BIORATIONAL MANAGEMENT AGAINST SUCKING PESTS OF FRENCH BEAN (*Phaseolus vulgaris* L.)

Thesis

submitted to

NAGALAND UNIVERSITY

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of

Doctor of Philosophy

in

ENTOMOLOGY

By

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2022

Affectionately
Dedicated
to
Mom and Dad
And
my
Sisters

DECLARATION

I, Nokchensaba Kichu, 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 had not been submitted by me for any research degree in any other university/institute.

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CERTIFICATE – I

This is to certify that the thesis entitled **“Biorational management against sucking pests of French bean (*Phaseolus vulgaris* L.)”** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in Entomology is the record of research work carried out by Mr. Nokchensaba Kichu Registration No. Ph.D./ENT/00045 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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This is to certify that the thesis entitled **"Biorational management against sucking pests of French bean (*Phaseolus vulgaris* L.)"** submitted by NOKCHENSABA KICHU, Admission No. Ph-218/16 Registration No. Ph.D./ENT/00045 to the NAGALAND UNIVERSITY in partial fulfillment 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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LIST OF ABBREVIATIONS

%	Per cent
@	at the rate
°C	Degree Celsius
i.e.	id est (that is)
etc.	*et cetera*
et al.	*Et alli* (and other)
viz.	videlicet (namely)
m	Meter
mt	Metric Tonnes
g	Gram
mg	Mili gram
ml	millilitre
SMW	Standard Meteorological Week
WAS	Weeks After Sowing
DAS	Days After Spraying
Fig.	Figure
SEm	Standard error of mean
DBS	Day Before Spraying
ANOVA	Analysis of Variance
DMRT	Duncan's Multiple Range Test
mm	Milimeter
HAT	Hours after treatment

ABSTRACT

The present experimental study was carried out on ‘Biorational management against sucking pests of French bean (*Phaseolus vulgaris* L.)’ under field and laboratory condition in the Department of Entomology, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus during 2017 to 2020. First seasonal incidence field trial experiment was done using simple line sowing and then the major pest was selected for laboratory bioassay using probit. The field efficacy experiment was done using Factorial RBD.

During the study the major sucking pest observed were *viz.*, Aphids (*Aphis craccivora* Koch), Whitefly (*Bemisia tabaci* Gennadius), thrips (*Megaleurothrips usitatus* Bagnal) and leafhopper (*Empoasca fabae* Harris) out of which the most abundant insect pest observed were aphids. From the seasonal incidence field trial of sucking pest in French bean, it was observed that aphid population reached to a peak level of 3.85 aphid index on the 10th WAS (1st week of December). Further the thrips and whitefly population multiplied till the 9th WAS and reached to a peak level of 7.38 and 9.25 per 3 leaves respectively, on the 10th WAS, which generally coinciding with the peak stage of flowering in the last week of November to 1st week of December. In correlation with weather parameters of the pest population both aphids and thrips showed (r = -0.544* and r = -0.503*) negatively significant correlation with rainfall parameters. The natural enemy observed were spiders, species of ladybird beetle like *Coccinella septempunctata* L., *Chilomenes sexmaculata* Fabr, and robber fly (*Dysmachus trigonus*). The highest attended density of coccinellids was observed in 9th WAS *i.e.* 47th SMW (6.75 coccinellids/ 6 plants). Similarly for natural enemies like spiders and robber fly, the highest attended density was observed in 8th and 10th WAS *i.e.* 46th SMW (6.60/ 6 plants) and 48th SMW (4.25/ 6 plant) respectively.

For the bioassay on toxicity of plant extract on aphids (*Aphis craccivora* Koch), the results from the probit analysis at 24, 48 and 72 hours showed that the standard check dimethoate 30 EC was the most toxic @ 0.01%. For botanicals, *L. camara* and *A. indica*

extract @ 3% concentration, reported the highest mortality followed by *D. stramonium* extract @ 4%. While *E. globules* and *C. winterianus* @ 5% reported the lowest mortality.

For evaluation of field efficacy on different botanical extracts among the different treatments with different concentration values the standard check dimethoate 30 EC recorded the highest reduction percentage for the entire sucking pest studied. Results for efficacy order of plant extract in percentage reduction from overall mean of aphid population (Aphid index) are as follows; *D. stramonium* > *L. camara* > *A. indica* > *E. globules* > *C. winterianus*. Where, highest reduction percentage from overall mean for aphids (aphid index) was observed in *D. stramonium* @ 3% (21.47%), 4% (25.68%) and 5% (29.26%) and lowest efficacy was seen in *C. winterianus* @ 4% (9.52%), 5% (9.78%) and 6% (12.43). Similarly for whitefly the efficacy order of plant extracts in percentage reduction from overall mean of whitefly population are as follows; *D. stramonium* > *L. camara* > *A. indica* > *E. globules* > *C. winterianus*. Where, highest reduction percentage from overall mean for leafhopper was observed in *D. stramonium* @ 3% (56.65%), 4% (58.23%) and 5% (64.95%) and the lowest efficacy was seen in *C. winterianus* @ 4% (51.36%), 5% (52.29%) and 6% (58.62%). For leafhopper the efficacy order of plant extracts in percentage reduction from overall mean of leafhopper population are as follows; *D. stramonium* > *A. indica* > *E. globules* > *L. camara* > *C. winterianus*. Where, highest reduction percentage from overall mean for leafhopper was observed in *D. stramonium* @ 3% (56.65%), 4% (58.23%) and 5% (64.95%) and the lowest efficacy was seen in *C. winterianus* @ 4% (51.36%), 5% (52.29%) and 6% (58.62%). Based on efficacy order of plant extracts in percentage reduction from overall mean of thrips population are as follows; *D. stramonium* > *E. globules* > *A. indica* > *L. camara* > *C. winterianus*. Where, the highest reduction percentage from overall mean for thrips was observed in *D. stramonium* @ 3% (56.14%), 4% (62.01% NS) and 5% (66.97% NS) and the lowest efficacy was seen in *C. winterianus* @ 4% (44.90%), 5% (50.64%) and 6% (56.26%).

Keywords: French bean, Seasonal incidence, Sucking pest, Correlation, Natural enemy, Botanicals, Bioassay, Field efficacy.

CHAPTER I

INTRODUCTION

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is the the world's most significant grain and legume sources of protein for human consumption (Broughton, 2003). French bean belongs to family '*Fabaceae*' and genus of '*Phaseolus*'. French bean or green beans are also known as 'string beans' and 'snap beans'. They rank second only to cereals as a source of sustenance for both humans and animals, making them significant foods in the majority of tropical and subtropical nations worldwide (Graham and Vance, 2003). It is cultivated for the tender vegetables, shelled green beans and dry beans (Schoonhoven and Voysest, 1991). French bean has evolved in the highlands of middle America and Ander from a wild vine over a period of 7000 to 8000 years. These fresh vegetables can be eaten fresh or canned frozen while the dried beans are rich in protein and closely compared with meat. There are many varieties of French bean grown in all the regions. However, selected high yielding, disease resistant variety is most important factor for successful commercial cultivation. French bean plays a crucial role in India's fight against protein calorie malnutrition due to its high protein content (21.1%). (Kumar *et al.,* 2006) and lowering the danger of chronic illness (Raju and Mehta, 2009) in developing countries (Van Heerden and Schonfeldt, 2004). These vegetables are extremely important for human nutrition and also significantly increase soil fertility due to their excellent nitrogen-fixing capacity. Legume crops are also important for their nitrogen fixing capabilities (Piha and Munns, 1987; Keyser and Li, 1992 and Amannuel *et al*., 2000), and can be used in crop rotation systems to improve soil conditions. The seeds are sown throughout the year in three seasons Kharif – June/July, Rabi – October/November and Summer – February/March.

Due to its short duration, great production potential, and high nutritional content, it is becoming an increasingly valuable crop. The common bean or

French bean provides one of the most important sources of protein (Boudoin and Maquet, 1999 and Arulbalachandran and Mullainathan, 2009). It is a great source of dietary fibre, two minerals, and vitamins (Kelly and Scott, 1992 and Ndegwa *et al*., 2006). French beans are a delicate warm-season vegetable that cannot withstand frost, extreme heat, or rain. Seeds do not germinate below 15° C and the ideal soil temperature for their germination is between 18 to 24° C. The ideal mean air temperature for its growth and high pod output is between of 20 to 25° C. French bean is also known as Kidney bean and is one of the many varieties of French beans. These edible beans are annual plants grown all over the world. Red kidney beans resemble human kidney with its shape and colour. The French bean is a species with a long history and great variability. While pole or runner varieties produce vines 2 to 3 m long, bush varieties grow erect bushes 20 to 60 cm tall. Each variety has three oval, smooth-edged leaflets that are alternately green or purple and differ in size from 6 to 15 cm long to 3 to 11 cm wide. 1 cm long white, pink, or purple blooms give rise to pods that grow 8 to 20 cm long and 1 to1.5 cm wide. These may be green, yellow, black, or purple in colour, each containing 4 to 6 beans. The beans differ greatly in colour and are usually patterned in two or more colours. They are smooth, plump, kidney-shaped, and up to 1.5 cm long.

Green beans have been reported to contain 6.2 per cent protein, 0.2 per cent fat, and 63 per cent carbohydrate (Sandsted, 1980). The common bean's agricultural output is severely hampered by pest and disease issues, especially in the tropics (Graham and Vance, 2003). An estimated 35 per cent to 100 per cent of crop losses worldwide are attributed to insect pests alone each year (Singh and Schwartz, 2011). The crop is attacked by a number of insect pests during its life span. One of the main obstacles to French bean production is the invasion of numerous insect pests like hadda beetle (*Epilachna vigintioctopunctata*), flea beetle (*Longitarsus belgaumensis*), aphid (*Smynthurodes betae*), and bean fly (*Ophiomyia phaseoli*) which leads to seriously disrupt (Golob and Kilminster, 1982; Pajni and Jabbal, 1986; Rizvi and Singh, 1994; Flood *et al.*, 1995; Srivastava and Agarwal, 2004; Oyewale and Bamaiyi, 2013). The minor insect pest of common bean also includes black bug, grasshopper, armyworm, leaf miners and thrips. In Brazil, *Zabrotes subfasciatus* was reported as a serious pest of beans, *P. vulgaris* (Carvalho *et al.*, 1968; Golob and Kilminster, 1982). In eastern USA, the Mexican bean beetle (*Epilachna varivestis*) is reported as the serious pest of common beans. The other pests include, bean leaf beetle (*Cerotoma trifurcata*), seed corn maggot (*Delia platura*), bean weevil (*Acanthoscelides obtectus*), bean thrips (*Caliothrips fasciatus*) and bean aphid (*Aphis rumicis*) (Liebenberg, 2000). In some Indian areas of Jammu and Kashmir, the crop failed completely, while losses of between 90 to 95 per cent were seen in other areas. (Abrol *et al*., 2006). About 30 species of insects have been reported damaging French bean (Srivastava and Butani, 1998). Among them the sucking insect pests like, aphid (*Aphis craccivora* Koch), whitefly (*Bemisia tabaci* Gennadius), thrips (*Megalurothrips sjostedti* Trybom**),** leafhopper (*Empoasca dolichi*) and mite (*Tetranychus urticae* Koch) are common one.

Lady bird beetles *Menochilus sermaculatus*, spiders and *Staphylinids* are the main predators affecting the population of the different sucking pests. The adverse impacts of employing synthetic pesticides have prompted the quest for alternative pest control methods, which include reducing the frequency of pesticide application and utilising environmentally friendly alternatives such seed dressers, bio-pesticides, and cropping system modifications. (Nderitu *et al*., 2009). In vegetable production the biopesticides used for pests management includes *Bacillus thuringiensis*, *Metarhizium anisopliae*, *Beauveria bassiana*, and *Paecilomyces* spp. and neem (*Azadirachtin*) (SP-IPM, 2006). Beneficial insects, particularly parasitoids, predators, and pollinators, improve the ecological stability of cropping systems in agronomic systems, which increases crop output (Nuessly *et al.*, 2004; Landis *et al.*, 2005; Kasina *et al.*, 2006).

French bean is produced on 1.48 million ha of land worldwide, with a productivity of 11.95 t per ha and an annual production of 17.65 million MT. It is grown on 0.21 million ha in India, where it produces 0.58 million MT and has a productivity of 2.8 tonnes per ha (Anonymous, 2010). It is grown in Karnataka over an area of 0.107 lakh ha, producing 1.12 lakh tonnes annually and producing 10.51 t per ha, respectively. (Anonymous, 2010). With 33% of the global area and 20% of the global production, India is both the world's greatest producer and consumer of pulses. Jammu and Kashmir has 118000 hectares of land planted with beans and vegetables, with a 2011–12 production estimate of 1151000 tonnes (Anonymous, 2013). However, uncontrolled use of pesticides not only leads to environmental pollution but also develops pest resistance in French bean.

