Main factor):

The rhizomes were planted on three different dates of planting starting from 15th February, 2018 (15th February, 2019) with 30 days interval and the different letter keys adopted to designate the dates of planting are shown below:

Date of planting	Letter keys
15.02.2018	D_1
17.03.2018	D_2
16.04.2018	D_3

3.12 Efficacy of certain biopesticides against ginger shoot borer (Sub-factor):

To assess the efficacy of selected botanicals and biopesticides against *C. punctiferalis*, field trial was conducted with 7 treatments, replicated 3 times.

The sprays were imposed using knapsack sprayer with hollow cone nozzle. Two spray schedules were followed. The first spray schedule was applied at the time of moth emergence and the second spray schedule was followed when the first symptom of pest attack is seen on the plants. Both spray schedules were administered twice at fortnightly intervals.

3.13 Description of plant materials

3.13.1 *Litsea citrata* (Bl. Bijdr) (Plate 3.6)

Family: Lauraceae

It is a wild tree, grow wild in fallow land secondarily forest areas. Leaves are dark green in colour, buds naked or scaly. Fruits are inserted in small calyx tube, copular and enlarged. Bark and leaves are used as carminative, expectorant and stimulant. Paste of leaves and fruits are used as acaricide and fruits are used as spices. Twigs are crushed and used as insecticides and the plant is smoked inside the house to kill the larvae which eats away the roof of palm leaves.

3.13.2 Neem (*Azadirachta indica*) (Plate 3.6)

Family: Meliaceae

Neem is a fast-growing tree that can reach a height of 15-20 metres. It is evergreen, but in severe drought it may shed most of its leaves. The opposite, pinnate leaves are 20-40 centimeters long, with 20 to 31 medium to dark green leaflets about 3-8 centimeters long. The terminal leaflet often is missing. The petioles are short. The fruit is smooth, olive-like drupe which varies in shape from elongate oval to nearly roundish. Neem is a key ingredient in nonpesticidal management (NPM), providing a natural alternative to synthetic pesticides. Neem acts as anti-feedant, repellant, and egg-laying deterrent, protecting the crop from damage.

3.14 Seed extraction process (Plate 3.5)

Seeds of *Litsea citrata* were collected from various places of Nagaland and they were dried under the shades. Well dried plant parts were crushed evenly using electric grinder. Crushed powders were sieved to obtain fine powder. These plant powders were used for extraction in soxhlet using acetone as solvents. The seed extract prepared were used to test for their insecticidal activity against *C. Punctiferalis.*

Soxhlet extractor

Acetone (Solvent)

Grinder

Plate 3.4 Equipments and chemicals used for preparation of seed extract

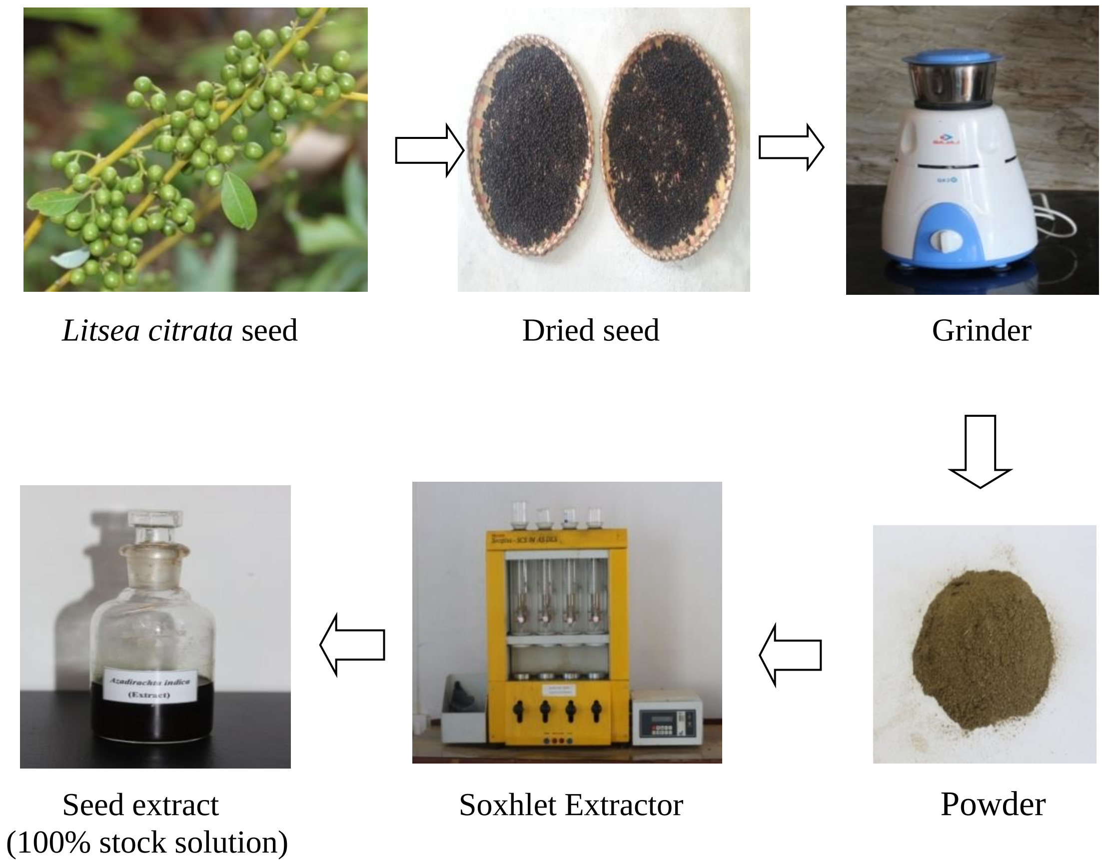

Plate 3.5 Preparation of seed extract

3.15 Treatment details:

Table 3.3 Details of the insecticides/biopesticides which were used in the experiment

Sl. No.	Common Name	Dose(ml/l)	Symbol
1.	Spinosad 48% S.C	0.5	T_1
2.	Multineem	3	T_2
3.	Neem oil 1500ppm	3	T_3
4.	Imidacloprid 17.8 SL	0.5	T_4
5.	*Litsea citrata* (Seed extract)	20	T_5
6.	Malathion 50% E.C (Standard)	1	T_6
7.	Control	-	T_0

The pest populations were recorded one day before the application of treatments as per the below described sampling methods to assess the extent of infestation before insecticides spray and the dates of post treatments were recorded at 3rd, 5th and 7th days after each treatment to study the effect of the different treatments and work out the per cent reduction on pest infestation.

Imidacloprid 17.8 SL	Spinosad 48% S.C	Malathion 50% E.C

Neem oil	Multineem	*Litsea citrata*

Plate 3.6 Pesticides/Bio-pesticides used in the experiment

3.16 Field observation of shoot borer (*C. punctiferalis*) infestation:

Infestation of shoot borer was assessed by recording the number of total and affected shoots on each of the ten randomly selected plants per treatment and per cent infestation of shoots for each plant was calculated using the formula given below:

$$\text{Infestation (\%)} = \frac{\text{Number of shoots infested per plot}}{\text{Total number of shoots per plot}} \times 100$$

3.17 Statistical analysis:

Efficacy of treatments with reference to infestation in different treatments was calculated using formula given below:

$$\text{Per cent (\%) efficacy of treatments} = \frac{\text{Infestation \% in pre treatment count} - \text{Infestation \% in post treatment count}}{\text{Infestation \% in pre treatment count}}$$

The per cent values were transformed into angular transformed values which were subjected to statistical analysis to observe the effect of the treatments.

CHAPTER – 4
RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 Incidence of ginger shoot borer, *Conogethes punctiferalis* at different dates of sowing and its correlation with abiotic factors in the year 2018.

In the present investigation seasonal incidence of ginger shoot borer and their correlation with abiotic factors like maximum and minimum temperature, relative humidity and rainfall was carried out during the investigation period to find out the impact of abiotic factors.

The data from the two years experimental trial as indicated in table 4.1 revealed that the incidence of *Conogethes punctiferalis* in the year 2018 was observed from 120 DAP (Days after planting) with 10.70 % larvae in D_1 (15^{th} February planting) which falls in the second week of June followed by D_2 (17^{th} March planting) with 11.65 % larvae which falls in the second week of July and D_3 (16^{th} April planting) with 12.72 % larvae during the second week of August. The highest mean incidence of *C. punctiferalis* on first date of planting was recorded to be 16.52 at 210 DAP and the lowest mean population was 10.70 at 120 DAP. Highest mean incidence in the second date of planting was observed on 210 DAP with 17.75 and the lowest mean population of 11.65 was observed at 120 DAP. The highest and the lowest mean population of 18.90 and 12.72 *C. punctiferalis* were recorded on third date of planting at 201 DAP and 120 DAP respectively.

4.2 Incidence of ginger shoot borer, *C. punctiferalis* on ginger variety Nadia at different dates of sowing and its correlation with abiotic factors in the year 2019.

The incidence of *C. punctiferalis* in the year 2019 was also observed from 120 DAP (Days after planting) with 11.40 % larvae in D_1 (15^{th} February planting)

Frass

Dead heart

Infested rhizome

Plate 4.1 Stages of pest infestation in the experimental plot

Eggs

Larva

Pupa

Adult (male)

Plate 4.2 Life stages of ginger shoot borer, *C. punctiferalis* which falls in the second week of June followed by D_2 (17th March planting) with 12.42 % larvae that falls in the second week of July and D_3 (16th April planting) with 13.50 % larvae during the second week of August respectively. The highest mean incidence of *C. punctiferalis* on first date of planting was recorded to be 17.05 at 210 DAP and the lowest mean population was 11.40 at 120 DAP. Highest mean incidence in the second date of planting was observed on 210 DAP with 18.10 and the lowest mean population of 12.42 was observed at 120 DAP. The highest and the lowest mean population of 19.28 and 13.50 *C. punctiferalis* were recorded on third date of planting at 210 DAP and 120 DAP respectively.

In both the years of experimental trials, the incidence of *C. punctiferalis* showed an increasing trend till 210 DAP and then decreased thereafter. In both the experimental year, the highest incidence of 18.90 and 19.28 of *C. punctiferalis* per cent larvae was observed at 210 DAP in D_3 *i.e.* second week of November whereas the lowest incidence of 10.70 and 11.40 larvae per plant was recorded at 120 DAP in D_1 which falls in the second week of June for both the years respectively.

Pooled data indicated in table 4.1 revealed that the highest total mean population of 19.09 % larvae was observed in third date of planting (D_3) and the least mean population of 11.05 % larvae of *C. punctiferalis* was observed in first date of planting (D_1).

The findings of the present study are in line with the work of Koya (1984), who stated that the percentage of shoots bored by *C. punctiferalis* in ginger was at the minimum of 5% in July and it steadily increased reaching a peak of 14.8% in November.

Table 4.1 Incidence of ginger shoot borer, *C. punctiferalis* on ginger variety Nadia at different dates of sowing during 2018 and 2019

Date of sowing	*Shoot borer incidence (%)*														
	120 DAP			*150 DAP*			*180 DAP*			*210 DAP*			*240 DAP*		
	2018	*2019*	*Pooled*	*2018*	*2019*	*Pooled*	*2018*	*2019*	*Pooled*	*2018*	*2019*	*Pooled*	*2018*	*2019*	*Pooled*
15th February: (D_1)	10.70 (19.09)	11.40 (19.73)	11.05 (19.41)	12.22 (20.46)	12.87 (21.02)	12.55 (20.74)	14.15 (22.10)	14.72 (22.56)	14.44 (22.33)	16.52 (23.98)	17.05 (24.39)	16.79 (24.18)	15.47 (23.16)	15.90 (23.49)	15.69 (23.33)
17th March: (D_2)	11.65 (19.95)	12.42 (20.62)	12.04 (20.29)	13.50 (21.55)	14.10 (22.05)	13.80 (21.80)	15.24 (22.97)	15.80 (23.41)	15.52 (23.19)	17.75 (24.92)	18.10 (25.17)	17.93 (25.04)	16.50 (23.96)	16.97 (24.32)	16.74 (24.14)
16th April: (D_3)	12.72 (20.89)	13.50 (21.55)	13.11 (21.22)	14.75 (22.58)	15.35 (23.06)	15.05 (22.82)	16.40 (23.88)	17.26 (24.55)	16.83 (24.21)	18.90 (25.77)	19.28 (26.05)	19.09 (25.91)	17.62 (24.82)	18.16 (25.22)	17.89 (25.02)
SEm±	*0.27*	*0.30*	*0.20*	*0.28*	*0.33*	*0.22*	*0.32*	*0.35*	*0.24*	*0.29*	*0.31*	*0.21*	*0.27*	*0.31*	*0.20*
CD (P= 0.05)	*1.07*	*2.78*	*0.66*	*1.09*	*2.78*	*0.71*	*1.24*	*2.78*	*0.77*	*1.15*	*2.78*	*0.69*	*1.04*	*2.78*	*0.66*

Note: Figures in the table are mean values and those in parenthesis are arc sine transformed values.

Gupta and Arora (2001) also reported that *C. punctiferalis* appeared only on late season crop *i.e.* the second week of October to last week of November which agrees to the present findings. It is also in partial agreement with the work of Jacob (1981b), who reported that the pest incidence of *C. punctiferalis* in ginger was highest during September to October. Patel *et al*. (2015) also stated that higher activity of the pest was observed from first week of November to second week of January, with a peak level (20.04) on third week of November.

The correlation of *C. punctiferalis* with the abiotic factors for the year 2018 as indicated in table 4.2 had revealed a non significant negative effect with maximum temperature on all the three planting dates *i.e.* D_1 (first date of sowing), D_2 (second date of sowing) and D_3 (third date of sowing). Correlation of minimum temperature with the incidence of *C. punctiferalis* showed a non-significant positive effect on the first date of sowing (D_1), negative non-significant on second date of sowing (D_2) whereas significant negative effect on D_3 (third date of sowing). Correlation of maximum relative humidity (RH) with the incidence of *C. punctiferalis* showed a non significant positive effect on D_1 *i.e.* first date of sowing whereas significant positive effect on D_2 (second date of sowing) and D_3 (third date of sowing). Correlation of minimum relative humidity (RH) with the incidence of *C. punctiferalis* showed a significant negative effect on and first date of sowing (D_1) and third date of sowing (D_3) whereas non significant negative effect on D_2 (second date of sowing). Correlation of rainfall with the incidence of *C. punctiferalis* showed a non significant negative effect on D_1 (first date of sowing) and D_2 (second date of sowing) whereas significant negative effect on D_3 *i.e.* third date of sowing respectively.

The correlation of *C. punctiferalis* with the abiotic factors for the year 2019 also revealed a non significant negative effect with maximum temperature on all the three different dates. Correlation of minimum temperature with the incidence of *C. punctiferalis* showed a non-significant negative effect on first date of sowing (D_1), second date of sowing (D_2) and third date of sowing (D_3). Correlation of maximum relative humidity (RH) with the incidence of *C. punctiferalis* showed a non significant positive effect on D_1, and D_2 *i.e.* first date of sowing and second date of sowing whereas significant positive effect on D_3 (third date of sowing). Correlation of minimum relative humidity (RH) with the incidence of *C. punctiferalis* showed a non significant positive effect on first date of sowing (D_1) whereas non-significant negative effect on second date of sowing (D_2) and third date of sowing (D_3). Correlation of rainfall with the incidence of *C. punctiferalis* showed a non significant negative effect on all the three planting dates as mentioned in table 4.2.

The present finding is in partial agreement with the work of Goel and Kumar (1990) who have stated that maximum and minimum temperature influenced positively with significant effect on per cent infestation of capsule by shoot and capsule borer, *C. punctiferalis*. It is also in line with the work of Kasareddy *et al*. (2018) who have reported that population of *C. punctiferalis* was significant and positively correlated with relative humidity and rainfall. Rashmi (2014) reported that the incidence of borer showed significant positive correlation with maximum temperature, while the relative humidity and rainfall showed a negative correlation with the incidence of shoot borer. Stanley *et al.* (2009) reported that increasing relative humidity increases damage caused by *C. punctiferalis*. Madhuri (2005) reported that incidence of *C. punctiferalis* showed significant and positive correlation with maximum temperature, whereas relative humidity showed significant and negative correlation while rainfall showed non significant and negative correlation which is in similarity to the present findings.

Table 4.2 Correlation coefficient (r) of ginger shoot borer, *C. punctiferalis* incidence with abiotic factors during June to December 2018 & 2019

Pearson correlation coefficient	***Ginger shoot borer incidence***					
	15th February: (D₁)		***17th March: (D₂)***		***16th April: (D₃)***	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**
Maximum temperature (ºC)	-0.327	-0.454	-0.730	-0.763	-0.815	-0.818
Minimum temperature (ºC)	0.447	-0.428	-0.690	-0.658	-0.885*	-0.819
Maximum relative humidity (%)	0.485	0.864	0.899*	0.762	0.938*	0.988**
Minimum relative humidity (%)	-0.944*	0.723	-0.613	-0.308	-0.921*	-0.686
Rainfall (mm)	-0.828	-0.173	-0.839	-0.510	-0.934*	-0.821

Note: df = (5-2) = 3 $r_{0.05}$ = 0.878 $r_{0.01}$ = 0.959

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Those values in the table without assign any symbols are non-correlated at 5% and 1% level of significance respectively.

4.3 Relative abundance of natural enemies in ginger ecosystem in the year 2018-2019

The beneficial arthropods (natural enemies) in ginger ecosystem recorded during 2018 and 2019 are shown in Table 4.3. Total 8 predacious arthropods species were recorded from 8 families under 6 orders of insects and arachnid of spiders. Observed species belong to the order Coleoptera, Diptera, Dictyoptera, Hymenopera, Odonata, Dermaptera and Araneae respectively.

Table 4.3: List of beneficial arthropods (natural enemies) species recorded through visual searching method from ginger ecosystem during 2018 and 2019.

Sl. No	Order	Family	Common name	Scientific name
1.	Araneae	Oxyopidae	Spider	*Oxyopes* sp.(Fig. b)
2.	Coleoptera	Coccinellidae	Lady bird beetle	*Coccinella septempunctata* (Fig. a)
3.	Dictyoptera	Mantidae	Preying mantid	*Mantis religiosa* (Fig. g)
4.	Hymenoptera	Formicidae	Black ant	*Camponotus compressus* (Fig. d)
5.	Diptera	Asilidae	Robber fly	*Promachus* sp. (Fig. h)
6.	Odonata	Anisoptera	Dragonfly	*Sympetrum flaveolum* (Fig. c)
7.	Dermaptera	Forficulidae	Earwig	*Forficula auricularia* (Fig. f)
8.	Coleoptera	Carabidae	Carabid beetle	*Ophionea nigrofasciata* (Fig. e)

The relative abundance of natural enemies in ginger ecosystem (spinosad treated plot) during the year 2018 showed that among the natural enemies, the highest relative abundance was observed in spider (37.73%) which was followed by black ant (24.52%), lady bird beetle (17.61%), Carabid beetle (8.17%), preying mantid (5.67%), robber fly (3.14%), dragonfly (1.89%) and the lowest relative abundance was reported in earwig (1.23%) as mentioned in table 4.4. During the year 2019 the relative abundance of natural enemies in ginger ecosystem (spinosad treated plot) showed the highest relative abundance in spider (39.37%) which was followed by black ant (23.12%), lady bird beetle (16.25%), Carabid beetle (9.37%), preying mantid (4.37%), robber fly (3.75%), dragonfly (2.50%) and the lowest relative abundance was reported in earwig (1.25%) as indicated in table 4.4.

The relative abundance of natural enemies in ginger ecosystem (multineem treated plot) during the year 2018 indicated that among the natural enemies, the highest relative abundance was observed in spider (40.24%) which was followed preying mantid (4.87%), robber fly (3.65%), and the lowest relative abundance was reported in earwig (1.82%) and dragonfly (1.82%). During the year 2019 the relative abundance of natural enemies in ginger ecosystem (multineem treated plot) showed the highest relative abundance in spider (41.71%) which was followed by black ant (23.31%), lady bird beetle (14.72%), Carabid beetle (9.81%), preying mantid (4.29%), robber fly (2.45%), dragonfly (2.45%) and the lowest relative abundance was reported in earwig (1.22%) as shown in table 4.5.

The relative abundance of natural enemies in ginger ecosystem (neem oil treated plot) during the year 2018 showed that among the natural enemies, the highest relative abundance was observed in spider (34.19%) which was followed by black ant (25.16%), lady bird beetle (18.70%), Carabid beetle (10.97%), preying mantid (4.51%), robber fly (3.22%), earwig (1.93%) and the lowest relative abundance was reported in dragonfly (1. 29%). In the year 2019 the relative abundance of natural enemies in ginger ecosystem (neem oil treated plot) indicated that the highest relative abundance was observed in spider (36.60%) which was followed by black ant (24.18%), lady bird beetle (18.3%), Carabid beetle (9.15%), preying mantid (3.92%), robber fly (3.92%), dragonfly (2.61%) earwig (1.93%) and the lowest relative abundance was reported in earwig (1.30%) as mentioned in table 4.6.

Table 4.4: Relative abundance of natural enemies in spinosad (T_1) treated plot during 2018 & 2019.

Name of natural enemies	Total no. of each natural enemy population plot^{-1}		Relative abundance (%)	
	2018	2019	2018	2019
Spider	60	63	37.73	39.37
Lady bird beetle	28	26	17.61	16.25
Preying mantid	9	7	5.67	4.37
Black ant	39	37	24.52	23.12
Robber fly	5	6	3.14	3.75
Dragonfly	3	4	1.89	2.5
Earwig	2	2	1.23	1.25
Carabid beetle	13	15	8.17	9.37
Total	159	160		

Table 4.5: Relative abundance of natural enemies in multineem (T_2) treated plot during 2018 & 2019.

Name of natural enemies	Total no. of each natural enemy population plot^{-1}		Relative abundance (%)	
	2018	2019	2018	2019
Spider	66	68	40.24	41.71
Lady bird beetle	26	24	15.85	14.72
Preying mantid	8	7	4.87	4.29
Black ant	38	38	23.17	23.31
Robber fly	6	4	3.65	2.45
Dragonfly	3	4	1.82	2.45
Earwig	3	2	1.82	1.22
Carabid beetle	14	16	8.53	9.81
Total	164	163		

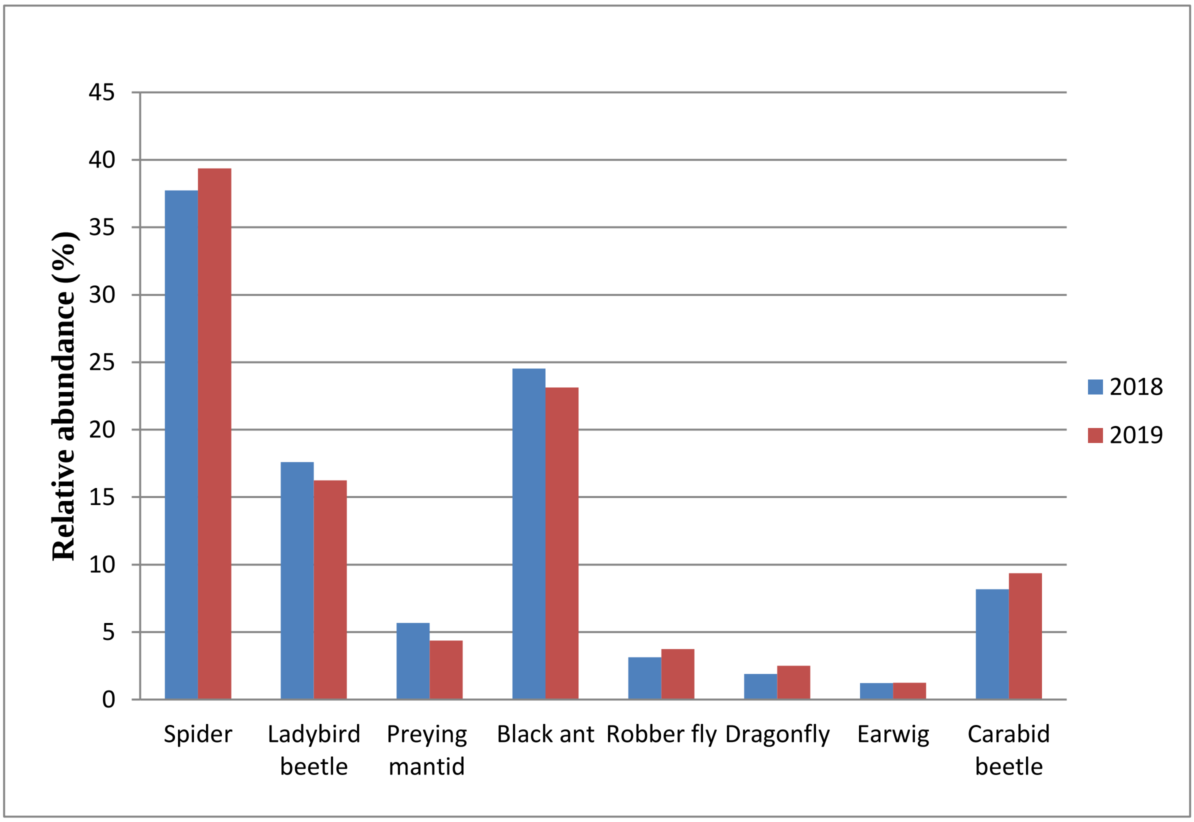

Fig 4.1 Relative abundance of natural enemies in spinosad (T_1) treated plot during 2018 & 2019.

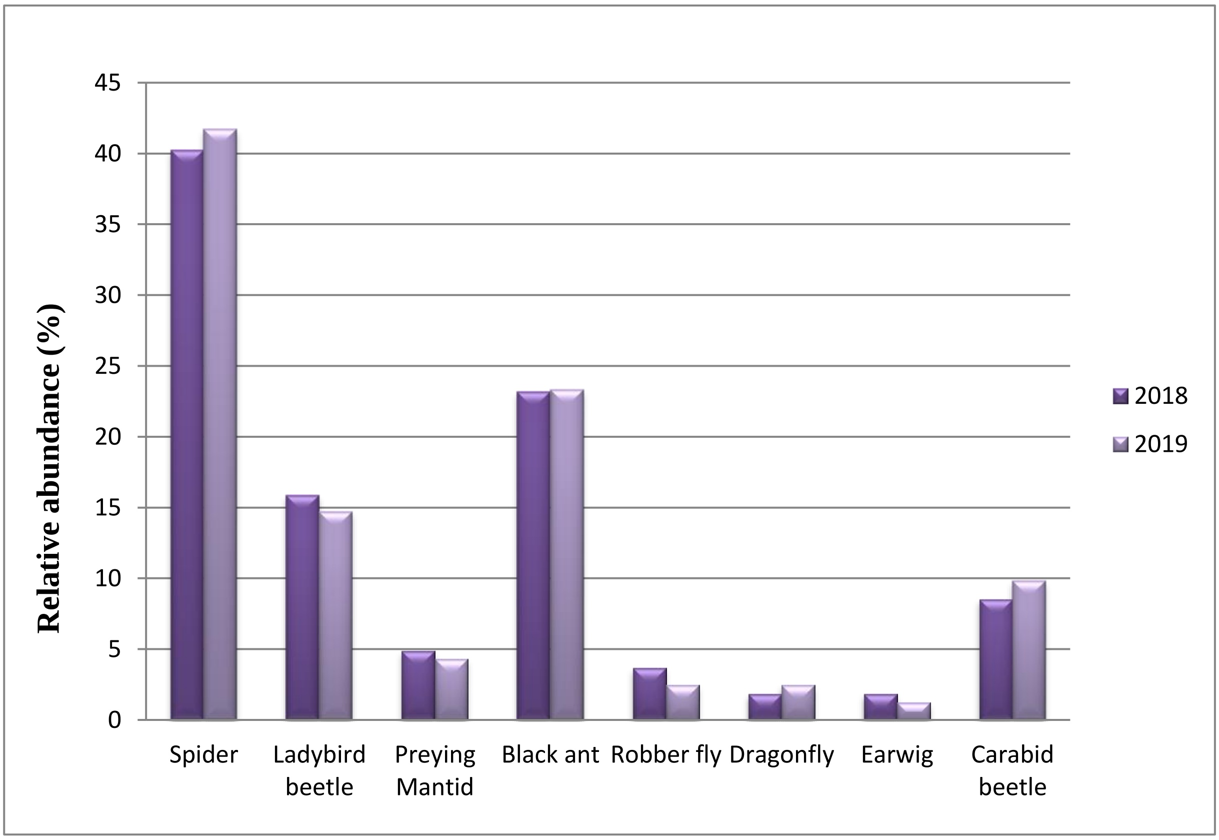

Fig 4.2 Relative abundance of natural enemies in multineem (T_2) treated plot during 2018 & 2019.

(a) Ladybird beetle

(b) Spider

(c) Dragon fly

(d) Black ant

(e) Carabid beetle

(f) Earwig

(g) Preying mantid

(h) Robber fly

Plate 4.3 Natural enemies observed in ginger ecosystem

The relative abundance of natural enemies in ginger ecosystem (imidacloprid treated plot) during the year 2018 indicated that among the natural enemies, the highest relative abundance was observed in spider (38.96%) which was followed by black ant (22.72%), lady bird beetle (16.89%), Carabid beetle (9.09%), robber fly (5.19%), preying mantid (3.89%), dragonfly (1. 94%) and the lowest relative abundance was reported in earwig (1.29%). In the year 2019 the relative abundance of natural enemies in ginger ecosystem (imidacloprid treated plot) showed that the highest relative abundance in spider (39.24%) which was followed by black ant (23.41%), lady bird beetle (15.18%), Carabid beetle (10.75%), robber fly (3.79%), preying mantid (3.79%), dragonfly (2.53%) and the lowest relative abundance was reported in earwig (1.26%) as indicated in table 4.7.