"Biorational" are recently been proposed to describe those insecticides that are efficacious against the target pest but are less detrimental to natural enemies. According to Pathak and Dhaliwal (1986) and Dhaliwal and Arora (2003), "Biorational Control" means the use of chemicals that suppress insect populations in a control system by modifying behaviour, disrupting growth and impeding reproduction of the insects populations. Natural substances found in bacteria, plants, minerals, and other sources are used to make biological pesticides. Since they utilize living organisms to kill target pests, microbial pesticides, are generally product of a microbes (viruses, bacteria, fungi, or protozoa) and are regarded as a type of biological control. (Eilenberg *et al*., 2001; Wahengbam *et al*., 2021). It has sparked interest in pest control through the use of botanicals, biopesticides, and bio-control agents (natural enemies), which offers a good alternative to manage the insect, pests, and diseases in an eco-friendly manner given the growing environmental safety concerns and the desire for pesticide-free food globally. Various plant parts, including leaves, stems, seeds, roots, bulbs, rhizomes, unripe fruits, and flower heads *etc.*, are used to make botanicals. Plant extracts are often referred to as ecological pesticides, plant pesticides, botanical pesticides, and green pesticides. The usage of essential oils appears to be the best option, and the use of green insecticides is especially advised for stored grain pests. Studies have revealed that when compared to synthetic pesticides, essential oils are more easily biodegradable and less harmful to non-target organisms (Baysal, 1997). Botanical pesticides have a wide range of qualities, including toxicity to the pest, repellence, anti-feedant, and insect growth regulation activities against pests of agricultural significance. It has been discovered that more than 2500 plant species from 235 families possess the qualities needed for the perfect botanical insecticide. More than 800 insect feeding inhibitors, a good number of insect development inhibitors, and over 350 insecticidal substances have all been identified from a variety of plant species.

In Nagaland the crops are grown in many districts giving its major importance, the seeds are usually sown in August to September and February to March. In Nagaland French bean is cultivated under an area 17280 hectares with a yield of 22140 MT (Statistical Handbook of Nagaland, 2021). Cultivation is done in huge quantities mostly in districts like Tuensang, Kiphire and Longleng in Nagaland. Due to certain reasons crop failure occurs and its climax of yield cannot be achieved, the major reason behind those crop failures is due to high infestation by pest and diseases. Small holder farmers in Nagaland produces low yields of French beans mainly due to challenges of pests, diseases and poor agronomic practices. These problems are mainly controlled using chemical pesticides or by doing nothing undergoing great loss in production. Furthermore some of the chemicals used to control pests and diseases are pollutants of the environment and are expensive. The chemical residues make the produce unmarketable hence leading to loss of income for farmers. There is need to evaluate other optional ways of managing pests and diseases such as use of botanical pesticides and which can reduce the cost of production, increase yields per unit area, enhance the family income and promote a clean environment. French bean is an important crop for farmers in some district in Nagaland for income generation. Production constraints are mainly due to pests, diseases and poor agronomical practices. Pesticide residues and environmental pollution caused by overuse of pesticides are major matters of concern for both scientists and the consumers. There is need to search for selective and biodegradable pesticides to solve problems of pests on farms and long term toxicity to non-targeted insects, mammals and environment. The plant extracts which are locally available and can be a cheap alternative to the small holder farmers. Botanical pesticides may be the key to organic, renewable and cost effective pest management strategy using readily available materials. The use of botanical pesticides is another way of producing French beans free of chemical residues. The results will contribute to the knowledge on clean environment and safe production of crops in the country.

Considering the stated above facts, the present study titled "**Biorational management against sucking pests of French bean (*Phaseolus vulgaris* L.)**" was undertaken under the following specific objectives:

1. To study the seasonal incidence of sucking pests of French bean and their natural enemies
2. To study the bioassay of different botanicals extracts against major sucking pests of French bean in laboratory condition
3. To evaluate the field efficacy of different botanical extracts against sucking pests of French bean

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A perusal through the literature revealed that there is vast range of host plants attached to sucking pests and their incidence. However, information on its incidence and botanicals management in French bean is very meagre. So, some of the available relevant literatures are reviewed here below.

2.1 Seasonal incidence of sucking pests of French bean and its natural enemies

2.1.1 Major sucking pest

Nderitu *et al.* (1997) from Kenya reported that *Ophiomyia* spp., *Bemesia tabaci*, *Megalurothrips sjostedts*, *Tetranychus* spp., *Clavigralla horrins*, and C. *tomentosicollis* were the major insect pests of bean, *Phaseolus vulgaris.*

Pai and Dhuri (1991) studied the incidence of nine species of insect pests at different crop stages on cowpea during October and November in Maharashtra. The major pests reported were *A. craccivora* and *E. kerri* with peak population in second week of November and *B. tabaci* with peak population in fourth week of October. Among natural enemies *Coccinella* spp. and unidentified spiders were recorded.

Chaudhuri *et al.* (2001) observed highest population density of whiteflies on bean was during mid-February. High infestation levels were maintained from mid-February to mid-March when temperature, relative humidity, sunshine hours and rainfall were 17.07 to 22.13 °C, 65.29 to 72.78 per cent, 7.79 to 8.9 hours per day and 5 mm, respectively.

Kumar *et al.* (2004) reported that the peak population of whitefly on mung bean and urd bean was in first forthnight of May and second forthnight of September in zaid and kharif crops respectively. Temperature and sunshine hours were favourable for whitefly population as they depicted positive correlation.

Choudhary (2006) in his study on population built up of insect pests of green gram, *viz*., jassid, whitefly and thrips found that the infestation of these pests started in the last week of July and reached to peak in the first week of September when maximum and minimum temperature was 33.5°C and 23.8°C, respectively with 78 per cent relative humidity. The maximum temperature showed significant negative correlation whereas minimum temperature and relative humidity showed significant positive correlation with the population of pests.

Sharma (2008) reported that whitefly *(Bemisia tabaci* Genn.), jassid *(Amrasca devastans* Distant), aphid *(Aphis craccivora* Koch) and serpentine leaf miner *(Liriomyza trifolii* Burgess), were the major insect pests infesting French bean crop.

Mohan *et al*. (2008) in a study on population dynamics in field bean revealed that, among sucking pests *Aphis craccivora* Koch, leaf hoppers, thrips, *Riptortus pedestris* F., *Riptortus strennus* Horvarth, *Coptosoma cribraria* F, *Anoplocnemis phasiana* F. and *Nezara viridula* L. were more predominant. Defoliators like *Spilactia oblique* Walker and grass hoppers were also observed but in less number.

Nitharwal *et al.* (2013) reported three insect pest species, *viz*. jassid, *Empoasca motti*; whitefly, *Bemisia tabaci* and thrips, *Caliothrips indicus* are the major insect pests of green gram, *Vigna radiate* in the semi-arid region of Rajasthan. The population started appearing from first week of August and remained active throughout the crop season. The infestation gradually reached the peak with 12.40 jassids, 10.80 whiteflies and 9.40 thrips/3 leaves during *kharif* 2006 and 13.2 jassids, 11.20 whiteflies and 9.87 thrips/3 leaves during *kharif*, 2007 in the first week of September during both the years. Among natural enemies, the populations of *Chrysoperla carnea* and *Coccinella septempunctata* were high, whereas, *Monomorium indicum*, *Menochilus sexmaculatus* and *Brumus suturalis* were low.

Nyasani *et al*. (2013) studied the seasonal abundance of western flower thrips (WFT) and its natural enemies on French bean in two agro-ecological zones (AEZs) (high and mid altitude) from January to December 2009 in Kenya. Results showed that colonization of French bean with WFT in both farm scales studied in the two AEZs started at 2 to 3 leaf stage. There was an increase in the population density of WFT from budding stage to podding/flowering stage, and it declined at crop senescence. The population density of WFT was not correlated with temperature and relative humidity, but was negatively correlated with rainfall.

Gauns *et al.* (2014) in their study observed increasing trend of cowpea aphid up to middle of August, 2011 and decreased during last week of August, 2011. Thereafter, population of cowpea aphid showed increased trend and reached its peak during 3rd week of October, 2011. Infestation of cowpea aphid showed negative correlation with minimum temperature and evening relative humidity and positive correlation with maximum temperature.

Kumar and Kumar (2015) conducted experiment in cowpea field during *Kharif* season of 2007-2008. The results showed that pest population like aphids, jassid, thrips and pod borer was highest of 116.20 per 15 cm shoots tip, 8.60 per compound leaves, 5.87 per flower bud and 0.73 per flower bud and 1.80 per pod, respectively. Abiotic factors influenced the infestation and stabilization of various insect pests in cowpea. The population of aphids and pod borer influenced positively relative humidity.

Yadav *et al*. (2015) carried out a study on population dynamics of major insect pests that attack cowpea [*Vigna ungiculata* (L.) Walp.] during 2012-13. The results revealed that aphid and jassid population started from 3rdweek of October, reached a peak of 3.4 aphid index and 3.8 jassids per leaf by 1stweek of December whereas whitefly population started from 3rdweek of October and reached to a peak level of 3.7 whiteflies per leaf in 4thweek of November. Cowpea pod borer population started in 2ndweek of November and reached to a peak level (2.8 larvae per plant) in 1st week of December and thereafter, decreased gradually.

Mandal *et al.* (2016) reported in their study that the thrips were active throughout the year and lower population level during 3rdweek of March to last week of June and higher population level during last week of November to 3rdweek of January. Peak population (12.77 per 3 leaves) was recorded on 49thstandard week that on 1stweek of December. Thrips population had a positive correlation with maximum temperature and maximum relative humidity while negative correlation with temperature minimum temperature. This indicates that activity of thrips population increased with the rise of relative humidity and population decrease with the minimum temperature.

Rani and Hanumantharaya (2016) studied on population dynamics of French bean revealed that a total of 11 insect taxa and non-insect taxa belonging to 7 orders and 9 families were recorded throughout the cropping period for two seasons. The peak incidence of thrips, *Megaleurothrips* spp. was noticed during the second week of November and third week of February. The peak incidence of *Helicoverpa armigera* was noticed during the third week of November and last week of March whereas *Maruca testulalis* was noticed during the last week of December and last week of March. Further, the peak incidence of aphids, whitefly and leafhopper were recorded in third week of November and second week of February; third week of November and last week of February; third week of November and March, respectively.

Mondal *et al.* (2018) more than 37 species were observed to be associated with French bean crop as pest in the Jammu region. Among this, the stem fly, aphid, mites, whitefly, leaf miner, pod borer, and bean gall weevil were found to be the major pest. The correlation analysis revealed a strong influence of environmental variables such as weather parameters on population buildup of these.

Ekram *et al*. (2019) in their study recorded the major pests during two successive summer plantation 2017 and 2018. The highest total number recorded by *Aphis craccivora* Koch. exhibited 1100.33 individuals per 25 leaves and the lowest total number recorded by *Ophiomyia phaseoli*(Tryon) as 64.33 individuals per 25 leaves during summer season 2017 and 2018, respectively. The highest total number recorded during spring seasons during both 2017 and 2018, represented by *A. craccivora* being 1125.63 individuals per 25 leaves and the lowest number of *O. phaseoli* being 74.00 individuals per 25 leaves and the results noticed no significant difference between the two seasons.

Singh *et al*. (2019) in their investigation on seasonal incidence and management of sucking insect pests of green gram [*Vigna radiate* (**L**.) Wilczek] under semi-arid condition which was conducted during *Kharif*, 2015 found that the initiation of jassid and whitefly population recorded in the first week of August (32 SMW) which reached its peak in first week of September, *i.e.* 36thSMW (12.90 jassid and 14.20 whitefly/ three leaves) when maximum temperature, minimum temperature and relative humidity was 36.1 °C and 21.7 °C and 90 percent, respectively and gradually decline thereafter. The relationship between jassid, *Empoasca motti* population with maximum temperature, minimum temperature, relative humidity and rainfall revealed negative correlation (r=-0.621, r=-0.289, r=-0.425, r=-0.329, respectively). The whitefly, *Bemisia tabaci* population with maximum temperature revealed significant positive correlation (r=0.764) but minimum temperature, relative humidity and rainfall revealed negative correlation (r=-0.288, r=-0.515, r=-0.282, respectively).

Bhathesar *et al.* (2021) in an experiment which was conducted on seasonal abundance of major sucking insect pests of leafhopper, *Empoasca motti* (Pruthi.), whitefly, *Bemisia tabaci* (Genn.) and thrips, *Caliothrips indicus* (Bagnall) on moth bean, *Vigna aconitifolia* (Jacq.) Marechal. The incidence of leafhopper reached peak population of 7.84 leafhopper per three leaves. The incidence of whitefly commenced in the first week of August of 32^{nd} standard meteorological week of which gradually increased and reached its peak of 11.40 whitefly per three leaves of moth bean in the first week of September of 36th standard meteorological week. The incidence of thrips reached peak population of 9.48 thrips per three leaves in the first week of September of 36^{th}standard meteorological week, thereafter, the population of thrips declined on moth bean crop. The relative humidity showed positive significant correlation with leafhopper (r = 0.69), whitefly (r= 0.66) and thrips (r= 0.67) population whereas, maximum temperature, minimum temperature and rainfall showed non-significant correlation with leafhopper population.