The relative abundance of natural enemies in ginger ecosystem (*Litsea citrata* treated plot) during the year 2018 showed that among the natural enemies, the highest relative abundance was in spider (38.46%) which was followed by black ant (21.89%), lady bird beetle (17.75%), Carabid beetle (9.46%), preying mantid (4.73%), robber fly (4.73%), earwig (1.77%) and the lowest relative abundance was reported in dragonfly (1. 18%) as mentioned in table 4.8. In the year 2019 the relative abundance of natural enemies in ginger ecosystem (*Litsea citrata* treated plot) indicated that among the natural enemies, the highest relative abundance was observed in spider (38.59%) which was followed by black ant (20.46%), lady bird beetle (16.95%), Carabid beetle (9.35%), preying mantid (5.26%), robber fly (5.26%), dragonfly (2.33%) and the lowest relative abundance was reported in earwig (1.75%).

Table 4.6: Relative abundance of natural enemies in neem oil (T_3) treated plot during 2018 & 2019.

Name of natural enemies	Total no. of each natural enemy population $plot^{-1}$		Relative abundance (%)	
	2018	**2019**	**2018**	**2019**
Spider	53	56	34.19	36.6
Lady bird beetle	29	28	18.7	18.3
Preying mantid	7	6	4.51	3.92
Black ant	39	37	25.16	24.18
Robber fly	5	6	3.22	3.92
Dragonfly	2	4	1.29	2.61
Earwig	3	2	1.93	1.30
Carabid beetle	17	14	10.97	9.15
Total	155	153		

Table 4.7: Relative abundance of natural enemies in imidacloprid (T_4) treated plot during 2018 &2019.

Name of natural enemies	Total no. of each natural enemy population $plot^{-1}$		Relative abundance (%)	
	2018	**2019**	**2018**	**2019**
Spider	60	62	38.96	39.24
Lady bird beetle	26	24	16.89	15.18
Preying mantid	6	6	3.89	3.79
Black ant	35	37	22.72	23.41
Robber fly	8	6	5.19	3.79
Dragonfly	3	4	1.94	2.53
Earwig	2	2	1.29	1.26
Carabid beetle	14	17	9.09	10.75
Total	154	158		

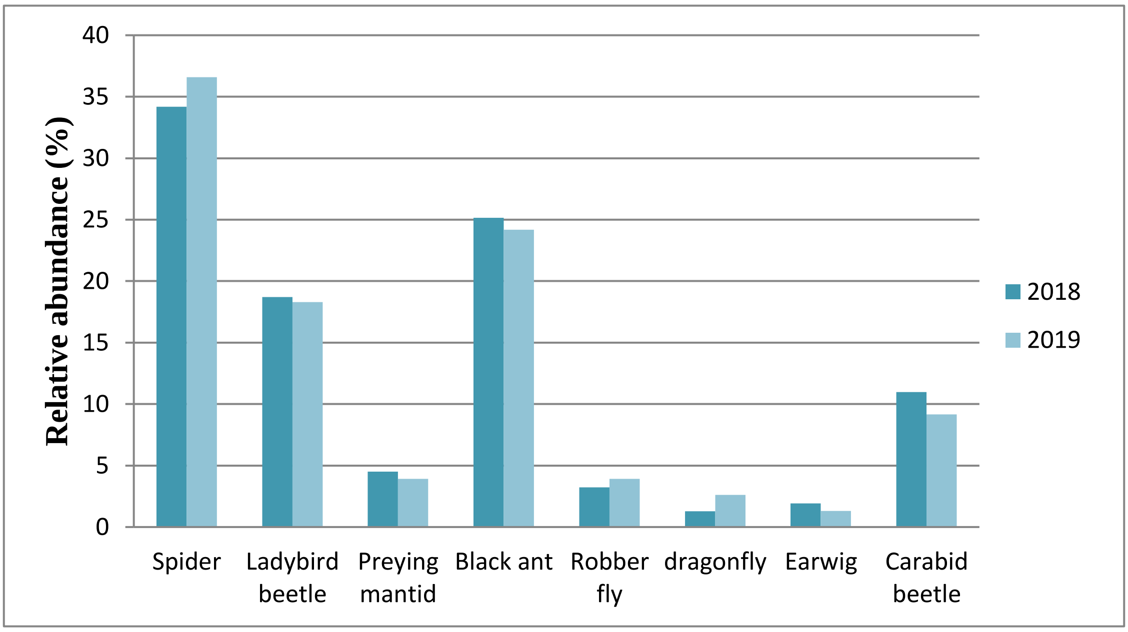

Fig 4.3 **Relative abundance of natural enemies in neem oil (T_3) treated plot during 2018 & 2019.**

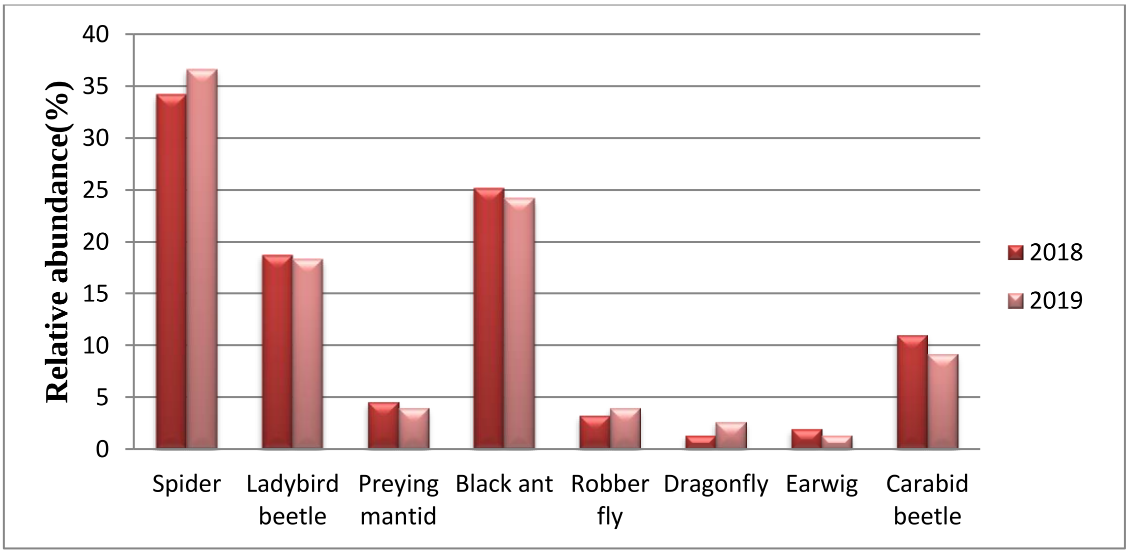

Fig 4.4 **Relative abundance of natural enemies in imidacloprid (T_4) treated plot during 2018 &2019.**

The relative abundance of natural enemies in ginger ecosystem (Malathion treated plot) during the year 2018 showed that among the natural enemies, the highest relative abundance was in spider (40.64%) which was followed by black ant (21.93%), lady bird beetle (17.41%), Carabid beetle (7.74%), preying mantid (5.16%), robber fly (3.22%), and the lowest relative abundance was observed in dragonfly (1.93%) and earwig (1.93%) respectively. In the year 2019 the relative abundance of natural enemies in ginger ecosystem (Malathion treated plot) showed that among the natural enemies, the highest relative abundance was in spider (40.6%) which was followed by black ant (20.64%), lady bird beetle (18.06%), Carabid beetle (9.03%), preying mantid (4.51%), robber fly (3.87%), dragonfly (1.93%) and the lowest relative abundance was reported in earwig (1.29%) as indicated in table 4.9.

The relative abundance of natural enemies in ginger ecosystem (untreated plot) during the year 2018 revealed that among the natural enemies, the highest relative abundance was observed in spider (41.17%) which was followed by lady bird beetle (20.36%), black ant (16.74%), Carabid beetle (7.23%), preying mantid (5.89%), robber fly (3.61%), dragonfly (3.16%) and the lowest relative abundance was reported in earwig (1.80%) respectively. During the year 2019 the relative abundance of natural enemies in ginger ecosystem (untreated plot) showed that the highest relative abundance was observed in spider (40.63%) which was followed by lady bird beetle (21.00%), black ant (17.35%), Carabid beetle (8.21%), preying mantid (6.84%), robber fly (2.73%), dragonfly (2.28%) and the lowest relative abundance was reported in earwig (0.91%) as indicated in table 4.10.

Table 4.8: Relative abundance of natural enemies in *Litsea citrata* (T_5) treated plot during 2018 & 2019.

Name of natural enemies	Total no. of each natural enemy population plot^{-1}		Relative abundance (%)	
	2018	**2019**	**2018**	**2019**
Spider	65	66	38.46	38.59
Lady bird beetle	30	29	17.75	16.95
Preying mantid	8	9	4.73	5.26
Black ant	37	35	21.89	20.46
Robber fly	8	9	4.73	5.26
Dragonfly	2	4	1.18	2.33
Earwig	3	3	1.77	1.75
Carabid beetle	16	16	9.46	9.35
Total	169	171		

Table 4.9: Relative abundance of natural enemies in malathion (T_6) treated plot during 2018 & 2019.

Name of natural enemies	Total no. of each natural enemy population plot^{-1}		Relative abundance (%)	
	2018	**2019**	**2018**	**2019**
Spider	63	63	40.64	40.6
Lady bird beetle	27	28	17.41	18.06
Preying mantid	8	7	5.16	4.51
Black ant	34	32	21.93	20.64
Robber fly	5	6	3.22	3.87
Dragonfly	3	3	1.93	1.93
Earwig	3	2	1.93	1.29
Carabid beetle	12	14	7.74	9.03
Total	155	155		

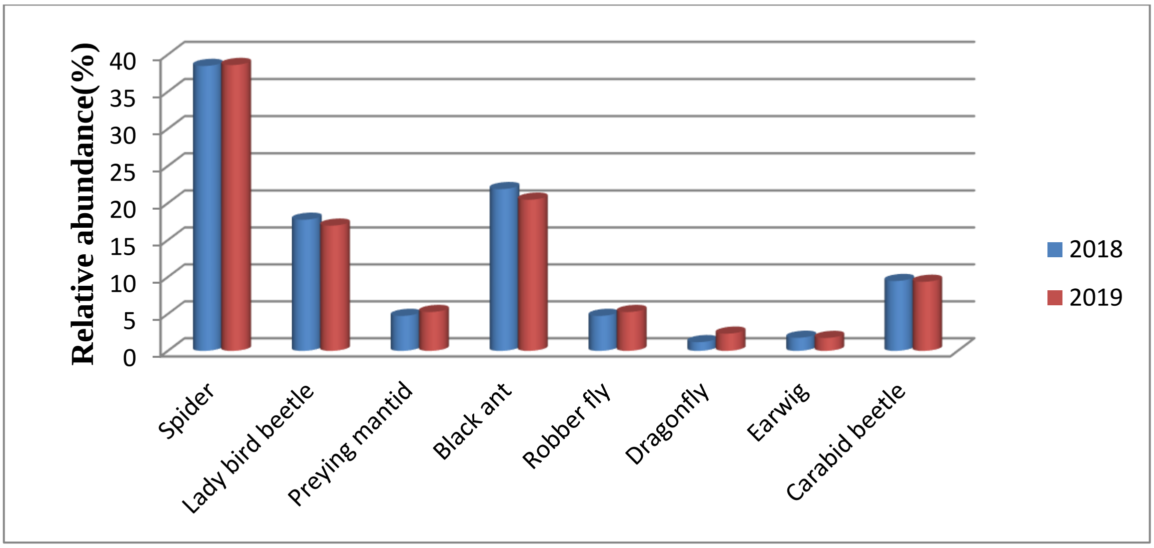

Fig4.5 **Relative abundance of natural enemies in *Litsea citrata* (T_5) treated plot during 2018 & 2019.**

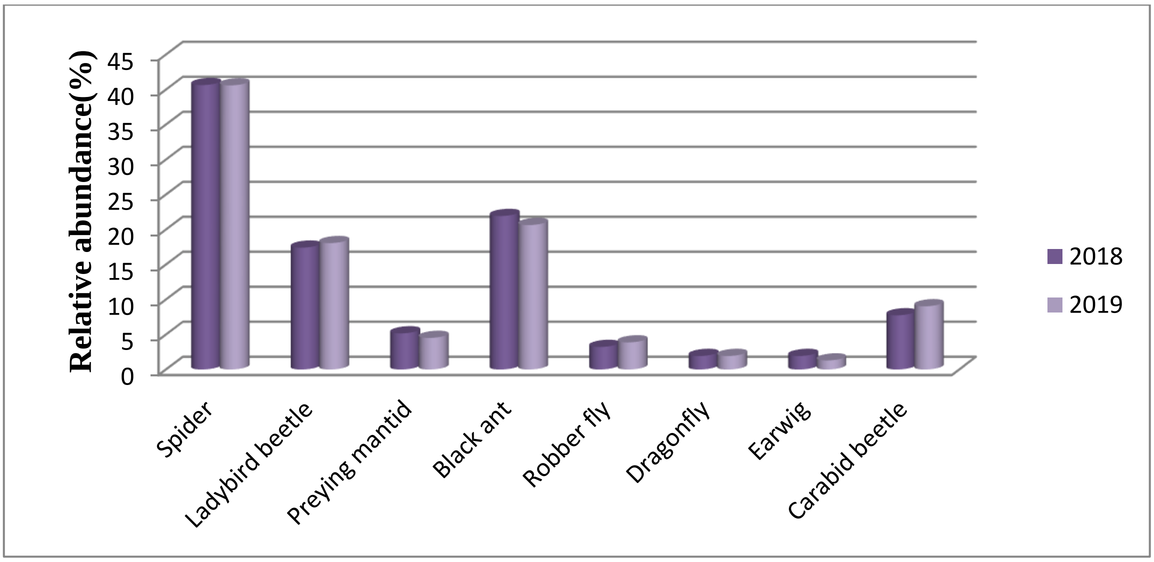

Fig4.6 **Relative abundance of natural enemies in malathion (T_6) treated plot during 2018 & 2019.**

The relative abundance of natural enemies like spider, lady bird beetle, preying mantid, black ant, robber fly, dragonfly, earwig and carabid beetle were higher in ecological plot (untreated plot) as compared to botanicals/insecticides (treated plot) for both the experimental years *i.e.* 2018 and 2019.

Though various natural enemies have been recorded on *C. punctiferalis* in many crops, specific records on gingers are limited. The present findings are in partial agreement with Jacob (1981) who reported that earwig, *Euborellia stali*, asilid flies (*Philodicus* sp. and *Heligmoneura* sp.) and spiders (*Araneus* sp., *Micaria* sp. and *Thyene* sp.) as general predators infesting turmeric shoot borer in Kerala. In a similar study, predatory beetle and ant were also reported by Devasahayam (1996) in ginger ecosystem. The present findings are in conformity with the findings of Choudhury *et al*. (2016) who reported that spiders were the most abundant natural enemies observed as predator in brinjal ecosystem followed by black ant, *Camponotus compressus* respectively. The natural enemies recorded on the shoot borer infesting ginger include mermithid nematode, hymenopterous parasitoids and entomopathogenic nematodes that play an important role in the suppression of insect pest in the field (Devasahayam & Koya, 1994; Pervez *et al.* 2012) and hence use of low-risk insecticides in the ginger ecosystem is important.

4.4 Effect of different sowing dates and pesticides against ginger shoot borer, *Conogethes punctiferalis*

Studies on the effect of sowing dates and pesticides against ginger shoot borer was carried out to understand which date of sowing could escape the peak infestation period and also to find out the date of sowing on which maximum number of the pest could be harboured.The study on the efficacy of different insecticides were also added to find out the most effective treatment against shoot borer and also to understand the interaction between the two

Table 4.10: Relative abundance of natural enemies in Ecological plot (untreated plot) during 2018 & 2019.

Name of natural enemies	Total no. of each natural enemy population plot^{-1}		Relative abundance (%)	
	2018	2019	2018	2019
Spider	91	89	41.17	40.63
Lady bird beetle	45	46	20.36	21.00
Preying mantid	13	15	5.89	6.84
Black ant	37	38	16.74	17.35
Robber fly	8	6	3.61	2.73
Dragonfly	7	5	3.16	2.28
Earwig	4	2	1.80	0.91
Carabid beetle	16	18	7.23	8.21
Total	221	219		

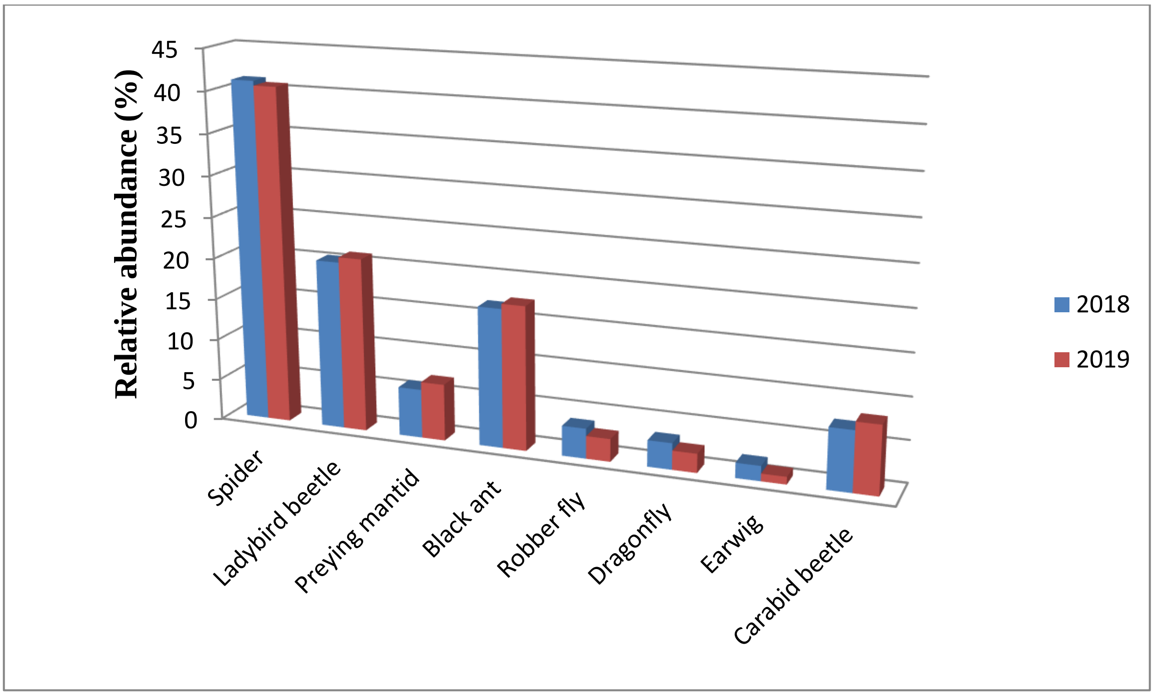

Fig 4.7 **Relative abundance of natural enemies in Ecological plot (untreated plot) during 2018 & 2019.**

factors against ginger shoot borer. The experimental findings pertaining to the mean population of insect pest in ginger due to the effect of different sowing dates and pesticides are tabulated and statistically analyzed. The results thus obtained are presented under the following headings.

4.4.1 Effect of different sowing dates on ginger shoot borer, Conogethes punctiferalis during 2018

The data pertaining to the *C. Punctiferalis* population one day before spraying and the percent reduction at 3, 5 and 7 days after spraying in two different spray schedule are presented in table 4.11. Results obtained on the effect of planting dates and pesticide application against ginger shoot borer population revealed a significant influence on all the planting dates at 3rd, 5th and 7th days after spray (DAS) respectively.

4.4.1.1 First spray schedule

In the first year experimental trial, the ginger shoot borer populations one day before spray ranges from 4.48 to 5.33. The highest per cent reduction in the population of *C. punctiferalis* was observed at 7 DAS on all the planting dates with per cent reduction of 42.43, 43.06 and 45.47 on D_1, D_2 and $D_{3.}$ The lowest per cent reduction was recorded at 3DAS on all the three planting dates (D_1, D_2 and $D_{3)}$ with per cent reduction of 24.92, 27.06 and 29.26 respectively.

4.4.1.2 Second spray schedule

In the first year experimental trial, the ginger shoot borer populations one day before spray ranges from 3.62 to 4.38. The highest per cent reduction in the population of *C. punctiferalis* was observed at 7 DAS on all the planting dates with per cent reduction of 46.22, 48.08 and 48.71 on D_1, D_2 and $D_{3.}$

The lowest per cent reduction was recorded at 3DAS on all the three planting dates (D_1, D_2 and D_3) with per cent reduction of 28.57, 29.92 and 31.75.

In the first year experimental trial, the highest mean per cent reduction (38.97%) in the population of *C. punctiferalis* was observed in D_3 *i.e.*16th April planting while the lowest total mean per cent reduction was recorded on 15th February (D_1) planting with per cent reduction of 35.78% respectively. It was also observed that the per cent reduction of *C. punctiferalis* population increased over time. The mean per cent reduction was recorded to be 37.24% for D_2 *i.e.*17th March planting.

4.4.2 Effect of different sowing dates on ginger shoot borer, *Conogethes punctiferalis* during 2019

The data pertaining to the *C. punctiferalis* population one day before spraying and the percent reduction at 3, 5 and 7 days after spraying in 2 different spray schedule are presented in table 4.12. Results obtained on the effect of planting dates and pesticide application against ginger shoot borer population revealed a significant influence on all the planting dates at 3rd, 5th and 7th days after spray (DAS).

4.4.2.1 First spray schedule

In the second year experimental trial, the ginger shoot borer population one day before spray ranges from 4.81 to 5.10. The highest per cent reduction in the population of *C. punctiferalis* was observed at 7 DAS on all the planting dates with per cent reduction of 43.38, 44.17 and 45.90 respectively on D_1, D_2 and D_3. The lowest per cent reduction was recorded at 3DAS on all the three planting dates (D_1, D_2 and D_3) with per cent reduction of 24.92, 27.22 and 29.63.

Table 4.11 Effect of different sowing dates and insecticides/biopesticides against ginger shoot borer, *C. punctiferalis* on ginger during 2018

Treatments	***First spray***				***Second spray***				***Mean***
	Pre-treatment count	***Percent reduction***			***Pre-treatment count***	***Percent reduction***			
		3 DAS	***5 DAS***	***7 DAS***		***3 DAS***	***5 DAS***	***7 DAS***	
Sowing dates									
15th February: (D_1)	5.33	24.92 (27.73)	35.19 (34.09)	42.43 (38.36)	3.62	28.57 (30.02)	37.38 (35.39)	46.22 (40.61)	*35.78*
17th March: (D_2)	4.67	27.06 (29.15)	36.51 (34.86)	43.06 (38.72)	3.90	29.92 (30.88)	38.83 (36.24)	48.08 (41.75)	*37.24*
16th April: (D_3)	4.48	29.26 (30.48)	37.87 (35.68)	45.47 (40.18)	4.38	31.75 (32.02)	40.76 (37.39)	48.71 (42.12)	*38.97*
SEm±	*0.18*	*0.53*	*0.24*	*0.41*	*0.18*	*0.30*	*0.25*	*0.31*	-
CD (P=0.05)	*NS*	*2.07*	*0.95*	*1.62*	*NS*	*1.18*	*0.99*	*1.22*	-
Insecticides/Biopesticides									
Spinosad 48% SC @ 0.5 ml/lt of water: (T_1)	4.67	33.33 (35.25)	45.18 (42.24)	54.56 (47.62)	3.89	36.67 (37.27)	47.40 (43.51)	59.71 (50.60)	*46.14*
Multineem @ 3 ml/lt of water: (T_2)	5.00	27.91 (31.86)	39.15 (38.73)	46.66 (43.08)	3.89	30.37 (33.43)	42.22 (40.52)	51.11 (45.64)	*39.57*
Neem oil @ 3 ml/lt of water: (T_3)	4.78	26.67 (31.06)	38.15 (38.14)	42.96 (40.95)	4.00	29.81 (33.09)	40.37 (39.44)	49.62 (44.78)	*37.93*
Imidacloprid 17.8 SL @ 0.5 ml/lt of water: (T_4)	4.67	30.92 (33.76)	41.67 (40.20)	51.85 (46.07)	4.00	33.15 (35.14)	45.19 (42.24)	55.56 (48.19)	*43.06*
Litsea citrata (Seed extract) @ 20 ml/lt of water: (T_5)	5.00	19.63 (26.26)	28.52 (32.27)	37.04 (37.49)	3.78	22.04 (27.96)	31.29 (34.01)	38.52 (38.36)	*29.51*
Malathion 50% EC @ 1 ml/lt of water: (T_6)	4.78	51.11 (45.64)	63.00 (52.54)	72.51 (58.41)	3.89	58.52 (49.91)	66.44 (54.65)	79.18 62.88	*65.13*

Untreated control: (T_0)	4.89	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.33	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
SEm±	*0.24*	*0.52*	*0.37*	*0.44*	*0.27*	*0.47*	*0.35*	*0.36*	-
CD (P=0.05)	*NS*	*1.49*	*1.07*	*1.25*	*NS*	*1.34*	*0.99*	*1.02*	-

Note: Figures in the table are mean values and those in parenthesis are arc sine transformed values.

NS: Non-significant at 5% level of significant

4.4.2.2 Second spray schedule

In the second year experimental trial, the ginger shoot borer population one day before spray ranges from 3.76 to 4.67. The highest per cent reduction in the population of *C. punctiferalis* was observed at 7 DAS on all the planting date with per cent reduction of 46.70, 48.71 and 49.35 on D_1, D_2 and $D_{3.}$ The lowest per cent reduction was recorded at 3 DAS on all the three planting dates (D_1, D_2 and $D_{3)}$ with per cent reduction of 29.32, 31.06 and 32.75.

In the second year experimental trial, the highest mean per cent reduction (39.50%) in the population of *C. punctiferalis* was observed in 16th April planting (D_3) while the lowest mean per cent reduction was recorded on 15th February planting (D_1) with per cent reduction of 36.48%. The mean per cent reduction was recorded to be 38.13% for 17th March planting (D_2). It was also observed that the per cent reduction of *C. punctiferalis* population increased over time.

The pooled data as indicated in table 4.13 and illustrated in Fig 4.8 revealed that for the first spray schedule, all the three different planting dates has significant effect on the population of *C. punctiferalis.* The ginger shoot borer population one day before spray ranges from 4.64 to 5.21. The highest per cent reduction in the population of *C. punctiferalis* was observed at 7 DAS on all the planting dates with per cent reduction of 42.90, 43.62 and 45.69 on D_1, D_2 and $D_{3.}$ The per cent reduction 5 DAS for D_1, D_2 and D_3 was 35.93, 37.09 and 38.18. The lowest per cent reduction was recorded at 3DAS on all the three planting dates (D_1, D_2 and $D_{3)}$ with per cent reduction of 24.92, 27.14 and 29.45 respectively. For the second spray schedule, all the three different planting dates has significant effect on the population of *C. punctiferalis.* The ginger shoot borer population one day before spray ranges from 3.69 to 4.00. The highest per cent reduction in the population of *C. punctiferalis* was observed at 7 DAS on all the planting dates with percent reduction of 46.46, 48.40 and 49.00 respectively on D_1, D_2 and $D_{3.}$ The per cent reduction 5 DAS

Table 4.12 Effect of different sowing dates and insecticides/biopesticides against ginger shoot borer, *C. punctiferalis* on ginger during 2019

Treatments	***First spray***				***Second spray***				***Mean***
	Pre-treatment count	***Percent reduction***			***Pre-treatment count***	***Percent reduction***			
		3 DAS	***5 DAS***	***7 DAS***		***3 DAS***	***5 DAS***	***7 DAS***	
Sowing dates									
15th February: (D_1)	5.10	24.92 (27.75)	36.67 (34.95)	43.38 (38.91)	3.76	29.32 (30.49)	37.87 (35.68)	46.70 (40.89)	*36.48*
17th March: (D_2)	4.90	27.22 (29.23)	37.67 (35.53)	44.17 (39.36)	4.10	31.06 (31.57)	39.93 (36.88)	48.71 (42.12)	*38.13*
16th April: (D_3)	4.81	29.63 (30.69)	38.48 (36.02)	45.90 (40.43)	4.67	32.75 (32.62)	40.92 (37.48)	49.35 (42.49)	*39.50*
SEm±	*0.11*	*0.31*	*0.30*	*0.38*	*0.19*	*0.39*	*0.17*	*0.40*	-
CD (P=0.05)	*NS*	*1.22*	*1.18*	*1.49*	*NS*	*1.52*	*0.68*	*1.58*	-
Insecticides/Biopesticides									
Spinosad 48% SC @ 0.5 ml/lt of water: (T_1)	4.78	34.44 (35.92)	47.78 (43.73)	56.30 (48.62)	4.22	38.41 (38.29)	48.14 (43.93)	59.71 (50.60)	*47.46*
Multineem @ 3 ml/lt of water: (T_2)	4.89	27.67 (31.72)	39.63 (39.01)	47.40 (43.51)	4.00	31.89 (34.36)	42.22 (40.52)	52.22 (46.27)	*40.17*
Neem oil @ 3 ml/lt of water: (T_3)	5.11	26.55 (30.98)	39.26 (38.80)	45.93 (42.66)	4.33	31.30 (34.01)	41.48 (40.09)	51.11 (45.64)	*39.27*
Imidacloprid 17.8 SL @ 0.5 ml/lt of water: (T_4)	4.89	29.92 (33.13)	43.93 (41.51)	52.22 (46.28)	4.00	34.41 (35.88)	45.93 (42.66)	56.30 (48.62)	*43.78*
Litsea citrate (Seed extract) @ 20 ml/lt of water: (T_5)	4.89	20.00 (26.53)	28.52 (32.27)	37.04 (37.49)	4.22	22.78 (28.47)	32.04 (34.47)	39.26 (38.80)	*29.94*
Malathion 50% EC @ 1 ml/lt of water: (T_6)	4.78	52.22 (46.28)	64.11 (53.20)	72.51 (58.41)	4.00	58.52 (49.91)	67.22 (55.11)	79.18 (62.89)	*65.63*

Untreated control: (T_0)	5.22	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.44	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
SEm±	*0.23*	*0.64*	*0.29*	*0.44*	*0.22*	*0.57*	*0.50*	*0.42*	-
CD (P=0.05)	*NS*	*1.84*	*0.83*	*1.26*	*NS*	*1.62*	*1.43*	*1.20*	-

Note: Figures in the table are mean values and those in parenthesis are arc sine transformed values.