Ashraf *et al.* (2021) studied on the bean aphid *Aphis fabae* Scopoli, whitefly *Bemisia tabaci* (Genn.), bean weevil *Conapium* spp. indet., flea beetle *Altica himensis* Shukla which were found associated as pests at different phenological stages of the common bean *Phaseolus vulgaris* L. of these *A. fabae*, *B. tabaci* and *Conapium* spp. indet. were categorized as major pests as they caused significant damage. The incidence of these pests showed a peak on the 35^{th}standard meteorological week (SMW) in all the three locations studied

Dawar *et al.* (2022) reported that the peak population of Jassid, whitefly and mite were observed during 37th SMW (1st week of September) (5.66, 5.67 and 3.68 individuals/plant, respectively) while peak population of thrips were observed during 38th SMW (2nd week of September) (4.75 individuals/plant respectively), aphid peak population was observed 36th SMW (5th week of August) (4.61 leaves/plant) and flea beetle were observed during 39th SMW (3 rd week of September) (5.20%). Population of thrips, Jassid, and flea beetle showed strong positive significant correlation with rainfall (r= 0.701**), (r= 0.519*), and (0.583*) respectively. Population of jassid and showed highly significant positive correlation with maximum temperature, morning & evening relative humidity (r= 0.795**), (r= 0.802**) and (r= 0.803**) respectively. Population of jassid showed significant negative correlation with minimum temperature (r= -0.643**). Aphid population morning and evening RH showed positive and significant value of correlation coefficient (0.531*), (0.550*). Whitefly population evening relative humidity and rainfall was found only significant (0.596*), (0.636*).population of flea beetle morning relative humidity and rainfall (0.867**), (0.583*) significant to highly significant while strong negative correlated (-0.710**).

2.1.2 Natural enemies

Sardana and Verma (1986) reported that the activity of *Coccinella septempunctata* (Linn.) was maximum after third week of March at pod formation stage in summer cowpea.

Shrikanth and Lakkundi (1990) observed that the population of *A. craccivora* on cowpea increased rapidly with crop growth and peaked during pod formation in summer (March-May) and kharif (August-October). The activity of predatory coccinellids started one to three weeks after the appearance of aphids and peak population of predator more or less coincided with peak aphid population. Highly significant positive correlations were found between weekly aphid and predator population. The prey predator ratio was highest two weeks after the incidence of aphids during peak pod formation and at the time of harvest. Among the predatory coccinellids, *Menochilus sexmaculatus* Fab. constituted 77 to 78 and 83 to 95 percent of the total predatory population in summer and kharif season, respectively.

Varghese (2003) found that, various organics and botanicals were quite safe to coccinellid beetles and predatory mites, which were found comparable to untreated plots.

Angayarkanni and Nadarajan (2008) studied the biology and seasonal activity of *A. craccivora* in cowpea ecosystem and revealed that the aphid population remained active throughout the year. Three predators, *viz.*, *Menochilus sexmaculatus, Micrapis* spp. and *C. transversalis* and spiders were observed feeding and breeding on the aphid colonies under the field conditions.

Borah and Dutta (2004) reported that the natural enemies recorded on pigeon pea were the parasitoids, *Campoletis chlorideae* (Uchida), *Cotesia flavipes* (oshima), *Carcelia illota* (Curran), and the predatory spiders *Oxyopes ratnae,* (Tikader), *O. shewta* (Tikader), *Neoscona* spp. And *Plexippus paykulli* (Audouni). The peak activities of the natural enemies were mostly during November-January.

Harish (2008) studied the seasonal incidence of natural enemies in soybean ecosystem during *Kharif* season 2006-2007 at Dharwad and observed that natural enemies (coccinellids, chrysopids and *Nomuraea rileyi* Farlow) were found on the crop sown at all the dates of sowing and higher incidence was noticed in the late sown crop.

Thejaswi *et al*. (2008) studied population dynamics of insect pests of field bean and reported that a total of 22 species of insect pests were recorded on the crop. Among sucking pests *A. craccivora*, leaf hoppers, thrips, *Riptortus pedestris* F., *Riptortus strennus* Horvarth, *Coptosoma cribraria* F., *Anoplocnemis phasiana* F. and *Nezara viridula* L. were more predominant. The natural enemies recorded included *Campoletis chlorideae* Uchida, *Bracon* spp. Green bug, *Herpector costalis* (Str.), *Cryptopeltis tenuis* (Mirid), ladybird beetles, mirids, syrphids and carabid predators.

Godwal (2010) studied population dynamic of *A. craccivora* infesting Indian bean at Jobner and reported that population of aphid appeared on 5^{th}September, 2009 (1.0 aphid/ shoot) and reached peak on 10^{th}October, 2009 (194.80 aphids/ shoot). Among natural enemies, the population of lady bird beetle, *M. sexmaculatus* was high, whereas, syrphid fly, *Xanthogramma scutellare* Fab. and black ant, *Monimorium* spp. were few in numbers. The population of *M. sexmaculatus* was high and ranged between 0.4 to 6.2 per plant, the minimum being in the 3rd week of September and maximum in the second week of October. The peak population of the coccinellid predator was recorded as 6.20 individuals per plant in second week of October. The maximum temperature and relative humidity showed non-significant correlation, whereas, the minimum temperature depicted negative significant correlation with aphid population. The correlation coefficients between *M. sexmaculatus* and weather parameters were also computed which depicted a significant negative correlation between *M. sexmaculatus* and minimum temperature. But exhibited a non significant correlation with maximum temperature and relative humidity. There is a significant positive correlation between mean aphid population and *M. sexmaculatus* population.

Patel *et al.* (2010) reported that the activity of predatory coccinellids on cowpea crop started from second week of March and continued up to harvest of crop *i.e.* second week of April. Major activity period of the predator was found during second fortnight of March.

Harish *et al.* (2013) identified two species of spiders, lynx spider and an unidentified golden preying spider, preying upon the sucking insects in soybean.

Jakhar and Chaudhary (2013) observed the number of sucking pests like aphids, leafhoppers, whiteflies, thrips, mites and predators *viz.,* ladybird beetles, spiders and *Staphylinids* were recorded from each tagged plant at weekly intervals starting from two weeks after sowing. On the basis of overall results, it can be concluded that presence of ladybird beetles, spiders and *Staphylinids* in French bean field may keep under check the population of mites, aphids and thrips.

Gauns *et al.* (2014) reported that the ladybird beetle population were active throughout the crop season initial population was noticed during 2nd week of August, 2011. The ladybird beetle population was negatively correlated with minimum temperature and evening relative humidity and positively correlated with cowpea aphids.

Kishor *et al.* (2019) studied the seasonal incidence of aphids, pod borer and their natural enemies on lentil at Research Farm of Tirhut, College of Agriculture, Dholi, Muzaffarpur. Initially *Coccinella septempunctata* population was very low in 4thMSW of January, 2018 (0.90/plant) and after that the population gradually increased. The maximum population of *C. septempunctata* (4.50/plant) was recorded in 8thMSW of February, 2018. Spider population was very low (1.10 spiders/plant) in 4thMSW of January, 2018 and the maximum population (2.00 spiders/plant) of spider was recorded in 6thMSW of February.

2.2 Efficacy of botanical extracts against sucking pest

Bright (1990) found that the reduction in aphid population were due to contact toxicity as well as antifeedent effect of botanicals. The mortality percentage increased gradually with an increase in concentration of the plant extracts. NSE (5%) crude extract gave poor control of jassid, whitefly and aphid. Comparatively low yield was recorded in NSE treated plots than other pesticide treatments (Kalawate and Dethe. 2012).

Rajan and Nair (1992) reported that 5 per cent neem suspension was effective against aphid population.

Gopakumar *et al*. (1993) found that the pesticidal property of aqueous suspension (1 %) of acetone extract of stem of *L. camara* against 8thinstar larvae of *Eupterote undata* and on second instar larvae of *Conogethes punctifolia* shows higher mortality rate by 20 per cent in larvae and 22 per cent in pupae.

Ravikumar *et al*. (1999) documented that botanicals were safe to natural enemies in different crop ecosystems.

Minja *et al.* (2000) revealed that neem extract and *B. thuringiensis* were not as effective as the synthetic insecticides against the major insect pests on pigeon pea pod borers, pod-sucking bugs and pod fly.

Dhamaniya *et al.* (2005) evaluated the bioefficacy of insecticides, out of them Dimethoate (0.03 %) was found highly effective for the control of jassid, *E. motti,* and thrips, *C. indicus* followed by Monocrotophos (0.036 %), while phosphamidon (0.03 %) was found highly effective against whitefly, *B. tabaci* followed by Dimethoate (0.03 %).The azadirachtin (5 ml/l) was found least effective for the control of jassid, whitefly and thrips.

Oparaeke *et al.* (2005) at Zaria, (Nigeria) studied the mixtures of neem and eucalyptus leaf extracts with extracts of other plant species for the management of major post flowering insect pests (pod borers, *M. vitrata*) of cowpea. The results revealed that in 2000 and 2001 seasons the mean number of *M. vitrata* was reduced (< 1.0/flower and/or pod) on plots sprayed with leaf extracts of Neem + Lemongrass, Neem + African curry, Neem + Tomato, Neem + Bitter leaf, and Eucalyptus + African Bush tea. These extracts mixtures caused great reductions in pod damage per plant and ensured higher grain yield.

Gandhi *et al*. (2006) neem oil could be used as a potential seed dresser for managing sucking pests like leafhopper and aphids in okra.

Jat and Jeyakumar (2006) conducted a study to evaluate the efficacy of NSKE (3, 5 or 7%) and neem oil (1, 2 or 3%) against jassids *A. biguttula biguttula* and whitefly *B. tabaci* on cotton. Results indicated that neem oil was more effective against jassids than NSKE. The jassid population increased by upto 8.7 per cent with 5 per cent NSKE, did not vary at 7 per cent NSKE, but decreased by 33.30 per cent with 3 per cent NSKE.

Singh *et al.* (2006) conducted a field experiment to study the efficacy of plant extract (from *Azadirachta indica* A. Juss., *Datura innoxia* Mill., *Melia* *azedarach* L., *Lantana camara* L., *Lawsonia inermis* L. and *Nicotiana tabacum* L.) for the management of whitefly in tomato. All the plant extract modules gave significantly superior control of the pest over the untreated check.

Nirmal *et al.* (2009) reported that due to the presence of Lantanolic acid and Lanticacid which were the active principles present in Lantana, shows growth inhibition and repellent activity against insect pests.

Nabi and Sultan. (2009) found that leaf and seed extracts of *Datura stramonium* L. which were applied in 167,250 and 145,750 mg/l concentrations, respectively caused 98 per cent and 25 per cent mortality among spider mite adults after 48 hours.

Manu (2005) reported that, foliar spray of commercial neem product, nimbecidine 5 ml/l was found superior in suppressing the population of the sucking insect pests of cotton and was comparable with monocrotophos intervention (RPP) followed by NSKE spray.

Singh *et al.* (2010) conducted an experiment during *Kharif* 2005 to test the bio-efficacy of some insecticides and plant products against jassids, whiteflies and thrips on mothbean crop. Dimethoate 30 EC (0.03 %) proved to be the most effective followed by imidacloprid 17.8 SL (0.005 %) and thiamethoxam 25 WG (0.025 %). The plant products like azadirachtin (5 ml/l), neem seed kernel extract (5 %) and karanj seed extract (5 %) proved to be least effective. The highest cost-benefit ratio was obtained in dimethoate 30 EC (1:11.27) followed by imidacloprid 17.8 SL (5.20) whereas, lowest C:B ratio was recorded in azadirachtin (1:2.03).

Devil *et al.* (2011) reported that due to the presence of Hyoscyamine, Atropine and Scopolamine which are the active principles present in Datura, shows repellent and oviposition deterrent activity against insect pests.

Patrícia *et al.* (2013) found that the citronella grass essential oil at a concentration of 1% (w v-1) was toxic to both pests evaluated, however a higher corrected mortality (96.9 ± 1.57%) (mean ± standard error) was observed for *M. persicae* than *F. schultzei* (34.3 ± 3.77%) ($F_{1,18} = 235.96$; $P < 0.0001$). In the control with *F. schultzei*, the observed mortality was 5.7 ± 3.67% and in the control with *M. persicae*, the observed mortality rate was 8.0 ± 2.92%.

Khan *et al* (2013) found that the effect of different plant extracts (neem oil, garlic, eucalyptus and datura) on the population of jassid, *Amrasca devastans* (Dist.), whitefly, *Bemisia tabaci* (Genn.) and thrips, *Thrips tabaci* (Lind.) were tested in Bt cotton under field conditions. All the plant products showed varying toxicity against sucking complex of Bt cotton 24, 72, 168 and 240 hours after application. Datura proved to be the most effective bringing about significant reduction in the pest population followed by neem oil. Garlic and eucalyptus also produced significant results compared to untreated check. However, the two times application of plant products revealed garlic and eucalyptus significantly less effective than Datura and neem.

Dhumal and Waghmare (2014) reported that due to the presence of Camphene, Limonene, Alpha & Beta pinenes and Alpha terpienol which are the active principles present in Nilgiri globules, shows repellent activity against insect pests.

Ghelani *et al.* (2014) in their study evaluated ten insecticides during *Kharif* 2012-13 against major sucking pests infesting the Bt cotton. Among them five were of bio-pesticides (Neem oil 1.0 %, NSKE (Neem seed kernel extract) 5.0 %, Azadirachtin 0.0009 %, *Verticillium lecanii* @ 2.5 kg/ha and *Beauveria bassiana* @ 2.5 kg/ha) and five were chemical pesticides (Acetamiprid 0.004 %, Thiamethoxam 0.01 %, Imidacloprid 0.0089 %, Dinotefuran 0.008 % and Flonicamid 0.02 %). Among the insecticidal treatments, flonicamid 0.02 per cent was found more effective against all major sucking pests, acetamiprid 0.004 per cent against aphid and whitefly, dinotefuran 0.008 per cent and imidacloprid 0.0089 per cent against jassid.

Among the bio-pesticides, neem oil 1.0 per cent, *V. lecanii* @ 2.5 kg/ha and azadirachtin 0.0009 per cent were found moderate effective against major sucking pests.

Sharma *et al*. (2014) evaluate the efficacy of organic inputs against aphids. Field aphid population were counted a day before and after 7 days of spray from 5 cm apical twig of each crop, while in laboratory dead insect counts on treated leaf discs were taken. For mustard aphid 10 % aqueous leaf extract of *Polygonum hydropiper* followed by panchgavya 10 %; dashparni 5% and *P. hydropiper* 10% against *M. persicae* in capsicum and a module containing soil treatment with panchgavya 10% followed by sprays at 10 day interval, respectively of neem oil, panchgavya and *Lantana camara* against cowpea and okra aphid were found significantly effective aphidicides.

Singh *et al*. (2014) in their experiment which was conducted to evaluate the efficacy of certain biopesticides against *thrips tabaci* on garlic during 2009/10 to 2010/11 observed that among the biopesticides, kalmegh (*Andrographis paniculata*) decoction was more effective against thrips (3.73–5.01 thrips per leaf) and the efficacy was similar to 0.03% dimethoate followed by lantana (*Lantana camara*), neem (*Azadirachta indica*), sickle senna (*Cassia tora*), sadaphuli (*Catharanthus roseus*), karanj (*Pongamia pinnata*), and arka (*Calotropis gigantea*).

Pezzini and Koch (2015) in their study tested the effects of lambda-cyhalothrin, two rates of flonicamid and a formulated mixture of azadirachtin and pyrethrins on soybean aphid, *Aphis glycines* and its natural enemies, *Chrysoperla rufilabris*, *Orius insidiosus* and *Hippodamia convergens*. All insecticides significantly reduced *A. glycines* population growth. Lambda-cyhalothrin was highly toxic to the natural enemies. Flonicamid showed the lowest toxicity to natural enemies, but the high rate did decrease survival of *O. insidiosus.* The mixture of pyrethrins and azadirachtin was toxic to larvae of *C. rufilabris* and adult *O. insidiosus*.

Iqbal *et al*. (2015) investigated botanicals as an alternative approach to control sucking insect pests of okra crop. The plant extracts of eight indigenous plants viz., tumha (*Citrullus colosynthis* L.), datura (*Datura innoxia* M.), neem (*Azadirachta indica* A.), castor (*Ricinus communis* L.), hing (*Ferula asafetida* L.), eucalyptus (*Eucalyptus* spp.) bitter gourd (*Memordica chrantia* L.) and garlic (*Allium sativum* L.) were tested for their potential insecticidal efficacy against sucking insect pests, jassid (*Amrasca bigutulla bigutulla* I.), whitefly (*Bemisia tabaci* G.) and thrips (*Thrips tabaci* L.). The mean sucking insect population and fruit damage caused by the chewing borers was monitored to evaluate the efficacy of targeted plant extracts. It was revealed that, neem followed by garlic significantly reduce the mean population of jassid (6.31, 6.86), whitefly (7.41, 8.21) and thrips (11.99, 12.43), respectively. Neem also showed minimum fruit damage percentage (3.38%) followed by garlic (6.67%). The maximum pod yield (3178.7 kg/ha) was observed in neem treated plots. It was concluded that the plants could be the possible alternate option in insect pest management program.

Abebe (2016) studied that the pea aphids, *Acyrthosiphon pisum* (Harris) an insect pest of economic importance in the production of pulses in Ethiopia. The research resulted that using Garlic bulbs *(Allium sativum*), Endod (*Phytolacca dodecandra*) and Neem seeds (*Azadirachta indica*) grounded and prepared at 5 and 10% dilutions was tested for their effect on pea aphid under laboratory condition of Arsi University, School of Agriculture and Environmental Science. Both levels of Garlic and 5% Neem have induced mortality similar to Endosulfan 35% EC within 24 hours of treatment application. Levels of Endod dilutions performed much less as compared to other botanicals in 24 hours of application.

Choudhary *et al.* (2017) reported that the treatment imidacloprid (0.03 %) was found most effective against *Aphis craccivora* followed by thiomethoxam (0.005 %). The treatment of diamethoate (0.03 %), acetameprid

(0.04 %), emamectin benzoate (0.002 %), chloronitraniliprole (0.005 %) and malathion (0.05 %) ranked in middle order of efficacy. The treatment of azadirachtin (0.02 %) proved least effective against Aphid, *A. craccivora*, on cowpea.

Shahzad *et al.* (2017) examined the efficacy of different bio-pesticides against major sucking pests on brinjal under field conditions. Four treatments with three replications were applied. The treatments were: T1=Neem (*Azadirachta indica*), T2= Tobacco (*Nicotiana tabacum*), T3= Datura (*Datura stramonium*) and T4=Control (untreated). Three insect pests were found infesting brinjal including white flies, jassid and mites. Pre-treatment and post-treatment observations were recorded. The results revealed that against white fly, the first spray of Neem extract showed highest reduction percent (82.60 %) followed by Tobacco extract (75.95 %), Datura extract (73.93 %), and lowest for untreated control (11.07 %), while in the second spray also Neem extract showed highest effect against white fly (67.53 %); followed by Tobacco extract (56.43 %), Datura extract (42.25 %), and least by untreated plot (5.49 %). Against jassid, Neem extract showed highest effect (55.95 %) as observed during 1st spray, followed by Tobacco extract (53.38 %), Datura extract (63.11 %) and untreated control (8.00 %), while after second spray also Neem extract showed highest reduction percent (68.73 %) followed by Tobacco extract (55.72 %), Datura extract (50.66 %) and the lowest was resulted by untreated control (13.90 %). Against mites population on brinjal the first spray results showed that Neem extract showed highest effect (96.19 %) followed by Tobacco extract (95.75 %), Datura extract (86.86 %) and least population was recorded in untreated control (9.96 %). After second spray, Neem extract showed highest reduction percent (98.33 %), followed by Tobacco extract (92.85 %), Datura extract (88.93 %) and the lowest reduction percent was resulted by untreated control (9.14 %) respectively. Neem extract showed its superiority in effect to combat sucking insect pests studied in brinjal, followed by, Tobacco extract, Datura extract and untreated control remained the least.

Essani *et al*. (2020) an experiment conducted during the season 2018 to 2019, Maximum reduction in thrips population (30.3 %) was observed in plot sprayed with neem seed extract followed by plot sprayed with neem oil (24.47%), tobacco extract (22.00 %) and akk plant extract (19.83). Neem seed extract showed higher efficacy (81.01 %) against thrips population on mustard crop followed by neem oil (66.13 %), tobacco extract (58.20 %) and akk plant extract (53.12%). Maximum reduction in whitefly population (13.00 %) was observed in plot sprayed with neem seed extract followed by plot sprayed with neem oil (10.33 %), tobacco extract (9.50 %) and akk plant extract (7.33 %). Neem seed extract showed higher efficacy (88.67 %) against whitefly population on mustard crop followed by neem oil (80.51 %), tobacco extract (79.16 %) and akk plant extract (64.69 %). Maximum reduction in aphid population (14.33 %) was observed in plot sprayed with neem seed extract followed by plot sprayed with neem oil (11.10%), tobacco extract (10.23 %) and akk plant extract (9.60 %). Neem seed extract showed higher efficacy (87.75 %) against aphid population on mustard crop followed by neem oil (76.02 %), tobacco extract (71.38 %) and akk plant extract (68.57 %).

Archunan and Pazhanisamy (2021) reported the experiment carried out to investigate the efficacy, aqueous extract of 8 botanicals *viz*., *Strychnos nux-vomica* seed, *Justicia adhatoda* leaf, *Pongamia pinnata* seed, *Thevetia peruviana* Seed, *Abrus precatorius* seed, *Chrysopogon zizanioides* root, *Datura metel* leaf and *Acorus calamus* rhizome against *S. dorsalis* in three concentrations *viz*., 1 %, 3 % and 5 %. Results indicated that the highest total per cent mortality of *S. dorsalis* was recorded in *A. precatorius* seed extract 5 % (77.78 and 81.11 %) followed by *Acorus calamus* rhizome extract 5 % (74.44 and 75.56 %) *C. zizanioides* root extract 5 % (67.78 and 68.89 %) and *D. metel* leaf extract 5 % (61.11 and 65.56 %). Less effects against *S. dorsalis* is seen in *S. nux-vomica* seed extract 1% (5.56 and 8.89 %) and *J. adhatoda* leaf extract.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present experimental study entitled "**Biorational management against sucking pests of French bean (*Phaseolus vulgaris* L.)**" was conducted in the field and laboratory of department of Entomology, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus during 2017 to 2020. The experimental site is located at Medziphema under the district of Chumukedima, Nagaland and it is located at an altitude of 304.8m above mean sea level situated at 25° 45′45′′N latitude and 93° 53′04′′E longitude.

The climate is moderate with maximum temperature ranging between 21℃ to 32℃ in summer and minimum temperature of 8℃ in winter. The annual average rainfall varying from 200 cm to 270 cm which mainly precipitates during April to October and from November to March the weather is dry. The climate is sub tropical. The soil is sandy loam in texture, acidic in nature with pH ranging from 4.5 to 6.5.

The details of materials and methodologies used in the study are described below

3.1 Description of plant materials and chemical used

3.1.1 Neem (*Azadirachta indica*)

Kingdom: Plantae

Order: Sapindales

Family: Meliaceae

Azadirachta indica, commonly known as neem or Indian lilac, is a tree in mahogany family Meliaceae. It is one of only two species on genus *Azadirachta* and is indigenous to Africa and Indian subcontinent. It is typically grown in tropical and sub-tropical region. Neem oil is produced from the plant's fruits and seeds. Neem is a fast-growing tree that rarely grows higher than 35 to 40 metres and can reach heights of 15 to 20 metres (49 to 66 feet).

Despite being evergreen, it may lose most or almost all of its leaves after a severe drought. The plant has broad, dispersed branches. In old, free-standing specimens, the roundish, moderately dense crown can grow to a diameter of 15 to 20 metres (49 to 66 feet). The neem tree and Chinaberry plant (*Melia azedarach*) have remarkably similar appearances. In India, dried neem leaves are put in rice storage canisters as well as cabinets to stop insects from devouring the garments. In tropical areas, neem leaves are burned after being dried to ward against mosquitoes. Neem is used in baths as an ayurvedic herb.

3.1.2 Datura (*Datura stramonium*)

Kingdom: Plantae

Order: Solanales

Family: Solanaceae

Datura belonging to the nightshade family genus Solanaceae and is among nine species of highly poisonous, vespertine-flowering plants. They go by the names thorn apples and jimsonweed, but they are also referred to as devil's trumpets. Other frequent names in English include hell's bells, moonflower, and devil's weed. Ingestion of any Datura species can cause respiratory depression, arrhythmias, fever, hallucinations, anticholinergic syndrome, psychosis, and even death. This is especially true of the seeds and blooms, which are also possibly psychotropic. Some Native American tribes have also employed common Datura species as entheogens in ritual settings. Plants in the Datura genus have long been used as traditional medicines in both the New and Old Worlds due to the presence of the alkaloids scopolamine and atropine, which are also produced by Old World plants including *Hyoscyamus niger*, *Atropa belladonna*, and *Mandragora officinarum*. The majority of non-psychoactive uses of the plant are for medicinal uses. Datura species can grow up to 2 metres tall and are herbaceous, leafy annuals and short-lived perennials.

Plate 1: Seeds of French bean, *P. vulgaris* L. used in the experiment

The leaves are alternate, 10 to 20 cm long and 5 to 18 cm broad, with a lobed or toothed margin. The flowers are erect, trumpet-shaped, 5 to 20 cm long and 4 to 12 cm broad at the mouth; colours vary from white, yellow, pink, and pale purple. When ripe, the fruit, a spiny capsule between 4 to 10 cm long and 2 to 6 cm wide, splits apart to release the numerous seeds. The datura plant's leaves can help with headache relief, and an ethanol extract from the plant's leaves has anti-mite characteristics that are acaricidal, repellant, and prevent oviposition. The ethanol extract of datura is also used as a mosquito and larva repellant.

3.1.3 Lantana (*Lantana camara*)

Kingdom: Plantae

Order: Lamiales

Family: Verbenaceae

Lantana camara (common lantana) is a species of flowering plant within the verbena family Verbenaceae, native to the American tropics. *Lantana camara* is a low erect vigorous shrub with tetrangular stem, stout recurved pickles and a strong odour smell of black current. Lantana plant is a branched, thick-formed shrub, 2 to 4 m tall. When young, the woody stems are square in cross-section and hairy, but as they become older, they turn cylindrical and can go as thick as 150 mm. The ovate leaves (20 to 100 mm long) occur in the opposing pairs along the stem. When crushed, the tough, finely haired leaves release a strong odour. Flower head is made up of 20 to 40 flowers, ranging in colour from white, cream or yellow to orange, pink, purple, or red. The fruit bears several berries with a single pale seed that ripen from green to glossy purple-black. The taproot of lantana is short, and its side roots are arranged in a mat. Lantana leaves can exhibit antibacterial, fungicidal, and insecticidal qualities, according to studies done in India. Various illnesses, such as cancer, skin rashes, leprosy, chicken pox, asthma, and ulcers have all been treated using *Lantana camara* in traditional herbal treatments.