NS: Non-significant at 5% level of significance.

for D_1, D_2 and D_3 was 37.63, 39.38 and 40.84 .The lowest per cent reduction was recorded at 3 DAS on all the three planting dates (D_1, D_2 and D_3) with per cent reduction of 28.95, 30.49 and 32.25 respectively. It was also observed from the pooled data that the per cent reduction of *C. punctiferalis* population increased over time. The highest mean per cent reduction (39.24%) in the population of *C. punctiferalis* was observed in D_3 *i.e.*16th April planting while the lowest total mean per cent reduction was recorded on 15th February planting (D_1) with percent reduction of 36.13%. The mean per cent reduction was recorded to be 37.69% for D_2 *i.e.*17th March planting.

The present findings are in line with the findings of Temjentoshi (2008) who have stated that date of planting ginger has significant effect on the incidence of ginger shoot borer and of all the three different dates of planting studied (31st March, 15th April and 30th April), the 15th April planting recorded the maximum infestation throughout the observation period and minimum infestation was recorded on 30th April planting which agrees to the present findings. Though workers like Mohanty *et al*. (1990), Pruthi (1998) and Yadav *et al*. (2013) have mentioned first fortnight of April as best time of planting ginger for obtaining maximum yield, but no such literature or citations were available on effect of different sowing dates on ginger shoot borer. Peter *et al*. (2005) reported that the yield of ginger vary greatly depending on cultivars, climate, planting time and maturity at harvest. Rekha *et al*. (2016) also reported planting of ginger in March or April with varieties like Maran and Himachal helps in overcoming the rhizome rot disease in ginger and realizing higher yields.

4.5 Efficacy of different insecticidal treatments against ginger shoot borer, *C. punctiferalis* during 2018

The data on mean population and per cent reduction of ginger shoot borer, *C. punctiferalis* recorded one day before and three, five and seven days after treatment on two different spray schedules are presented on Table 4.11.

4.5.1 First spray schedule:

In the first experimental year 2018, the results of different treatments was worked out in terms of per cent reduction over the pre-treatment count. The ginger shoot borer population one day before spray ranges from 4.67 to 5.00. After three days of spraying, the highest per cent reduction of (51.11%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (33.33%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of (51.11%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (33.33%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 30.92%, 27.91% and 26.67% respectively. The lowest per cent reduction (19.63%) was observed in *Litsea citrata* seed extract. After five days of spraying, the highest per cent reduction of (63.00%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (45.18%). This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 41.67%, 39.15% and 38.15%. The lowest per cent reduction (28.52%) was observed in *Litsea citrata* seed extract. After seven days of spraying, the highest per cent reduction of (72.51%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (54.56%). This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 51.85%, 46.66% and 42.96%. The lowest per cent reduction

(37.04%) was observed in *Litsea citrata* seed extract. The effect of all treatments on the population of *C. punctiferalis* was significantly superior to the untreated control.

4.5.2 Second spray schedule:

The result of different treatments was worked out in terms of per cent reduction over the pre-treatment count. The gingershoot borer population one day before spray ranges from 3.78 to 4.33.After three days of spraying. The highest per cent reduction of (58.52%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (36.67%) this was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 33.15%, 30.37% and 29.81%.The lowest per cent reduction (22.04%) was observed in *Litsea citrata* seed extract. After five days of spraying, the highest per cent reduction of (66.44%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (47.40%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 45.19%, 42.22% and 40.37% respectively.The lowest per cent reduction (31.29%) was observed in *Litsea citrata* seed extract. After seven days of spraying, the highest per cent reduction of (79.18%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (59.71%) which was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 55.56%, 51.11% and 49.62% respectively.The lowest per cent reduction (38.52%) was observed in *Litsea citrata* seed extract. All the treatments were superior to the untreated control and there was significant reduction over control.

Table 4.13 Effect of different sowing dates and insecticides/biopesticides against ginger shoot borer, *C. punctiferalis* on ginger during 2018 and 2019 (Pooled)

Treatments	***First spray***				***Second spray***				***Mean***
	Pre-treatment count	***Percent reduction***			***Pre-treatment count***	***Percent reduction***			
		3 DAS	***5 DAS***	***7 DAS***		***3 DAS***	***5 DAS***	***7 DAS***	
Sowing dates									
15th February: (D_1)	5.21	24.92 (27.74)	35.93 (34.52)	42.90 (38.63)	3.69	28.95 (30.25)	37.63 (35.53)	46.46 (40.75)	*36.13*
17th March: (D_2)	4.79	27.14 (29.19)	37.09 (35.20)	43.62 (39.04)	4.00	30.49 (31.23)	39.38 (36.56)	48.40 (41.93)	*37.69*
16th April: (D_3)	4.64	29.45 (30.58)	38.18 (35.85)	45.69 (40.31)	4.52	32.25 (32.32)	40.84 (37.44)	49.03 (42.30)	*39.24*
SEm±	*0.10*	*0.31*	*0.19*	*0.28*	*0.13*	*0.25*	*0.15*	*0.25*	-
CD (P=0.05)	*NS*	*1.00*	*0.63*	*0.92*	*NS*	*0.80*	*0.50*	*0.83*	-
Insecticides/Biopesticides									
Spinosad 48% SC @ 0.5 ml/lt of water: (T_1)	4.72	33.89 (35.58)	46.48 (42.98)	55.43 (48.12)	4.06	37.54 (37.78)	47.77 (43.72)	59.71 (50.60)	*46.80*
Multineem @ 3 ml/lt of water: (T_2)	4.94	27.79 (31.79)	39.39 (38.87)	47.03 (43.30)	3.94	31.13 (33.89)	42.22 (40.52)	51.67 (45.95)	*39.87*
Neem oil @ 3 ml/lt of water: (T_3)	4.94	26.61 (31.02)	38.70 (38.47)	44.45 (41.81)	4.17	30.56 (33.55)	40.93 (39.77)	50.37 (45.21)	*38.60*
Imidacloprid 17.8 SL @ 0.5 ml/lt of water: (T_4)	4.78	30.42 (33.45)	42.80 (40.85)	52.04 (46.17)	4.00	33.78 (35.51)	45.56 (42.45)	55.93 (48.41)	*43.42*
Litsea citrate (Seed extract) @ 20 ml/lt of water: (T_5)	4.94	19.82 (26.40)	28.52 (32.27)	37.04 (37.49)	4.00	22.41 (28.22)	31.67 (34.24)	38.89 (38.58)	*29.72*
Malathion 50% EC @ 1 ml/lt of water: (T_6)	4.78	51.67 (45.96)	63.56 (52.87)	72.51 (58.41)	3.94	58.52 (49.91)	66.83 (54.88)	79.18 (62.89)	*65.38*

Untreated control: (T_0)	5.06	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.93	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
SEm±	*0.16*	*0.41*	*0.24*	*0.31*	*0.18*	*0.37*	*0.50*	*0.28*	-
CD (P=0.05)	*NS*	*1.16*	*0.67*	*0.87*	*NS*	*1.03*	*1.42*	*0.78*	-

Note: Figures in the table are mean values and those in parenthesis are arc sine transformed values.

NS: Non-significant at 5% level of significance.

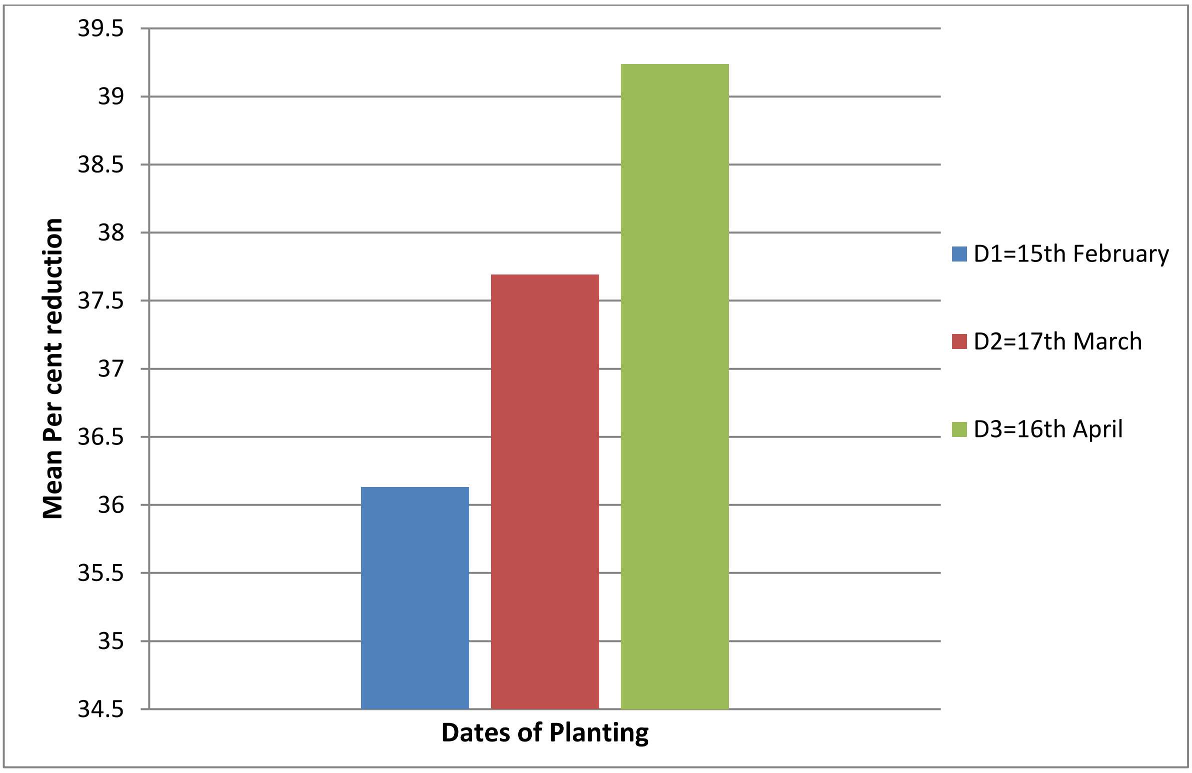

Fig 4.8 Pooled data on the effect of planting dates against ginger shoot borer (2018-2019)

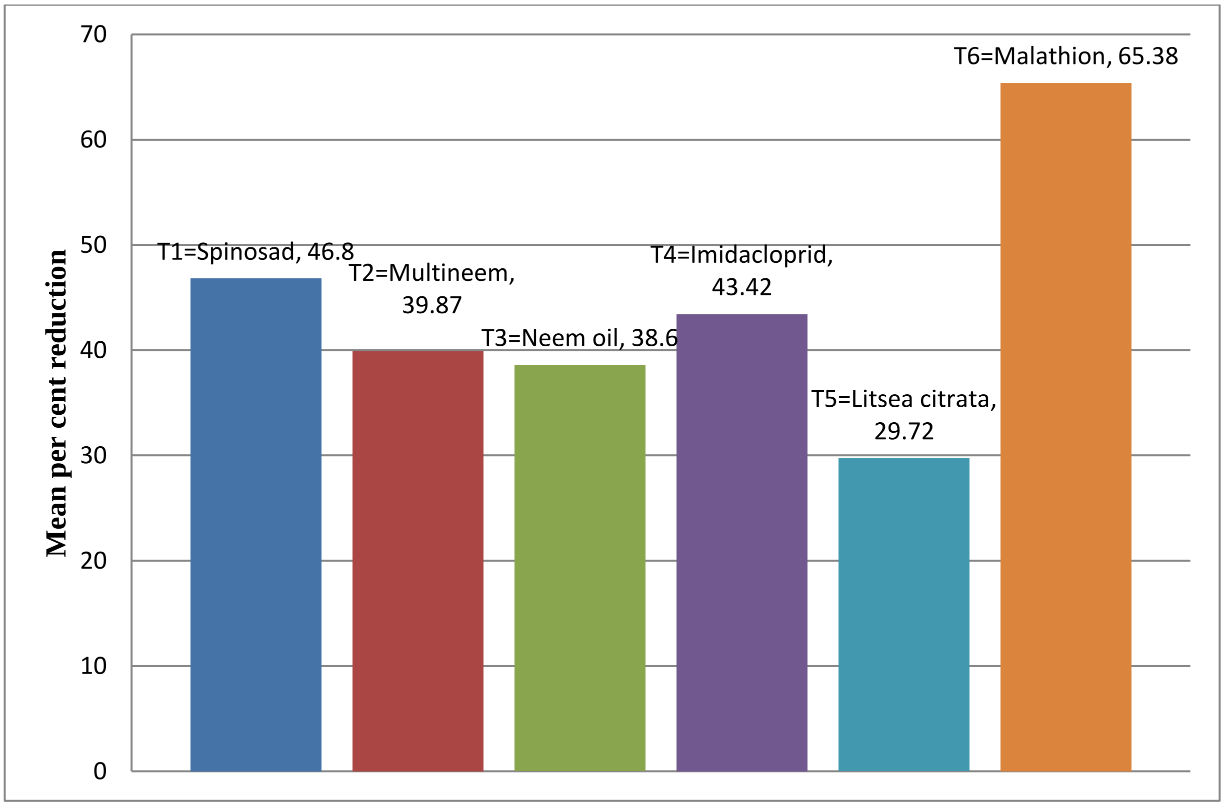

Fig 4.9 Pooled data on the effect of different insecticides/biopesticides against ginger shoot borer (2018-2019)

4.6 Efficacy of different insecticidal treatments against ginger shoot borer, *Conogethes punctiferalis* during 2019

The data on mean population and per cent reduction of ginger shoot borer, *C. punctiferalis* recorded one day before and three, five and seven days after treatment on two different spray schedules are presented on Table 4.12.

4.6.1 First spray schedule:

In the second experimental year 2019, the results of different treatments were worked out in terms of per cent reduction over the pre-treatment count. The ginger shoot borer population one day before spray ranges from 4.78 to 5.22. After three days of spraying. The highest per cent reduction of (52.22%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (34.44%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 29.92%, 27.67% and 26.55%. The lowest per cent reduction (20.00%) was observed in *Litsea citrata* seed extract. After five days of spraying, the highest per cent reduction of (64.11%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (47.78%) which was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 43.93%, 39.63% and 39.26% respectively. The lowest per cent reduction was observed in *Litsea citrata* seed extract with per cent reduction of 28.52%. After seven days of spraying, the highest per cent reduction of (72.51%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (56.30%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 52.22%, 47.40% and 45.93%. The lowest per cent reduction (37.04%) was observed in *Litsea* *citrata* seed extract. The effect of all treatments on the population of *C. punctiferalis* was significantly superior to the untreated control.

4.6.2 Second spray schedule:

The result of different treatments was worked out in terms of per cent reduction over the pre-treatment count. The ginger shoot borer population one day before spray ranges from 4.00 to 4.44. After three days of spraying, the highest per cent reduction of (58.52%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (38.41%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 34.41%, 31.89% and 31.30%. The lowest per cent reduction (22.78%) was observed in *Litsea citrata* seed extract. After five days of spraying, the highest per cent reduction of (67.22%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (48.14%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 45.93%, 42.22% and 41.48%. The lowest per cent reduction (32.04%) was observed in *Litsea citrata* seed extract. After seven days of spraying, the highest per cent reduction of (79.18%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (59.71%).This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 56.30%, 52.22% and 51.11%. The lowest per cent reduction (39.26%) was observed in *Litsea citrata* seed extract. All the treatments were superior to the untreated control and there was significant reduction over control.