3.1.4 Nigeria Eucalyptus (*Eucalyptus globules*)

Kingdom: Plantae

Order: Myrtales

Family: Myrtaceae

Tropical species of eucalyptus lose their leaves towards the end of the dry season despite the fact that the majority are evergreen. Eucalyptus leaves have oil glands just like those of other myrtle family plants. The abundance of oils generated is a main trait of the genus. Eucalyptus trees in their mature state can be tall and fully leafed, but their shadow is typically patchy because the leaf typically droops down. A mature eucalyptus plant often has lance-shaped, petiolate, seemingly alternating, waxy or glossy green leaves. The leaves of seedlings, in contrast, are often opposite, sessile, and glaucous, though there are numerous exceptions to this pattern. Flowers have several fluffy stamens that can be white, cream, yellow, pink, or red. When the flower is in the bud stage, the operculum, which is made of fused sepals, petals covers the stamens. As a result, flowers lack petals and instead adorn themselves with numerous, showy stamens. It is simple to steam distil eucalyptus oil from the leaves, which is used as a deodorizer, cleaner, and industrial solvent. It can also be found in very small amounts in a variety of food supplements, including cough syrup, toothpaste, and decongestants. It is a component in certain commercial mosquito repellents and possesses insect-repelling qualities. The main source of eucalyptus oil in the world is *Eucalyptus globulus*.

a) Neem (*A. Indica*)

b) Eucalyptus (*E. globules*)

c) Citronella (*C. winterianus*)

d) Datura (*D. stramonium*)

e) Lantana (*L. camara*)

Plate 2: Botanicals used in the study

3.1.5 Citronella (*Cymbopogan winterianus*)

Kingdom: Plantae

Order: poales

Family: Poaceae

Citronella grass is a species of perennial aromatic plant from the family Poaceae, originated from tropical Asia. This is the plant from which citronella oil, an essential oil, is extracted. Citronella grass (*Cymbopogon nardus* and *Cymbopogon winterianus*) has base stems that are magenta in colour and reaches a height of about 2 metres. These species are used to make citronella oil, which is used in soaps, candles, insect sprays, and aromatherapy. It is very effective against mosquitoes. Geraniol and citronellol, two of citronella's main chemical components, is an antiseptic, which explains why they are used in home cleaners and soaps. Citronella grass is not only used to make oil but also as flavouring in food. Citronella is typically grown in backyard gardens to fend off pests like adult whiteflies. Some vegetables can be grown thanks to its cultivation without the use of pesticides.

3.1.6 Chemical Dimethoate

An effective organophosphate insecticide and acaricide is dimethoate. American Cyanamid patented it and first made it available in the 1950s. Dimethoate, like all other organophosphates, inhibits acetylcholinesterase, a crucial enzyme for the proper operation of the central nervous system. It affects by ingesting as well as by coming into contact with them. It is easily absorbed, dispersed, and degrades rather quickly throughout plant tissues.

a) Soxhlet Extractor

b) Oven

c) Grinder

d) Acetone (solvent)

Plate 3: Equipments and chemical used in the experiment

3.2 Plant extraction process

The extracts of the plant materials were prepared according to Singh (2011) with modifications using an automated Soxhlet extractor (SOCS PLUS SCS04 AS DLS). Acetone was used as the solvent.

Different plants used were collected from nearby local areas and then it was dried under shade for 2 to 3 weeks. The dried plants were then crushed evenly using electric grinder. Crushed powder was sieved to obtain fine powder.

For extraction, 20 g of plant powder was weighed and transferred into thimbles and placed in beakers. 80 ml of solvent (acetone) was added to the beakers. Then the beakers were loaded in the extractor and boiled at 80 °C for 1 hour. After that, the temperature was increased to recovery temperature at 160 °C and boiled for 30 minutes. The thimbles were rinsed 2 to 3 times. The beakers were taken out from the extractor and the thimbles were removed. After that the beakers were placed in a hot air oven at 100 °C for 20 to 30 minutes to remove the leftover acetone. The beakers were then removed and placed in a desicator and cooled at room temperature. After extraction, the final extract was kept as a crude extract solution (100 %) in glass bottles. The crude extract was then used for testing insecticidal activities against the sucking pests of French bean.

3.3 FIELD EXPERIMENT

3.3.1 Experimental site

The field experiment was conducted in Department of Entomology field, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus, situated at an altitude of 304.8 m above mean sea level situated at 25° 45′45′′N latitude and 93° 53′04′′ E longitude.

a) Tractor ploughing

b) Manuring with FYM

Plate 4: Field preparation to study the seasonal incidence of pest on French bean, *P. vulgaris* L.

3.3.2 Collection of seeds

The seeds were collected directly through the farmers from the district of Kiphire and Tuensang. Though many local cultivars are available in Nagaland only one popular local cultivar was chosen accordingly through farmers need basis. Local cultivar named Jiphu Yak kholar was taken for experimental purpose.

3.3.3 Sowing time

The sowing time of French bean were done from last week of September to first week of October.

3.3.4 Plot preparation

A selected plot was acquired from the department incharge for the experiment to be done at the farm of the Department of Entomology. All the recommended pre sowing agronomical practices were done such as weeding, ploughing, tillage, unit plot preparation etc, before sowing.

3.3.5 Manuring

Well decomposed FYM were incorporated into the soil thoroughly before sowing

3.3.6 Gap filling

In order to maintain optimum plant population, gap filling of the damaged and missing plants were done at early stage.

3.3.7 Weeding

Frequent weeding were done to keep the field free from weeds and to facilitate proper growth and development of French bean plant.

3.3.8 Irrigation

Light irrigation were given right after transplanting. Irrigation was done every day during the initial growth stage.

3.3.9 Harvesting

Harvesting were done after full maturity and when the pods were fully matured and filled.

Plate 5: 7 weeks after sowing French bean, *P. vulgaris* plant

3.4 To study the seasonal incidence on sucking pests and their natural enemies

3.4.1 Design and layout of the field

In the 1st season (2017-18) of crop planting the plot design were done by simple line sowing in 3 unit plots with a plot size of 5×2.4 m each for observation of the seasonal incidence of sucking pests and natural enemies in French bean crop

3.4.2 Observation

Weekly observations of the prevalence of sucking pests were recored from the time the pests first appeared until the crop was fully mature, and the data were then correlated with weather parameters. Meteorological observations were recorded at standard week during the cropping period

3.4.3 Sampling technique and data collection

3.4.3.1 Whitefly and jassids

Random selection and tagging of 8 plants were done to study the number of jassids and whiteflies population. Each plant's top, middle, and bottom three leaves were examined for the presence of nymphs and adults pest population of whiteflies and jassids. Observations were recorded at weekly interval basis commencing from 10 days after sowing.

3.4.3.2 Aphids

8 plants were randomly selected and tagged. Through the use of the aphid infestation index Table 3.1, the population of aphids was recorded. the count was recorded based on the observation of leaves, flowers, and pods on tagged plants, the degree of infestation was recorded and categorized into grades as 0, 1, 2, 3, and 4. (Yadev *et al*., 2015).

Table 3.1 Infestation index of aphid	
Grade	Aphid Index
0	No aphid population on the plant
1	Plant with one or two aphids but no sign of a colony formation
2	No damage symptoms but small colony of aphids observed with countable numbers on plant
3	Damage symptoms seen with big colony of aphids observed on plant and aphids can be counted
4	A large aphid colony observed on a plant, impossible to count, with severe damage symptoms, and the plant withered.

3.4.3.3 Thrips and leaf hoppers

6 plants were tagged and from every tagged plant three leaves is observed and recorded by counting the number of individuals.

3.4.3.4 Spider Mites

6 plants were tagged for observation and from every tagged plant three leaves from top, middle, and bottom of the plant's canopy, spider mite population densities were recorded. The leaves were collected, placed in distinct polythene bags with proper labels, and brought to a laboratory for stereo binocular microscope analysis. From each leaf, the spider mite were counted (mobile stages) using stereo binocular microscope on 2 cm 2 leaf area. The data count recorded were averaged and converted into per unit area (per leaf bit or per leaf).

Under the following experimental field trial for seasonal incidence on major sucking pest of French bean. All the pest sampling techniques were used for observation of the pest and under the observation no pest population of spider mites and jassids were recorder during the study period.

3.4.4 Meteorological data during the study

The meteorological data during the period of study was recorded at standard week and are presented in the Table 3.2 and Fig 3.1.

3.4.5 To study Natural enemies complex of French bean

3.4.5.1 Observation

For counting the natural enemies, the observation were recorded once in a week on randomly selected tagged plants *i.e.* 6 tagged plants per plot. The observations taken were started immediately after germination and continued till the availability of the predators. The population was taken by visual observation, by counting the number of predators.

3.4.5.2 Identification of Natural enemies

The natural enemies were identified in the Department of Entomology, SASRD, NU, Medziphema campus.

3.5 Treatment detail for bioassay

Five crude plant extract *viz.*, Neem (*Azadirachta indica*), Datura (*Datura stramonium*), Lantana (*Lantana camara*), Nigeria Eucalyptus (*Eucalyptus globules*) and Citronella (*Cymbopogan winterianus*) @ 2,4,6,8 and 10 % was taken to evaluate their insecticidal property at laboratory in the 1st (2017-18) season of crop grown. In 2nd (2018-19) and 3rd (2019-20) season after acquiring the toxicity test concentration botanicals in laboratory, the perfect required concentration was used for further evaluation in field condition. Dimethoate was used as standard along with untreated control for comparison.

Table 3.2 Meteorological data for correlation with seasonal incidence (2017-18)

SMW	Maximum Temperature (%)	Minimum Temperature (%)	Dew Point (%)	Relative humidity (%)	Rainfall (mm)
39	31.76	25.09	25.40	91.44	8.61
40	31.70	24.57	30.48	91.00	8.40
41	30.67	24.30	29.47	91.14	1.89
42	27.79	20.70	24.15	91.28	7.46
43	27.01	19.97	23.67	91.71	2.63
44	28.60	15.01	20.37	90.71	0.00
45	28.10	17.80	20.49	89.14	0.74
46	26.51	17.66	20.93	89.42	0.00
47	25.07	15.26	17.21	87.29	0.00
48	24.93	13.70	16.36	88.29	0.00
49	24.16	15.26	16.64	85.00	0.77
50	25.13	15.19	16.46	89.00	0.00
51	24.37	12.87	14.53	88.43	0.00
52	24.07	12.13	14.01	88.00	0.79
1	24.26	12.83	14.04	90.20	0.79
2	23.33	13.81	14.03	88.29	0.00

*SMW: Standard Meteorological week

Source: Department of Soil and Water Conservation Dimapur

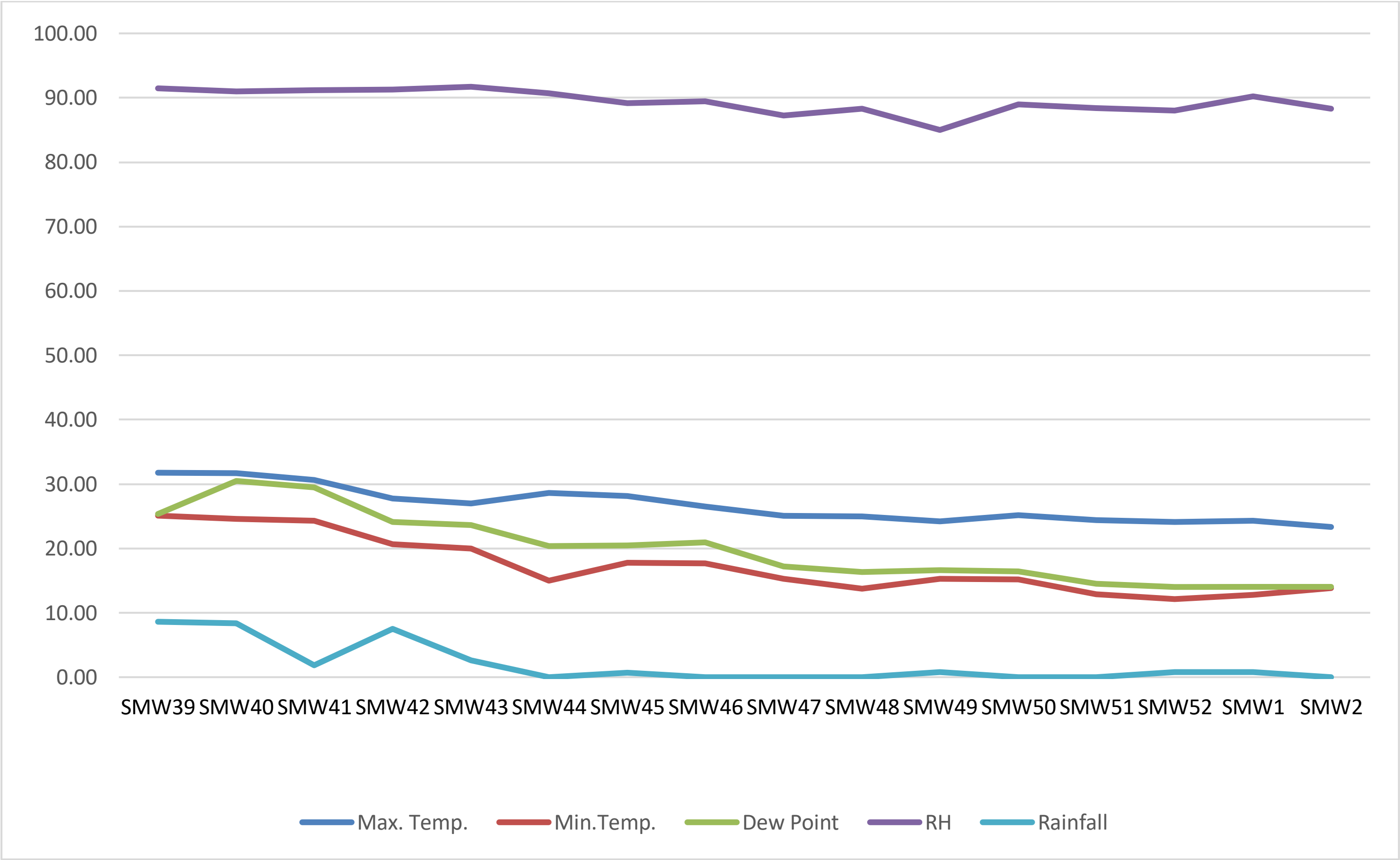

Fig. 3.1 Meteorological data for correlation with seasonal incidence (2017-2018)

a) Plant extracts

b) Dimethoate 30 EC

Plate 6: Plant extracts and chemical pesticide used in the experiment

3.6 Laboratory Experiments

In the laboratory, different concentrations of plant extracts were evaluated for their toxicity against sucking pests of French bean. Method adopted for the experiment are as follows:

Table 3.3 Treatment details for bioassay in Aphids, *Aphis craccivora* Koch. (2017-2018)

Sl. No.	Treatments/ crude plant extracts	Part used	Concentration (%)
1	Neem (*Azadirachta indica*)	Leaf	2,4,6,8,10
2	Datura (*Datura stramonium*)	Leaf	2,4,6,8,10
3	Lantana (*Lantana camara*)	Leaf	2,4,6,8,10
4	Nigeria Eucalyptus (*Eucalyptus globules*)	Leaf	2,4,6,8,10
5	Citronella (*Cymbopogan winterianus*)	Leaf	2,4,6,8,10
6	Dimethoate 30 EC / Rogor	-	0.03,0.04,0.05,0.06,0.07
7	Control (water)	-	-

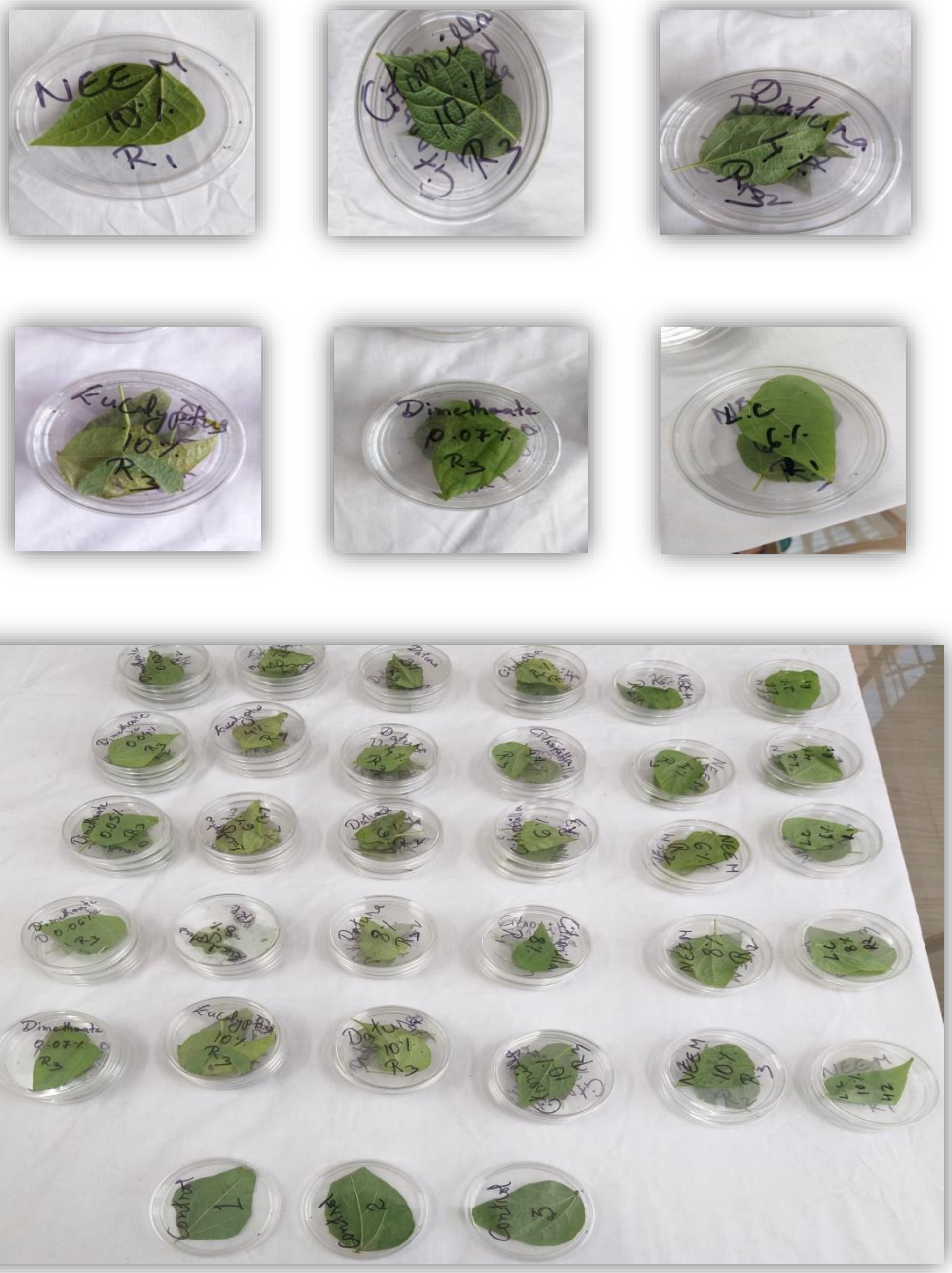

Plate 7: Bioassay study on Aphids (*A. craccivora*) with different plant products and chemical in Laboratory condition

3.6.1 Bioassay on toxicity of plant extracts on aphids (*Aphis craccivora* Koch.) by dipping method

The plant extracts emulsions of required concentrations were made by dilution with water and 1ml of triton X (0.1 %). The plant extracts were diluted to make 2, 4, 6, 8, and 10 % solutions. For comparison Dimethoate 30 EC @ 0.03, 0.04, 0.05, 0.06 and 0.07 % was used (Table 3.3). 10 Adult aphids (*Aphis craccivora* Koch.) was dipped for 10 seconds in each concentration with 3 replications. After that, the insects were removed, air-dried and kept for observation in Petri dishes containing fresh French beans leaves. Observation count was taken before treatment and after 24, 48 and 72 hours after treatment (Abou-Yousef *et al*., 2010). The mortality data was recorded for chemical and botanicals after 24, 48 and 72 hours after treatment. Insects were routinely observed, and those that did not move or respond to light touch were deemed dead. Insect mortality data was corrected by Abbott's formula (Abbott, 1925). The concentration mortality line was calculated using probit analysis (Finney, 1971) in SPSS software with a log10 transformation of the concentrations. The results were expressed as concentration (%) per insect.

$$\text{Corrected percent mortality} = \frac{\text{Percent mortality in treatment} - \text{Percent mortality in control}}{100 - \text{Percent mortality in control}} \times 100$$

3.7 To evaluate the field efficacy of different botanical extracts against major sucking pests of French bean

3.7.1 Design and field preparation

In 2nd (2018-19) and 3rd (2019-20) season of crop planting the field experiment were carried out in Factorial Randomized Block Design with 7 treatments including one standard and untreated control for each replication Table 3.4. Treatment was allocated randomly with 3 replications. The treatment was again divided into 3 concentrations with 3 replications each of the botanicals from the laboratory assessment of toxicity. The unit plot size for each replication were 2.5×1.2 m with an inter spacing of 1m in between blocks and 1m in between plots. The treatments concentration was randomly distributed within the plots of the block. Layout of the experimental field are shown in Fig 3.2.

3.7.2 Experimental Details

1. Design : Factorial Randomized block design

2. No. of treatments : seven (7)

3. No. of replication : Three (3)

4. No. of concentration per treatment: Three (3)

5. Seeds : Local cultivar Jiphu Yak kholar

6. Plot size : 2.5 x 1.2 m

7. Spacing : (a) plant to plant : 30 cm

   (b) Row to row : 50 cm

8. No. of tagged plants Per unit plot: six (6)

9. Season: 2018- 2019 and 2019- 2020

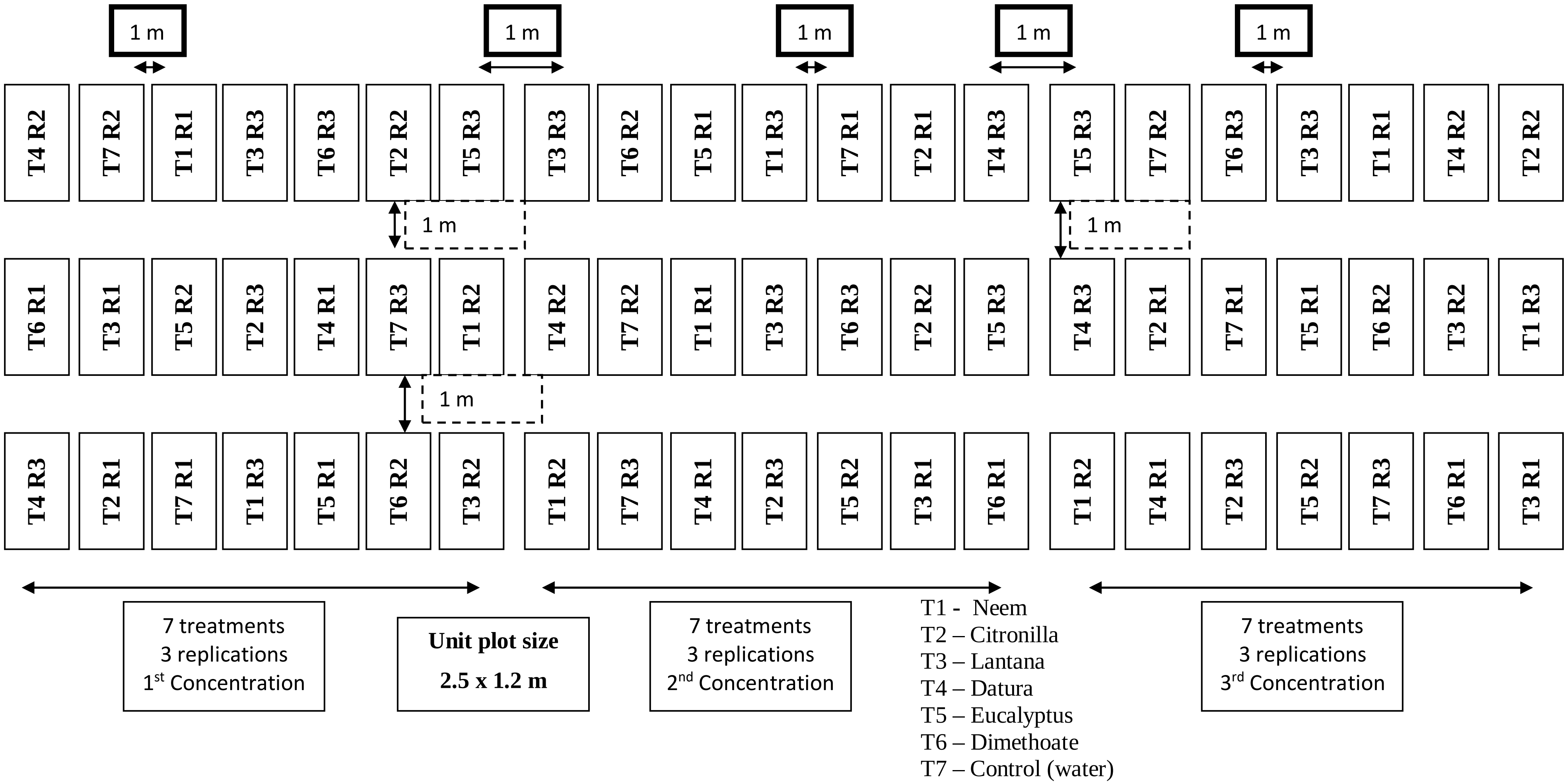

Fig. 3.2 Layout of experimental field

Plate 8: Plot to study the field efficacy of different botanicals extracts against major sucking pest of French bean, *P. vulgaris* L.

10. Location: Field of Department of Entomology, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus.

3.7.3 Observation

The concentration used in field condition was determined accordingly to the standard concentration dose level after the toxicity bioassay test in laboratory. The efficacy of treatment was recorded before the treatment and after 3, 7 and 14 days of first and second spray, respectively. The used treatment details are given in Table 3.4.

Table 3.4 Treatment details for field efficacy evaluation (2018- 2020)

Sl.No.	Treatments/ crude plant extracts	Part used	Concentration (%)
1	Neem (*Azadirachta indica*)	Leaf	2, 3, 4
2	Datura (*Datura stramonium*)	Leaf	3, 4, 5
3	Lantana (*Lantana camara*)	Leaf	2, 3, 4
4	Nigeria Eucalyptus (*Eucalyptus globules*)	Leaf	4, 5, 6
5	Citronella (*Cymbopogan winterianus*)	Leaf	4, 5, 6
6	Dimethoate 30 EC / Rogor	-	0.01, 0.02, 0.03
7	Control (water)	-	0, 0, 0

3.7.4 Efficacy of biopesticides

The treatments effects were studied and the percentage reduction of the pest infestation was worked out using the formula:

$$\text{Percent (\%) reduction} = \frac{\text{Pre treatment count} - \text{Post treatment count}}{\text{Pre Treatment count}} \times 100$$

The percentage data on different observations were transformed into suitable values and were statistically analysed. The means were compared by DMRT following Gomez and Gomez (1976).

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results and discussion on the present investigation entitled "Biorational Management against sucking pests of French bean (*Phaseolus vulgaris* L.)" are presented in this chapter under the following heads.

4.1 To study the seasonal incidence of major sucking pests and their natural enemies

Under this objective a study was carried out to know the abundance of major sucking insect pest in French bean where experiment was done during October 2017 to January 2018. In the 1st season (2017-18) of crop planting the plot design were done by simple line sowing in 3 unit plots with a plot size of 5×2.4 m each for observation of the seasonal incidence of sucking pests and natural enemies in French bean crop.

4.1.1 Insect pest fauna

4.1.1.1 Aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae)

From Table 4.1 and the graphical representation Fig. 4.1 showed that the pest population started from the 2nd week after sowing (WAS) *i.e.* the 1st week of October with 1.13 aphid index. Further aphid population continuously kept on increasing till the 9th week after sowing and reaches to a peak level of 3.85 aphid index on the 10th weeks after sowing, where generally coinciding with the peak stage of flowering and pod formation in the last week of November to 1st week of December. The peak activity of aphid pest population was seen from 5th to 12th weeks after sowing. And thereafter, the aphid population gradually decreased but remains active all round the cropping period. These results are in accord with Rani and Hanumantharaya (2016) where they stated that the incidence of aphids in French bean was noticed from 2nd week of November to 3rd week of December with its peak incidence during 3rd week of November with a mean population of 0.33 per leaf. Also more or less with Yadav *et al* (2015) under the crop cowpea on aphids where observation of

Table 4.1 Seasonal incidence data of major sucking pest of French bean (2017-2018)

Day of Observation	Weeks after sowing	SMW	Aphids (Aphid Index)	Thrips (3 leaves/plant)	Whitefly (3 leaves/plant)
28/9/2017	1	39	0.00^{j} (0.71)	0.00^{j} (0.71)	0.00^{j} (0.71)
5/10/2017	2	40	1.13^{i} (1.27)	0.00^{j} (0.71)	0.00^{j} (0.71)
12/10/2017	3	41	1.59^{ig} (1.44)	0.00^{j} (0.71)	0.00^{j} (0.71)
19/10/2017	4	42	1.98^{gfe} (1.57)	0.00^{j} (0.71)	1.13^{j} (1.27)
26/10/2017	5	43	2.55^{d} (1.75)	0.63^{j} (1.06)	3.13^{j} (1.90)
3/11/2017	6	44	3.13^{c} (1.90)	3.13^{i} (1.90)	3.75^{i} (2.06)
10/11/2017	7	45	3.28^{cb} (1.94)	5.25^{h} (2.40)	5.88^{h} (2.52)
17/11/2017	8	46	3.51^{cba} (2.00)	5.75^{h} (2.50)	6.38^{h} (2.62)
24/11/2017	9	47	3.68^{cba} (2.04)	6.13^{hg} (2.57)	7.00^{hg} (2.74)
1/12/2017	10	48	3.85^{ba} (2.09)	7.38^{g} (2.81)	9.25^{g} (3.12)
8/12/2017	11	49	3.28^{cb} (1.94)	5.50^{h} (2.45)	6.50^{h} (2.65)
15/12/2017	12	50	2.31^{ed} (1.68)	3.00^{i} (1.87)	4.38^{i} (2.21)
22/12/2017	13	51	1.69^{cde} (1.48)	1.25^{j} (1.32)	1.88^{j} (1.54)
29/12/2017	14	52	1.54^{hgf} (1.43)	0.38^{j} (0.94)	0.88^{j} (1.17)
5/1/2018	15	1	1.42^{h} (1.38)	0.13^{j} (0.79)	0.25^{j} (0.87)
12/1/2018	16	2	1.00^{i} (1.22)	0.00^{j} (0.71)	0.00^{j} (0.71)
	SE		0.00	0.01	0.01
	CD($p \leq 0.05$)		0.01	0.04	0.03

*SMW: Standard Meteorological weeks
*Table figures are mean values
Figures in parentheses are square root transformed values
Within column the values with different letter(s) are significantly different (P=0.05) by DMRT

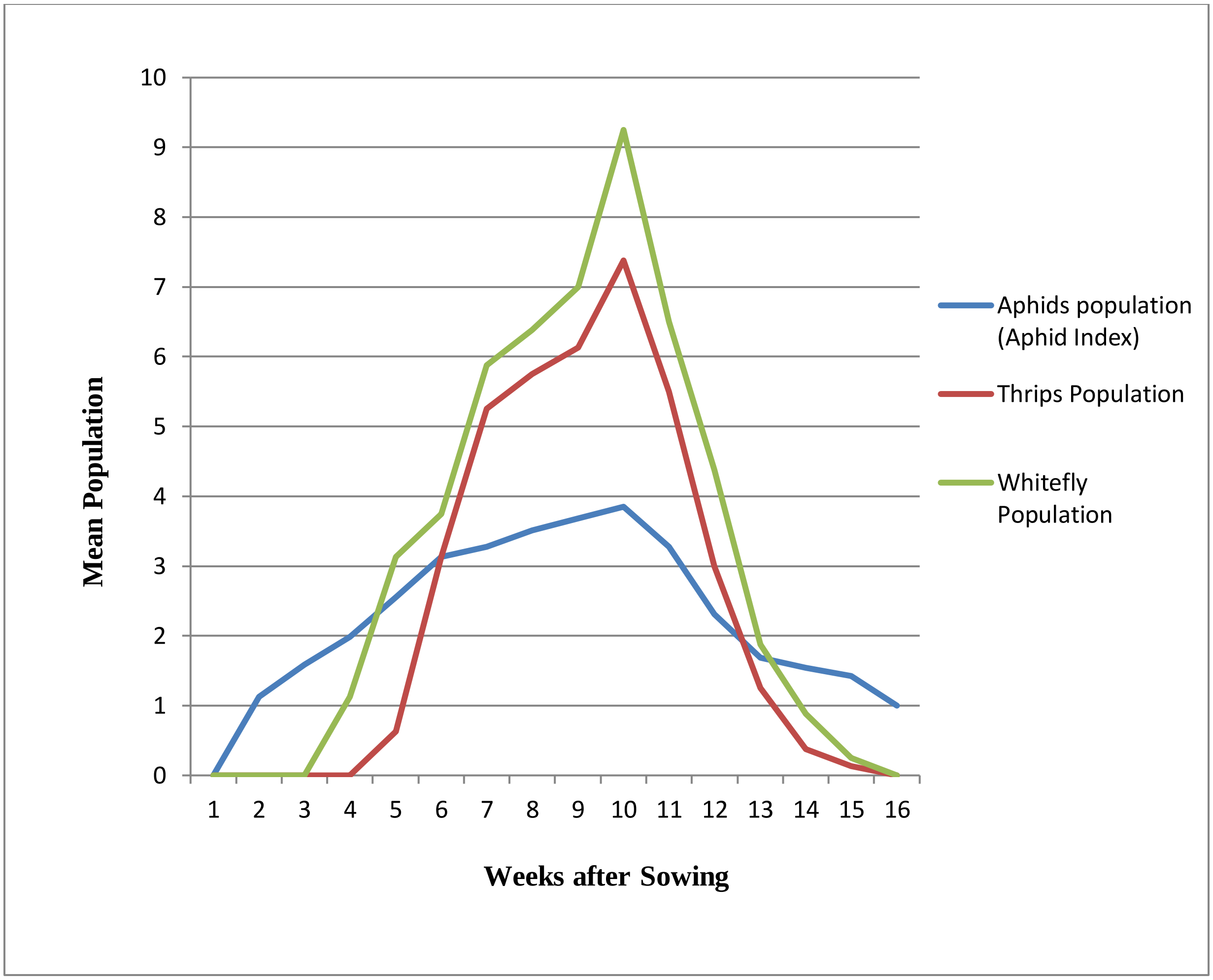

Fig. 4.1 Seasonal incidence of pest population of major sucking pest of French bean, *Phaseolus vulgaris* L. (2017-2018)

aphid population started from the 3^{rd} week of October reached its peak aphid index by 1^{st} week of December and also in accord with Augustine (2011) reported that the peak aphid activity was from 7^{th} to 10^{th} WAS and remain active all round the crop season.

4.1.1.2 Thrips, *Megaleurothrips usitatus* Bagnal (Thysanoptera: Thripidae)

From Table 4.1 and graphical depicted in Fig 4.1 showed that the pest population initiated from the 5^{th} week after sowing (WAS) *i.e.* the 4^{th} week of October with 0.63 per 3 leaves. Further the thrips population continuously kept on increasing till the 9^{th} week after sowing and reach its peak point level of 7.38 per 3 leaves per plant on the 10^{th} weeks after sowing, which generally coinciding with the peak stage of flowering in the last week of November to 1^{st} week of December. The thrips pest population peak activity of was observed from 5^{th} to 12^{th} weeks after sowing. And thereafter, the thrips population gradually decreased and eventually decreases to zero when the pods were matured for harvest. Buitenhuis and Shipp (2007) reported that for all genotypes under study, the thrips population peaked during the time of crop blossoming. The presence of flowers on the crop creates an environment that encourages thrips reproduction and quality feeding.

4.1.1.3 Whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)

In Table 4.1 and graphically depicted in Fig 4.1 showed that the pest population started from the 4^{th} week after sowing (WAS) *i.e.* the 3^{rd} week of October with 1.13 per 3 leaves per plant. Further the whitefly population continuously kept on increasing till the 9^{th} week after sowing and reaches to a peak level of 9.25 per 3 leaves on the 10^{th} weeks after sowing. The whitefly pest population peak activity of was observed from 4^{th} to 12^{th} weeks after sowing. And thereafter, the whitefly populations gradually decreased form the 13^{th} week after sowing but remain active throughout the cropping period. These results are more or less in agreement with Rani and Hanumantharaya (2016) where they stated that the whitefly population was noticed from the 2nd week of November to 2nd week of December with a peak incidence during the 3rd week of November with a mean population of 0.12 per leaf. Similarly, Pai and Dhuri (1991) reported that in cowpea, the pest first appeared in the 1st week after germination, peaking in the 5th week of October.

4.1.2 Correlation between weather parameters and major sucking pest of French bean

The population of insect pest is never truly stable in nature, thus abiotic factors play an important role in increasing or decreasing the population density of an organism. Such abiotic factors may be like temperature, humidity, rainfall, dewpoint etc. To know the effect of such weather parameters on population fluctuation of the sucking insect pest on French bean, simple correlation data obtained are summarized in Table 4.2 and graphically depicted in Fig 4.2, 4.3, 4.4 and 4.5

4.1.2.1 Aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae)

From the data Table 4.2 population of aphid exhibited significant negative correlation with rainfall (r = -0.544*). However, Maximum temperature (r = -0.35), Minimum temperature (r =-0.38), Dew point (r =-0.26) and relative humidity (r =-0.20) showed negatively non-significant correlation with aphid population on French bean. Similar more or less result by Kataria and Kumar (2017) results are also in accordance with present findings where, Aphid populations have been seen to exhibit a negative correlation with minimum temperature, relative humidity, and rainfall. The number of aphids was shown to multiply more as the maximum and lowest temperatures dropped. Gami *et al.* (2002) observed that there was significant negative correlation of aphid population with maximum and minimum temperature.