The pooled data on the effect of different pesticides against ginger shoot borer showed that for the first spray schedule, the ginger shoot borer population one day before spray ranges from 4.72 to 5.06. After three days of spraying, the highest per cent reduction of (51.67%) in the population of *C.*

punctiferalis was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (33.89%). This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 30.42%, 27.79% and 26.61% respectively. The lowest per cent reduction (19. 82%) was observed in *Litsea citrata* seed extract. After five days of spraying, the highest per cent reduction of (63.56%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (46.48%). This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 42.80%, 39.39% and 38.70% respectively. The lowest per cent reduction (28.52%) was observed in *Litsea citrata* seed extract. After seven days of spraying, the highest per cent reduction of (72.51%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (55.43%) which was at par with imidacloprid 17.8 SL (52.04%). This was followed by, multineem and neem oil with per cent reduction of 47.03% and 44.45%. The lowest per cent reduction (37.04%) was observed in *Litsea citrata* seed extract. Similarly for the second spray schedule, the ginger shoot borer populations one day before spray ranges from 3.94 to 4.93. After three days of spraying, the highest per cent reduction of (58.52%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (37.54%). This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 33.78%, 31.13% and 30.56% respectively. The lowest per cent reduction (22.41%) was observed in *Litsea citrata* seed extract. After five days of spraying, the highest per cent reduction of (66.83%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50 % EC followed by spinosad 48% SC (47.77%). This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 45.56%, 42.22% and 40.93%. The lowest per cent reduction (31.67%) was observed in *Litsea citrata* seed extract. After seven days of spraying, the highest per cent reduction of (79. 18%) in the population of *C. punctiferalis* was observed in the plots treated with malathion 50% EC followed by spinosad 48% SC (59.71%). This was followed by imidacloprid 17.8 SL, multineem and neem oil with per cent reduction of 55.93%, 51.67% and 50.37% respectively. The lowest per cent reduction (38.89%) was observed in *Litsea citrata* seed extract. The pooled data as indicated in Table 4.13 and illustrated in Fig 4.9 showed that all the treatments *viz*. spinosad, multineem, neem oil, imidacloprid, *Litsea citrata* and malathion has significant effect on the reduction of the pest with mean reduction of 46.80, 39.87, 38.60, 43.42, 29.72 and 65.38 per cent. Pooled data also revealed that, among the different treatments used malathion showed the highest percent reduction of *C. punctiferalis* with per cent reduction of 65.38 and the lowest percent reduction was recorded in *Litsea citrata* with per cent reduction of 29.72. The effect of all treatments on the population of *C. punctiferalis* was significantly superior to the untreated control.

The present findings are in conformity with the findings of Devasahayam *et al.* (2010) who stated that spraying of malathion (0.1 %) effectively suppressed shoot borers in ginger ecosystem. Singh *et al*. (2016) also reported malathion 50 EC 0.1% kg a.i. /ha (57.78%), neem oil @ 2.0% (45.56%) and NSKE @ 5.0% (38.33 %) as effective treatment against shoot borer in turmeric. The findings of present studies are corroborated with the findings of Senthil Kumar *et al*. (2017) who reported spinosad 0.0225% as effective insecticide against shoot borer (*C. punctiferalis*) in ginger with mean pseudo damage of 6.5% and they also reported that these low-risk insecticides and natural products can be utilized for the management of *C. punctiferalis* in ginger with reduced risk to the environment. The effectiveness of botanicals against *C. punctiferalis* was reported by many researchers. Mhonchumo (2007) reported spraying of quinalphos 0.05% + Ozoneem 1500 ppm (3 ml l^{-1}) as management option for *C. punctiferalis* in ginger, this is in line with the present findings. Naik *et al.* (2006) and Ganesha *et al.* (2014) also reported neem oil as one of the most effective botanical in reducing larval population of *C. punctiferalis* in cardamom. Similarly, the effectiveness of botanicals against *C. punctiferalis* was also reported by Lalnuntluanga and Singh (2008) who stated that spraying with NSKE (5%) during high pest incidence resulted in an increase in yield by 50 to72 % (164.68 q ha^{-1}) and this treatment was as effective as quinalphos (0.05%) in controlling the shoot borer (*C. punctiferalis* Guen.). Ganesh (2011) also reported the effectiveness of NSKE 5% against *C. punctiferalis* and recorded 50.37 and 30.03 per cent reduction in capsule damage after first and second spray. Whereas, spinosad 25 EC spared a per cent reduction of capsule damage of 47.15 and 15.92 with larval population of 1.91 and 3.15 larvae/plant after first and second spray respectively with seed yield of 9.73q/ha. The findings of present studies are in line with the findings of Rajabaskar and Regupathy (2013) who reported that sequential application of neem oil 0.03%, profenofos 50 EC 0.05%, diafenthiuron 50WP 0.06%, neem oil 0.03%, profenofos 50 EC 0.05% at 21 days interval as most effective treatment in controlling *Conogethes punctiferalis* infestation. Field evaluation of neem formulation showed that the greatest reduction of *C. punctiferalis* damages were reported in Neemazal 5% treated plot followed by TNAU neem 0.03% EC respectively. The present findings are also in partial agreement with Chethan *et al*. (2017) who reported that insecticides like lamda cyhalothrin, chloropyripos, carbofuron, phorate, imidacloprid, fipronil, chlorontronilprole and nimbicidine were effective in suppressing the incidence of *C. punctiferalis* in turmeric. Devasahayam and Koya (2004) reported that the best management method of *C. punctiferalis* is integrated management including cultural methods, such as pruning of freshly infested shoots at the initial stage of infestation and spraying of insecticide when high population density of the pest is recorded.

4.7 Interaction effect of different sowing dates and pesticides against ginger shoot borer population during 2018

The interaction between different sowing dates and pesticides against ginger shoot borer is presented in Table 4.14. The findings revealed that all the treatment combinations were significantly effective against ginger shoot borer.

The initial population of ginger shoot borer 1 day before first spray ranged from 4.33 to 5.67. After 3 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (53.33%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (50.00%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (50.00%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (17.78%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 5 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (65.67%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (63.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (60.00%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (27.78%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (27.78%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1 D_2 and D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 7 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (76.87%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (70.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (70.33%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (36.67%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (36.67%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

The initial population of ginger shoot borer 1 day before second spray ranged from 3.33 to 4.67. After 3 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (60.00%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (57.78%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (57.78%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (19.44%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 5 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (70.33%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (65.67%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (63.33%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (30.55%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (30.55%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 7 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (80.33%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (80.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (76.87%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (36.67%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

4.8 Interaction effect of different sowing dates and pesticides against ginger shoot borer population during 2019

The interaction between different sowing dates and pesticides against ginger shoot borer is presented in Table 4.15. The findings revealed that all the treatment combinations were found significantly effective against ginger shoot borer.

The initial population of ginger shoot borer 1 day before first spray ranged from 4.67 to 5.33. After 3 DAS highest reduction was observed in interaction of (D_3 and T_6) *i.e.* third date of sowing and malathion (56.67%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (50.00%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (50.00%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (18.89%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. After 5 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (65.67%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (63.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (63.33%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (27.78%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (27.78%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. After 5 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (65.67%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (63.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (63.33%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (27.78%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (27.78%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 7 DAS highest reduction was observed in interaction of (D_3 and T_6) *i.e.* third date of sowing malathion (76.87%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (70.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (70.33%). The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (36.67%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (36.67%) was lowest among the treated plots. The lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

The initial population of ginger shoot borer 1 day before second spray ranged from 3.33 to 5.00. After 3 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (60.00%)

which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (57.78%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (57.78%) respectively.The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (21.67%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (21.67%) was lowest among the treated plots the lowest reduction was observed in interaction of date of sowing (D_1, D_2, D_3) and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. After 5 DAS highest reduction was observed in interaction of (D_3 andT_6) *i.e.* third date of sowing and malathion (70.33%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (65.67%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (65.67%) respectively.The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (30.55%) was lowest among the treated plots. The lowest reduction was observed in interaction of all the date of sowing and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 7 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (80.33%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (80.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (76.87%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (38.89%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (38.89%) was lowest among the treated plots. The lowest reduction was observed in interaction of all the dates of sowing and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

Table 4.14 Interaction effect of different sowing dates and insecticides/biopesticides against ginger shoot borer, *C. punctiferalis* on ginger during 2018

Treatments	*First spray*				*Second spray*				*Mean*
	Pre-treatment count	*Percent reduction*			*Pre-treatment count*	*Percent reduction*			
		3 DAS	*5 DAS*	*7 DAS*		*3 DAS*	*5 DAS*	*7 DAS*	
D_1T_1	5.00	30.00 (33.21)	44.44 (41.81)	53.33 (46.91)	3.67	35.56 (36.61)	46.67 (43.09)	57.78 (49.48)	*44.63*
D_1T_2	5.33	24.44 (29.63)	37.44 (37.73)	44.45 (41.81)	3.33	27.78 (31.80)	40.00 (39.23)	50.00 (45.00)	*37.35*
D_1T_3	5.33	23.33 (28.88)	36.67 (37.27)	42.22 (40.53)	3.67	28.89 (32.51)	38.89 (38.58)	48.87 (44.35)	*36.48*
D_1T_4	5.00	28.89 (32.47)	40.00 (39.23)	50.00 (45.00)	3.67	30.56 (33.56)	42.22 (40.53)	53.33 (46.91)	*40.83*
D_1T_5	5.67	17.78 (24.92)	27.78 (31.80)	36.67 (37.27)	3.33	19.44 (26.16)	30.55 (33.56)	36.67 (37.27)	*28.15*
D_1T_6	5.33	50.00 (45.00)	60.00 (50.77)	70.33 (57.00)	3.67	57.78 (49.48)	63.33 (52.73)	76.87 (61.25)	*63.05*
D_1T_0	5.67	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.00	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
D_2T_1	4.67	33.33 (35.26)	44.44 (41.81)	53.33 (46.91)	4.00	35.56 (36.61)	46.67 (43.09)	60.67 (51.16)	*45.67*
D_2T_2	5.00	28.33 (32.16)	40.00 (39.23)	46.67 (43.09)	3.67	30.56 (33.56)	42.22 (40.53)	50.00 (45.00)	*39.63*
D_2T_3	4.67	26.67 (31.09)	37.78 (37.92)	42.22 (40.53)	4.00	30.56 (33.56)	40.00 (39.23)	50.00 (45.00)	*37.87*
D_2T_4	4.33	30.55 (33.56)	42.22 (40.53)	52.22 (46.27)	3.67	33.33 (35.26)	46.67 (43.09)	56.67 (48.84)	*43.61*
D_2T_5	5.00	20.56 (26.96)	27.78 (31.80)	36.67 (37.27)	4.00	21.67 (27.71)	30.55 (33.56)	38.89 (38.58)	*29.35*

D_2T_6	4.67	50.00 (45.00)	63.33 (52.73)	70.33 (57.00)	3.67	57.78 (49.48)	65.67 (54.15)	80.33 (63.67)	*64.57*
D_2T_0	4.33	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.33	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
D_3T_1	4.33	36.67 (37.27)	46.67 (43.09)	57.00 (49.03)	4.00	38.89 (38.58)	48.87 (44.35)	60.67 (51.16)	*48.13*
D_3T_2	4.67	30.95 (33.80)	40.00 (39.23)	48.87 (44.35)	4.67	32.78 (34.92)	44.45 (41.81)	53.33 (46.91)	*41.73*
D_3T_3	4.33	30.00 (33.21)	40.00 (39.23)	44.45 (41.81)	4.33	30.00 (33.21)	42.22 (40.53)	50.00 (45.00)	*39.45*
D_3T_4	4.67	33.33 (35.25)	42.78 (40.83)	53.33 (46.92)	4.67	35.56 (36.61)	46.67 (43.09)	56.67 (48.83)	*44.72*
D_3T_5	4.33	20.56 (26.92)	30.00 (33.21)	37.78 (37.92)	4.00	25.00 (30.00)	32.78 (34.92)	40.00 (39.23)	*31.02*
D_3T_6	4.33	53.33 (46.91)	65.67 (54.13)	76.87 (61.25)	4.33	60.00 (50.79)	70.33 (57.05)	80.33 (63.71)	*67.76*
D_3T_0	4.67	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.67	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
SEm±	*0.41*	*0.90*	*0.65*	*0.75*	*0.47*	*0.81*	*0.87*	*0.62*	-
CD (P=0.05)	*NS*	*2.58*	*1.86*	*2.16*	*NS*	*2.32*	*2.48*	*1.77*	-

Note: D_1: 15th February D_2: 17th March D_3: 16th April

T_1: Spinosad 48% SC @ 0.5 ml/lt of water

T_2: Multineem @ 3 ml/lt of water

T_3: Neem oil @ 3 ml/lt of water

T_4: Imidacloprid 17.8 SL @ 0.5 ml/lt of water

T_5: *Litsea citrata* (seed extract) @ 20 ml/lt of water

T_6: Malathion 50% EC @ 1 ml/lt of water

T_0: Untreated control

Figures in the table are mean values and those in parenthesis are angular transformed values.

NS: Non-significant at 5% level of significance.

The pooled data on the interaction between different sowing dates and pesticides against ginger shoot borer has exhibited significant effect in all the dates of observation except on the pre-treatment count as mentioned in Table 4.16. For the first spray schedule, the initial population of ginger shoot borer 1 day before spray ranged from 4.50 to 5.67. After 3 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (55.00%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (50.00%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (50.00%). The reduction in the interaction between ($D_1$and T_5) *i.e.* first date of sowing and *Litsea citrata* (18.33%) was lowest among the treated plots. The lowest reduction was observed in interaction of three dates of sowing and treatment in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 5 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (65.67%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (63.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (61.67%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (27.78%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (27.78%) was lowest among the treated plots. The lowest reduction was observed in interaction of three dates of sowing and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. After 7 DAS higher reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (76.87%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (70.33%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (70.33%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (36.67%) and date of sowing (D_2) and treatment (T_5) *Litsea citrata* (36.67%)

was lowest among the treated plots. The lowest reduction was observed in interaction of three dates of sowing and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

Table 4.15 Interaction effect of different sowing dates and insecticides/biopesticides against ginger shoot borer, *C. punctiferalis* on ginger during 2019

Treatments	*First spray*				*Second spray*				*Mean*
	Pre-treatment count	*Percent reduction*			*Pre-treatment count*	*Percent reduction*			
		3 DAS	*5 DAS*	*7 DAS*		*3 DAS*	*5 DAS*	*7 DAS*	
D_1T_1	5.00	31.11 (33.89)	46.67 (43.09)	55.55 (48.19)	4.00	36.90 (37.40)	46.67 (43.09)	57.78 (49.48)	*45.78*
D_1T_2	4.67	25.00 (30.00)	38.89 (38.58)	46.67 (43.09)	3.33	27.78 (31.80)	40.00 (39.23)	50.00 (45.00)	*38.06*
D_1T_3	5.67	23.33 (28.88)	37.78 (37.92)	44.45 (41.81)	4.00	30.56 (33.56)	40.00 (39.23)	50.00 (45.00)	*37.69*
D_1T_4	5.00	26.11 (30.73)	42.22 (40.53)	50.00 (45.00)	3.33	30.55 (33.51)	42.22 (40.53)	53.33 (46.91)	*40.74*
D_1T_5	4.67	18.89 (25.76)	27.78 (31.80)	36.67 (37.27)	3.67	21.67 (27.71)	30.55 (33.56)	38.89 (38.58)	*29.07*
D_1T_6	5.00	50.00 (45.00)	63.33 (52.73)	70.33 (57.00)	3.67	57.78 (49.48)	65.67 (54.14)	76.87 (61.25)	*64.00*
D_1T_0	5.67	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.33	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
D_2T_1	4.67	35.55 (36.60)	47.78 (43.73)	55.55 (48.19)	4.33	38.33 (38.25)	48.87 (44.35)	60.67 (51.16)	*47.79*
D_2T_2	5.33	27.78 (31.80)	40.00 (39.23)	46.67 (43.09)	4.00	33.33 (35.26)	42.22 (40.53)	53.33 (46.91)	*40.56*
D_2T_3	5.00	26.11 (30.72)	40.00 (39.23)	46.67 (43.09)	4.33	30.56 (33.56)	42.22 (40.53)	50.00 (45.00)	*39.26*
D_2T_4	4.67	30.55 (33.55)	44.78 (42.00)	53.33 (46.91)	3.67	35.78 (36.74)	47.78 (43.73)	57.78 (49.48)	*45.00*
D_2T_5	5.00	20.56 (26.96)	27.78 (31.80)	36.67 (37.27)	4.33	21.67 (27.71)	32.78 (34.92)	38.89 (38.58)	*29.72*

D_2T_6	4.67	50.00 (45.00)	63.33 (52.74)	70.33 (57.00)	4.00	57.78 (49.48)	65.67 (54.14)	80.33 (63.71)	*64.57*
D_2T_0	5.00	0.00 (0.00)	0.00 (0.00)	0.00 (0.0(	4.00	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
D_3T_1	4.67	36.67 (37.27)	48.89 (44.36)	57.78 (49.48)	4.33	40.00 (39.23)	48.87 (44.35)	60.67 (51.16)	*48.81*
D_3T_2	4.67	30.22 (33.35)	40.00 (39.23)	48.87 (44.35)	4.33	34.56 (36.01)	44.45 (41.81)	53.33 (46.91)	*41.91*
D_3T_3	4.67	30.22 (33.35)	40.00 (39.23)	46.67 (43.09)	4.67	32.78 (34.92)	42.22 (40.53)	53.33 (46.91)	*40.87*
D_3T_4	5.00	33.11 (35.12)	44.78 (42.00)	53.33 (46.92)	5.00	36.90 (37.40)	47.78 (43.73)	57.78 (49.48)	*45.61*
D_3T_5	5.00	20.56 (26.89)	30.00 (33.21)	37.78 (37.92)	4.67	25.00 (30.00)	32.78 (34.92)	40.00 (39.23)	*31.02*
D_3T_6	4.67	56.67 (48.85)	65.67 (54.13)	76.87 (61.25)	4.33	60.00 50.77)	70.33 (57.05)	80.33 (63.71)	*68.31*
D_3T_0	5.00	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.00	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
SEm±	*0.39*	*1.11*	*0.50*	*0.76*	*0.38*	*0.98*	*0.86*	*0.73*	-
CD (P=0.05)	*NS*	*3.18*	*1.45*	*2.18*	*NS*	*2.81*	*2.47*	*2.08*	-

Note: D_1: 15th February D_2: 17th March D_3: 16th April

T_1: Spinosad 48% SC @ 0.5 ml/lt of water T_2: Multineem @ 3 ml/lt of water

T_3: Neem oil @ 3 ml/lt of water T_4: Imidacloprid 17.8 SL @ 0.5 ml/lt of water

T_5: *Litsea citrate* (seed extract) @ 20 ml/lt of water T_6: Malathion 50% EC @ 1 ml/lt of water

T_0: Untreated control

Figures in the table are mean values and those in parenthesis are angular transformed values.

NS: Non-significant at 5% level of significance.

For the second spray schedule, the initial population of ginger shoot borer 1 day before spray ranged from 3.33 to 4.83. After 3 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (60.00%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (57.78%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (57.78%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (20.56%) was lowest among the treated plots. The lowest reduction was observed in interaction of three dates of sowing and treatment in control plot *i.e.* D_1T_0, D_2T_0 and D_3T_0. After 5 DAS highest reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (70.33%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (65.67%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (64.50%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (30.55%) was lowest among the treated plots. The lowest reduction was observed in interaction of three dates of sowing and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%). After 7 DAS higher reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (80.33%) and second date of sowing (D_2) and treatment (T_6) malathion (80.33%) which was at par with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (76.87%) respectively. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (37.78%) was lowest among the treated plots. The lowest reduction was observed in interaction of three dates of sowing and treatments in control plot *i.e.* D_1T_0 (0.00%), D_2T_0 (0.00%) and D_3T_0 (0.00%) respectively. All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

The pooled data on Interaction effect of different sowing dates and pesticides against ginger shoot borer revealed that the highest mean reduction was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (68.03%) which was at par with the interaction of second date of sowing (D_2) and treatment (T_6) malathion (64.57%) and with the interaction of first date of sowing (D_1) and treatment (T_6) malathion (63.52%) respectively. This was followed by interaction of first date of sowing (D_3) and treatment (T_1) spinosad (48.47%), second date of sowing (D_2) and treatment (T_1) spinosad (46. 73%) and first date of sowing (D_1) and treatment (T_1) spinosad (45.21%) respectively. The interaction of first date of sowing (D_1) and treatment (T_2) multineem (37.70%) , first date of sowing (D_1) and treatment (T_3) neemoil (37.08%), first date of sowing (D_1) and treatment (T_4) imidacloprid (40.79%), second date of sowing (D_2) and treatment (T_2) multineem (40.09%), second date of sowing (D_2) and treatment (T_3) neemoil (38.57%), second date of sowing (D_2) and treatment (T_4) imidacloprid (44.31%), third date of sowing (D_3) and treatment (T_2) multineem (41.82%), third date of sowing (D_3) and treatment (T_3) neemoil (40.16%), third date of sowing (D_3) and treatment (T_4) imidacloprid (45.17%) has significant effect on the reduction of ginger shoot borer. The reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (28.61%) was lowest among the treated plot which was at par with the interaction between date of sowing (D_2) and treatment (T_5) *Litsea citrata* (29.54%) respectively. All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

Though workers like Lalnuntluanga and Singh (2008), Singh *et al*. (2016) and Senthil Kumar *et al*. (2017) have mentioned effectiveness of different insecticide treatments against ginger shoot borer, *C. punctiferalis* no proper literature or citations were available after repeated search in the present line of study conducted *i.e.* interaction effect of different sowing dates and pesticides against ginger shoot borer population, so no further comparision could be conducted in support or against the present findings.

Table 4.16 Interaction effect of different sowing dates and insecticides/biopesticides against ginger shoot borer, *C. punctiferalis* on ginger during 2018 & 2019 (Pooled)

Treatments	*First spray*				*Second spray*				*Mean*
	Pre-treatment count	*Percent reduction*			*Pre-treatment count*	*Percent reduction*			
		3 DAS	*5 DAS*	*7 DAS*		*3 DAS*	*5 DAS*	*7 DAS*	
D_1T_1	5.00	30.56 (33.55)	45.56 (42.45)	54.44 (47.55)	3.83	36.23 (37.00)	46.67 (43.09)	57.78 (49.48)	*45.21*
D_1T_2	5.00	24.72 (29.81)	38.17 (38.15)	45.56 (42.45)	3.33	27.78 (31.80)	40.00 (39.23)	50.00 (45.00)	*37.70*
D_1T_3	5.50	23.33 (28.88)	37.22 (37.60)	43.34 (41.17)	3.83	29.72 (33.03)	39.45 (38.90)	49.44 (44.68)	*37.08*
D_1T_4	5.00	27.50 (31.60)	41.11 (39.88)	50.00 (45.00)	3.50	30.56 (33.53)	42.22 (40.53)	53.33 (46.91)	*40.79*
D_1T_5	5.17	18.33 (25.34)	27.78 (31.80)	36.67 (37.27)	3.50	20.56 (26.94)	30.55 (33.56)	37.78 (37.92)	*28.61*
D_1T_6	5.17	50.00 (45.00)	61.67 (51.75)	70.33 (57.00)	3.67	57.78 (49.48)	64.50 (53.44)	76.87 (61.25)	*63.52*
D_1T_0	5.67	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.17	0.00 (0.00)	0.00 0.00	0.00 (0.00)	*0.00*
D_2T_1	4.67	34.44 (35.93)	46.11 (42.77)	54.44 (47.55)	4.17	36.95 (37.43)	47.77 (43.72)	60.67 (51.16)	*46.73*
D_2T_2	5.17	28.06 (31.98)	40.00 (39.23)	46.67 (43.09)	3.83	31.95 (34.41)	42.22 (40.53)	51.67 (45.95)	*40.09*
D_2T_3	4.83	26.39 (30.90)	38.89 (38.58)	44.45 (41.81)	4.17	30.56 (33.56)	41.11 (39.88)	50.00 (45.00)	*38.57*
D_2T_4	4.50	30.55 (33.55)	43.50 (41.26)	52.78 (46.59)	3.67	34.55 (36.00)	47.22 (43.41)	57.23 (49.16)	*44.31*
D_2T_5	5.00	20.56 (26.96)	27.78 (31.80)	36.67 (37.27)	4.17	21.67 (27.71)	31.67 (34.24)	38.89 (38.58)	*29.54*
D_2T_6	4.67	50.00 (45.00)	63.33 (52.74)	70.33 (57.00)	3.83	57.78 (49.48)	65.67 (54.15)	80.33 (63.69)	*64.57*

D_2T_0	4.67	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.17	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
D_3T_1	4.50	36.67 (37.27)	47.78 (43.73)	57.39 (49.25)	4.17	39.44 (38.91)	48.87 (44.35)	60.67 (51.16)	*48.47*
D_3T_2	4.67	30.59 (33.57)	40.00 (39.23)	48.87 (44.35)	4.67	33.67 (35.47)	44.45 (41.81)	53.33 (46.91)	*41.82*
D_3T_3	4.50	30.11 (33.28)	40.00 (39.23)	45.56 (42.45)	4.50	31.39 (34.07)	42.22 (40.53)	51.67 (45.95)	*40.16*
D_3T_4	4.83	33.22 (35.18)	43.78 (41.42)	53.33 (46.92)	4.83	36.23 (37.00)	47.22 (43.41)	57.23 (49.15)	*45.17*
D_3T_5	4.67	20.56 (26.90)	30.00 (33.21)	37.78 (37.92)	4.33	25.00 (30.00)	32.78 (34.92)	40.00 (39.23)	*31.02*
D_3T_6	4.50	55.00 (47.88)	65.67 (54.13)	76.87 (61.25)	4.33	60.00 (50.78)	70.33 (57.05)	80.33 (63.71)	*68.03*
D_3T_0	4.83	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.83	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	*0.00*
SEm±	*0.28*	*0.71*	*0.41*	*0.54*	*0.31*	*0.64*	*0.61*	*0.48*	-
CD (P=0.05)	*NS*	*2.01*	*1.16*	*1.51*	*NS*	*1.79*	*1.72*	*1.35*	-

Note: D_1: 15th February D_2: 17th March D_3: 16th April

T_1: Spinosad 48% SC @ 0.5 ml/lt of water T_2: Multineem @ 3 ml/lt of water

T_3: Neem oil @ 3 ml/lt of water T_4: Imidacloprid 17.8 SL @ 0.5 ml/lt of water

T_5: *Litsea citrata* (seed extract) @ 20 ml/lt of water T_6: Malathion 50% EC @ 1 ml/lt of water

T_0: Untreated control

Figures in the table are mean values and those in parenthesis are angular transformed values.

NS: Non-significant at 5% level of significance.

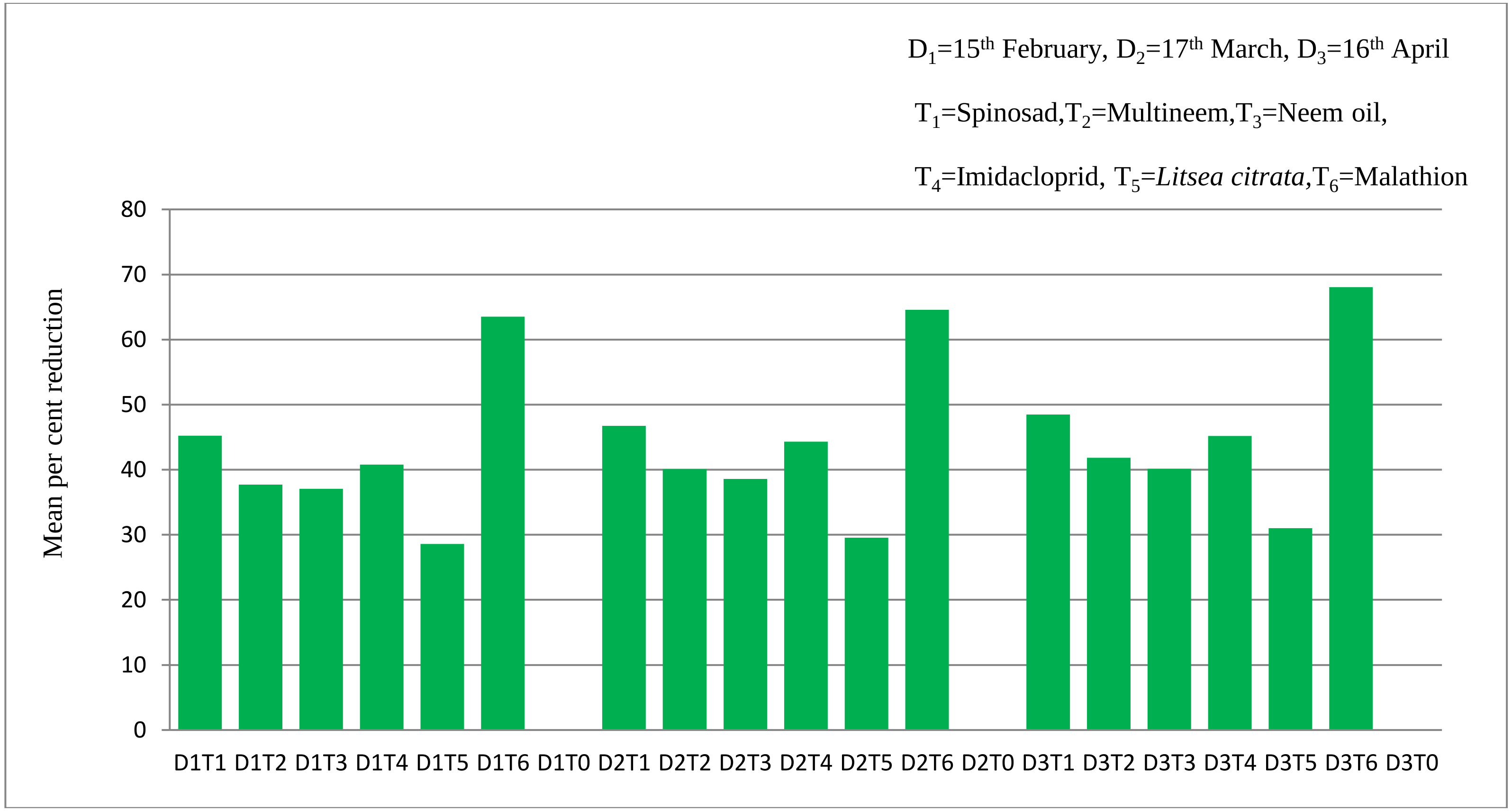

Fig 4.10 Pooled data on the interaction effect of different sowing dates and insecticides/biopesticides against ginger shoot borer (2018-2019)

CHAPTER – 5
SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The present experiment entitled "Eco-friendly pest management of ginger shoot borer, *Conogethes punctiferalis* guenee (Pyralidae: Lepidoptera)." was carried out at the Experimental cum Research Farm, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus, Nagaland during 2018-2019. The field trial was conducted using Split Plot Design (SPD) with three different dates of planting as main factor and seven treatments including control as sub-factor. An ecological plot was maintained few metres away from main experimental plot to study the seasonal incidence of ginger shoot borer under natural condition and relative abundance of natural enemies in ginger ecosystem. The data thus obtained was subjected to suitable and appropriate statistical analysis as per the requirement of the design. The salient findings of the study are summarized below.

The incidence of the *Conogethes punctiferalis* in the year 2018 was observed from 120 DAP (Days after planting) with 10.70 % larvae in D_1 (15^{th} February planting) which falls in the second week of June followed by D_2 (17^{th} March planting) with 11.65 % larvae which falls in the second week of July and D_3 (16^{th} April planting) with 12.72 % larvae which falls in the second week of August.

The incidence of the *C. punctiferalis* in the year 2019 was also observed from 120 DAP with 11.40 % larvae in D_1 (15^{th} February planting) which falls in the second week of June followed by D_2 (17^{th} March planting) with 12.42 % larvae which falls in the second week of July and D_3 (16^{th} April planting) with 13.50 % larvae which falls in the second week of August respectively.

The highest per cent incidence of 18.90 and 19.28 of *C. punctiferalis* larvae was observed at 210 DAP in D_3 which falls in the second week of November whereas the lowest per cent incidence of 10.70 and 11.40 larvae was recorded at 120 DAP in D_1 which falls in the second week of June for both the years respectively.

Abiotic factors play an important role in the incidence of *C. punctiferalis.*

The correlation of *C. punctiferalis* with the abiotic factors for the year 2018 had revealed a non significant negative effect with maximum temperature on D_1, D_2 and D_3 respectively. Correlation of minimum temperature with the incidence of *C. punctiferalis* showed a significant positive effect on D_1, negative non-significant on D_2 whereas significant negative effect on D_3. Correlation of maximum relative humidity (RH) with the incidence of *C. punctiferalis* showed a non-significant positive effect on D_1 whereas significant positive effect on D_2 and D_3. Correlation of minimum relative humidity (RH) with the incidence of *C. punctiferalis* showed a significant negative effect on D_1 and D_3 respectively whereas non significant negative effect on D_2. Correlation of rainfall with the incidence of *C. punctiferalis* showed a non-significant negative effect on D_1 and D_2 whereas significant negative effect on D_3.

The correlation of *C. punctiferalis* with the abiotic factors for the year 2019 also revealed a non significant negative effect with maximum and minimum temperature on D_1, D_2 and D_3 respectively. Correlation of maximum relative humidity (RH) with the incidence of *C. punctiferalis* showed a non-significant positive effect on $D_{1,}$ and D_2 whereas significant positive effect on D_3. Correlation of minimum relative humidity (RH) with the incidence of *C. punctiferalis* showed a non-significant positive effect on D_1 whereas non-significant negative effect on D_2 and D_3. Correlation of rainfall with the incidence of *C. punctiferalis* showed a non-significant negative effect on D_1, D_2 and D_3 respectively.

The relative abundance of natural enemies in ginger ecosystem (untreated plot) during the year 2018 shows that among the natural enemies, the highest relative abundance was observed in spider (41.17%) which was followed by lady bird beetle (20.36%) while the lowest relative abundance was reported in earwig (1.80%).

The relative abundance of natural enemies in ginger ecosystem (untreated plot) during the year 2019 shows that the highest relative abundance was observed in spider (40.63%) which was followed by lady bird beetle (21.00%) while the lowest relative abundance was reported in earwig (0.91%).

The relative abundance of natural enemies in ginger ecosystem both in treated and untreated plot during the year 2018 and 2019 shows that among the natural enemies, the highest relative abundance was observed in spider which was followed by lady bird beetle.

The relative abundance of natural enemies like spider, lady bird beetle, preying mantid, black ant, robber fly, dragonfly, earwig and Carabid beetle were higher in ecological plot (untreated plot) as compared to botanicals/insecticides (treated plot) for both the experimental years *i.e.* 2018 and 2019.

Late planting of ginger (D_3 *i.e.*16th April planting) was effective in reducing the incidence of ginger shoot borer, *C. punctiferalis.*

The per cent reduction of *C. punctiferalis* population increased over time.

The highest mean per cent reduction (38.97%) in the population of *C. punctiferalis* for the year 2018 was observed in 16th April planting (D_3) while the lowest total mean per cent reduction was recorded on D_1 *i.e.* 15th February planting with per cent reduction of 35.78% respectively.

The highest mean per cent reduction (39.50%) in the population of *C. punctiferalis* for the year 2019 was observed in 16th April (D_3) planting while the lowest mean per cent reduction was recorded on D_1 *i.e.* 15th February planting with per cent reduction of 36.48% respectively.

All the treatments *viz*. spinosad, multineem, neem oil, imidacloprid, *Litsea citrata* and malathion has significant effect on the reduction of the pest with mean per cent reduction of 46.80, 39.87, 38.60, 43.42, 29.72 and 65.38 respectively.

Among the different treatments used malathion showed the highest per cent reduction of *C. punctiferalis* with per cent reduction of 65.38 and the lowest per cent reduction was recorded in *Litsea citrata* with per cent reduction of 29.72 respectively.

Among the botanicals, multineem performed best in reducing *C. punctiferalis* population with per cent reduction of 39.57% and 40.17% during both the years.

The effect of all treatments on the population of *C. punctiferalis* was significantly superior to the untreated control.

The highest mean per cent reduction of combined treatment in the population of *C. punctiferalis* was observed in interaction of third date of sowing (D_3) and treatment (T_6) malathion (68.03%). While the per cent reduction in the interaction between date of sowing (D_1) and treatment (T_5) *Litsea citrata* (28.61%) was lowest among the treated plots.

All the treatment combinations against *C. punctiferalis* were significantly superior to the untreated control.

CONCLUSIONS

The findings of the present study showed that abiotic factors play an important role in the incidence of ginger shoot borer. Date of planting also play an important role in the incidence of ginger shoot borer as the manipulation of planting time helps to minimize pest damage by producing asynchrony between host plant and pest *i.e.* feeding stage of insect with the susceptible stage of the crop, thus effective in reducing the incidence of ginger shoot borer. The findings of the present study also provides information on the eco-friendly and sustainable management of the ginger pest by combining novel insecticides and botanicals. Botanicals contain a complex array of compounds with multiple effects and there is less chance of development of resistance. Moreover, they are cheap, safe for non-target organisms and for the environment. In addition, novel insecticides are classified as reduced-risk/ low-toxic pesticides and are ideal for conservation of natural enemies in ginger ecosystem and for developing Integrated Pest Management (IPM) strategies against *C. punctiferalis* in ginger.

Therefore, the present line of work indicates that more detail research study is needed for an effective and sustainable pest management without causing any harmful effects to the environment.

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APPENDIX-I

Effect of date of planting on the incidence of ginger shoot borer during 2018

(ANOVA TABLE)

Source of variation	**Degree of freedom**	**120 DAS**		**150 DAS**		**180 DAS**		**210 DAS**		**240 DAS**		**F Tab. at 5%**	**S/NS**
		MSS	**Cal F**	**MSS**	**Cal F**	**MSS**	**Cal F**	**MSS**	**Cal F**	**MSS**	**Cal F**		
Replication	2	0.34	1.52	0.89	3.87	0.87	2.89	0.21	0.82	0.37	1.74	6.94	NS
Treatment	2	2.42	10.87	3.39	14.73	2.39	7.96	2.39	9.21	2.06	9.75	6.94	S
Error	4	0.22		0.23		0.30		0.26		0.21			
Total	8												

APPENDIX-II

Effect of date of planting on the incidence of ginger shoot borer during 2019

(ANOVA TABLE)

Source of variation	Degree of freedom	120 DAS		150 DAS		180 DAS		210 DAS		240 DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F	MSS	Cal F	MSS	Cal F		
Replication	2	1.57	5.72	0.34	1.02	0.61	1.65	0.15	0.51	0.38	1.32	6.94	NS
Treatment	2	2.46	8.95	3.13	9.29	2.98	8.07	2.07	7.29	2.24	7.81	6.94	S
Error	4	0.28		0.34		0.37		0.28		0.29			
Total	8												

APPENDIX-III

Effect of date of planting on the incidence of ginger shoot borer (Pooled)

(ANOVA TABLE)

Source of variation	Degree of freedom	120 DAS		150 DAS		180 DAS		210 DAS		240 DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F	MSS	Cal F	MSS	Cal F		
Years	1	1.93	7.75	1.19	4.18	1.23	3.68	0.44	1.62	0.60	2.39	5.32	NS
Replication	4	0.96	3.84	0.62	2.18	0.74	2.20	0.18	0.66	0.37	1.50	3.84	NS
Treatment	2	4.89	19.62	6.51	23.00	5.35	15.98	4.45	16.38	4.29	17.26	4.46	S
Years X Treatment	2	0.00	0.00	0.00	0.01	0.02	0.07	0.01	0.04	0.00	0.01	4.46	NS
Error	8	0.25		0.28		0.33		0.27		0.25			
Total	17												

APPENDIX-IV

Efficacy of certain biopesticides and safer chemicals against ginger shoot borer, first spray (2018)

(ANOVA TABLE)

Source of variation	Degree of freedom	3DAS		5DAS		7DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F		
Replication	2	1.87	0.32	1.79	1.47	5.50	1.53	6.94	NS
Factor D	2	99.03	16.89	37.81	31.07	54.13	15.06	6.94	S
Error I	4	5.86		1.22		3.59			
Factor T	6	2131.58	878.47	3315.17	2633.72	4466.58	2614.41	2.36	S
DxT interaction	12	5.63	2.32	3.02	2.40	5.27	3.08	2.03	S
Error II	36	2.43		1.26		1.71			
Total	62								

APPENDIX-V

Efficacy of certain biopesticides and safer chemicals against ginger shoot borer, first spray (2019)

(ANOVA TABLE)

Source of variation	Degree of freedom	3DAS		5DAS		7DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F		
Replication	2	2.13	1.06	1.48	0.78	2.83	0.93	6.94	NS
Factor D	2	116.67	57.92	17.26	9.10	34.85	11.47	6.94	S
Error I	4	2.01		1.90		3.04			
Factor T	6	2217.42	600.29	3524.50	4621.35	4544.57	2615.60	2.36	S
DxT interaction	12	8.43	2.28	1.59	2.09	5.83	3.36	2.03	S
Error II	36	3.69		0.76		1.74			
Total	62								

APPENDIX-VI

Efficacy of certain biopesticides and safer chemicals against ginger shoot borer, first spray (Pooled (ANOVA TABLE)

Source of variation	Degree of freedom	3DAS		5DAS		7DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F		
Years	1	0.98	0.25	36.74	23.59	21.73	6.55	5.32	S
Replication	4	2.00		1.63		4.17			
Factor D	4	107.85	27.38	27.53	17.68	44.49	13.41	3.84	S
Error I	8	3.94		1.56		3.32			
Factor T	12	2174.50	710.57	3419.83	3383.63	4505.58	2615.01	1.89	S
DxT interaction	24	7.03	2.30	2.30	2.30	5.55	3.22	1.67	S
Error II	72	3.06		1.01	1.01	1.72			
Total	125								

APPENDIX-VII

Efficacy of certain biopesticides and safer chemicals against ginger shoot borer, second spray (2018) (ANOVA TABLE)

Source of variation	Degree of freedom	3DAS		5DAS		7DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F		
Replication	2	0.48	0.25	5.60	4.21	0.04	0.02	6.94	NS
Factor D	2	53.29	28.10	60.34	45.45	35.37	17.45	6.94	S
Error I	4	1.90		1.33		2.03			
Factor T	6	2747.04	1395.59	3682.06	1637.17	5357.41	4667.49	2.36	S
DxT interaction	12	4.34	2.20	5.13	2.28	2.85	2.48	2.03	S
Error II	36	1.97		2.25		1.15			
Total	62								

APPENDIX-VIII

Efficacy of certain biopesticides and safer chemicals against ginger shoot borer, second spray (Pooled)

(ANOVA TABLE)

Source of variation	Degree of freedom	3DAS		5DAS		7DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F		
Replication	2	0.48	0.25	5.60	4.21	0.04	0.02	6.94	NS
Factor D	2	53.29	28.10	60.34	45.45	35.37	17.45	6.94	S
Error I	4	1.90		1.33		2.03			
Factor T	6	2747.04	1395.59	3682.06	1637.17	5357.41	4667.49	2.36	S
DxT interaction	12	4.34	2.20	5.13	2.28	2.85	2.48	2.03	S
Error II	36	1.97		2.25		1.15			
Total	62								

APPENDIX-IX

Interaction effect of planting dates and pesticides against ginger shoot borer (Pooled) (ANOVA TABLE)

Source of variation	Degree of freedom	3DAS		5DAS		7DAS		F Tab. at 5%	S/NS
		MSS	Cal F	MSS	Cal F	MSS	Cal F		
Years	1	29.22	11.55	10.83	11.09	10.68	3.95	5.32	S
Replication	4	1.14		4.38		0.25			
Factor D	4	57.52	22.73	55.51	56.85	37.84	13.98	3.84	S
Error I	8	2.53		0.98		2.71			
Factor T	12	2763.54	1139.66	3724.83	1666.75	5367.71	3928.40	1.89	S
DxT interaction	24	5.51	2..27	5.18	2.32	3.36	2.46	1.67	S
Error II	72	2.42		2.23		1.37			
Total	125								

APPENDIX-X

Insecticides/biopesticides used in the experiment

Sl. No.	Common name	Dose (ml/l)
1.	Spinosad 48% S.C	T_1
2.	Multineem	T_2
3.	Neem oil	T_3
4.	Imidacloprid	T_4
5.	*Litsea citrata* (Seed extract)	T_5
6.	Malathion 50% E.C (Standard)	T_6
7.	Control	T_0