4.1.2.2 Thrips, *Megaleurothrips usitatus* Bagnal (Thysanoptera: Thripidae)

From the data in the Table 4.2 the thrips population showed negatively non-significant correlation with Maximum temperature (r = -0.325), Minimum

Table 4.2 Correlations table on seasonal incidence of sucking pests with meteorological parameters on French bean, *Phaseolus vulgaris* L. (2017-2018)

	Max. temp	Min. temp	Dewpoint	RH	Rainfall	Aphids	Thrips	Whitefly
Max. temp	1	0.916**	0.930**	0.162	0.742**	-0.35	-0.325	-0.362
Min. temp	0.916**	1	0.958**	0.018	0.810*	-0.383	-0.366	-0.371
Dewpoint	0.930**	0.958**	1	-0.006	0.734**	-0.257	-0.313	-0.312
RH	0.162	0.018	-0.006	1	0.105	-0.202	0.04	-0.128
Rainfall	0.742**	0.810**	0.734**	0.105	1	-0.544*	-0.503*	-0.49
Aphids	-0.35	-0.383	-0.257	-0.202	-0.544*	1	0.889**	0.929**
Thrips	-0.325	-0.366	-0.313	0.04	-0.503*	0.889**	1	0.977**
Whitefly	-0.362	-0.371	-0.312	-0.128	-0.49	0.929**	0.977**	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

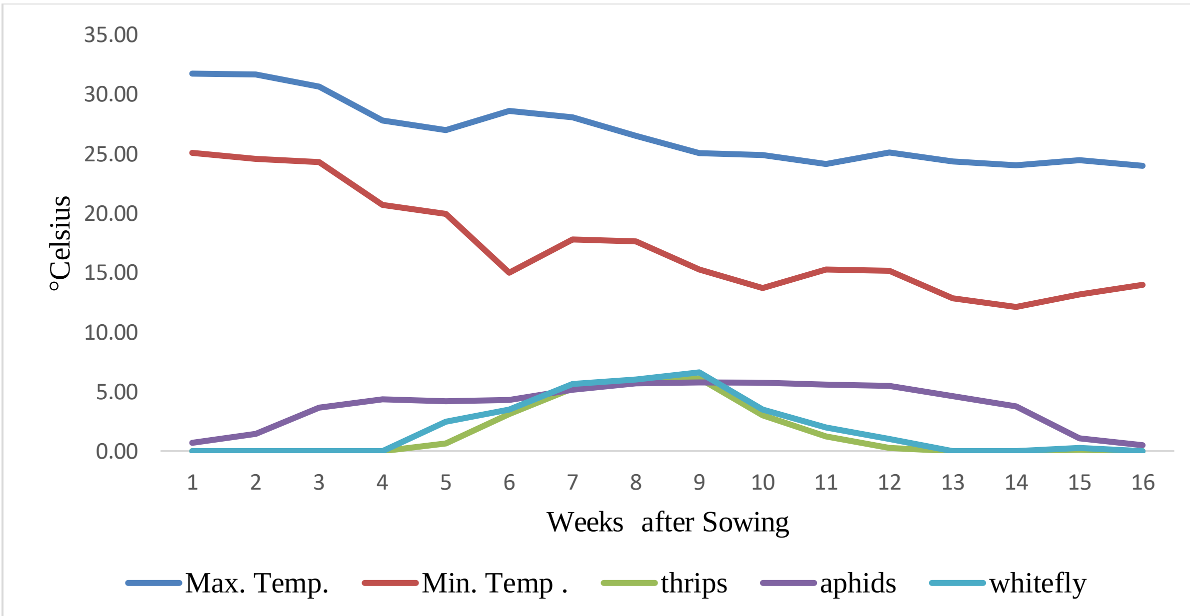

Fig. 4.2 Correlation of pest population with Maximum and Minimum temperature

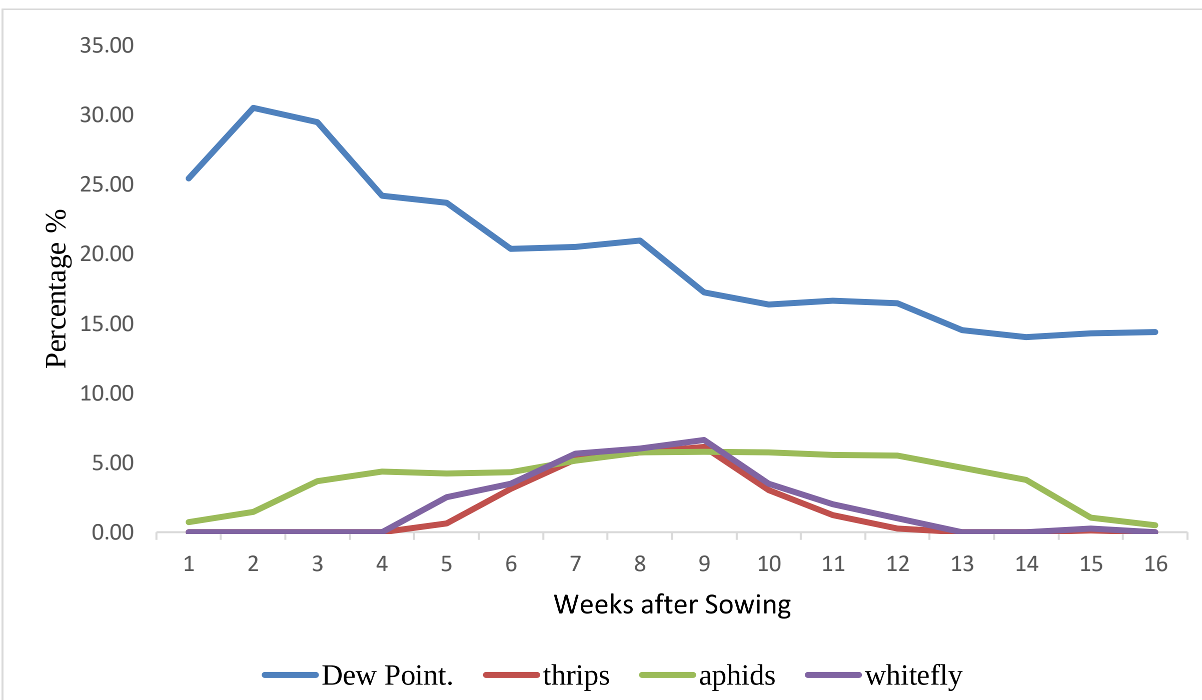

Fig. 4.3 Correlation of pest population with Dew point

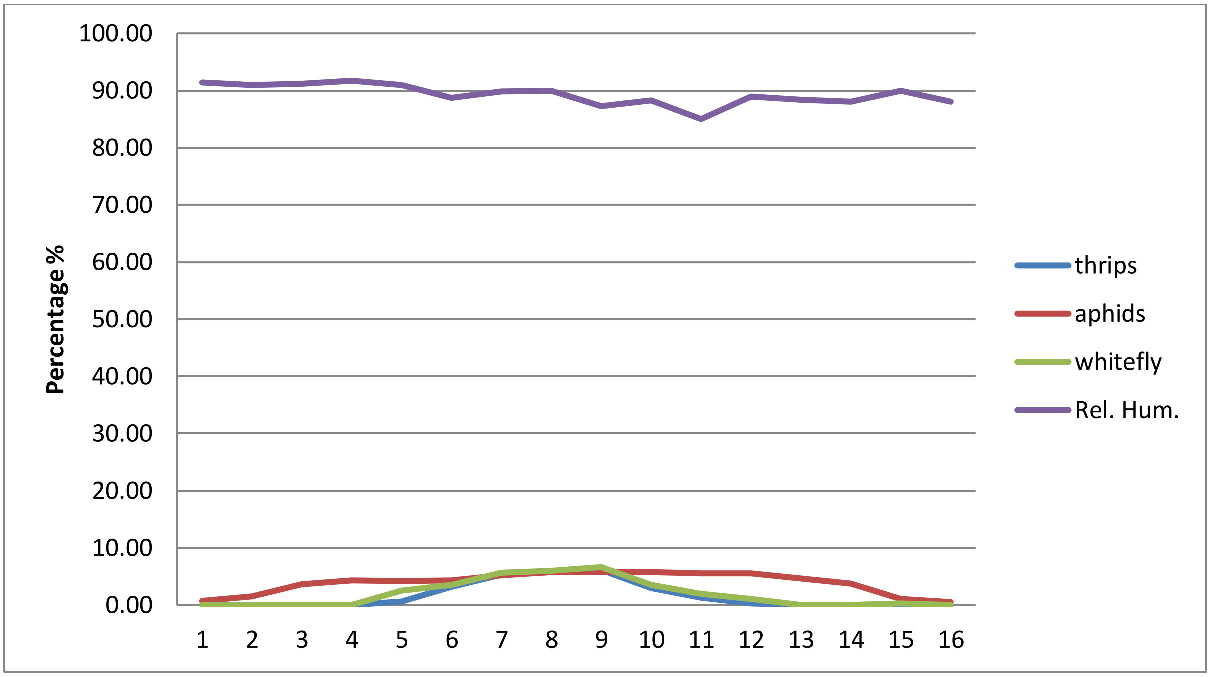

Fig. 4.4 Correlation of pest population with Relative Humidity

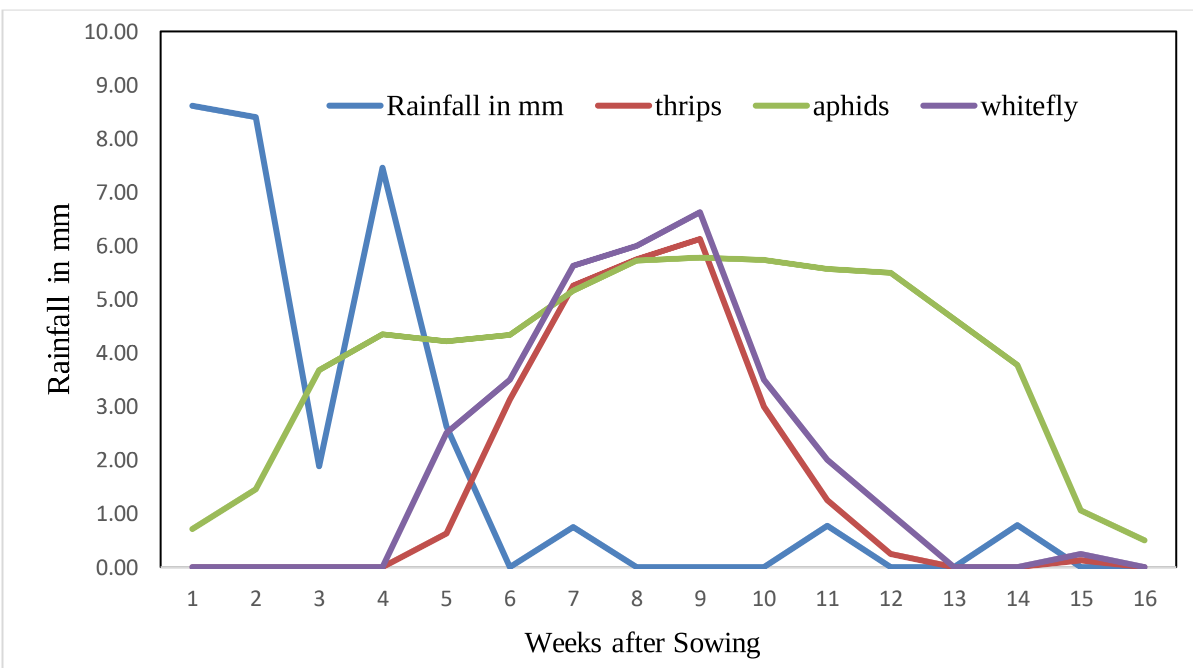

Fig.4.5 Correlation of pest population with Rainfall (mm)

temperature (r = -0.366), dew point (r =-0.313) and relative Humidity (r = 0.04). However, Rainfall (r = -0.503*) showed negatively significant correlation with thrips population in French bean. The results and findings are supported by Nitharwal *et al.* (2013) who found the significant negative correlation of thrips in maximum temperature (r = -0.54; 2006, r = -0.52; 2007) and positive significant correlation in relative humidity (r = 0.68; 2006, r = 0.72; 2007) in green gram.

4.1.2.3 Whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)

The data presented in the table 4.2 indicate that the whitefly population showed negatively non-significant correlation for all the weather parameters *i.e.* maximum temperature (r =-0.36), minimum temperature (r =-0.37), dew point (r =-0.312), relative humidity (r =-0.128) and rainfall (r =-0.49) in whitefly population in French bean. Bairwa and Singh (2017) also reported a negatively non-significant correlation between rainfall parameter. Singh and Kumar (2011) reported that in black gram the minimum temperature and relative humidity had non-significant positive correlation with the pest population, whereas maximum temperature and rainfall had a non-significant negative correlation with the pest population.

4.1.3 Predatory fauna

For the natural enemy complex on sucking pests of French bean the observation data result are detailed in table 4.3 and graphically presented in Fig 4.6. The first incidence of coccinellids was observed in 3rd week after sowing *i.e* on 41st SMW (0.25 coccinellids/ 6 plants). The highest attended density was observed in 9th week after sowing *i.e.* 47th SMW (6.75 coccinellids/ 6 plants). The results of our present study are comparable to that of some prior researchers Nitharwal and Kumawat (2013) who reported that *C. septempunctata* was higher during cropping season. The present findings are in accord with Srikanth and Lakkundi (1990) reported significant rise in *A.*

Table 4.3 Population fluctuation of natural enemies per 6 plants

Day of Observation	Week after sowing	SMW	*Coccinella* spp / 6 plants	*Dysmachus trigonus* / 6 plants	Spider spp / 6 plants
28/9/2017	1	39	0	0	0
5/10/2017	2	40	0	0	0.5
12/10/2017	3	41	0.25	0	0.75
19/10/2017	4	42	0.50	0.25	0.25
26/10/2017	5	43	1.25	0.5	3.40
3/11/2017	6	44	2.75	0.75	4.25
10/11/2017	7	45	4.25	1.25	5.60
17/11/2017	8	46	5.80	2.25	6.60
24/11/2017	9	47	6.75	2.50	5.9
1/12/2017	10	48	5.5	4.25	5.5
8/12/2017	11	49	5.75	4.10	4.4
15/12/2017	12	50	5.20	3.25	3.75
22/12/2017	13	51	3.25	2.05	3.25
29/12/2017	14	52	2.25	1.75	1.75
5/1/2018	15	1	1.25	0.75	0.2
12/1/2018	16	2	0.75	0.5	0

*SMW: Standard Meteorological weeks

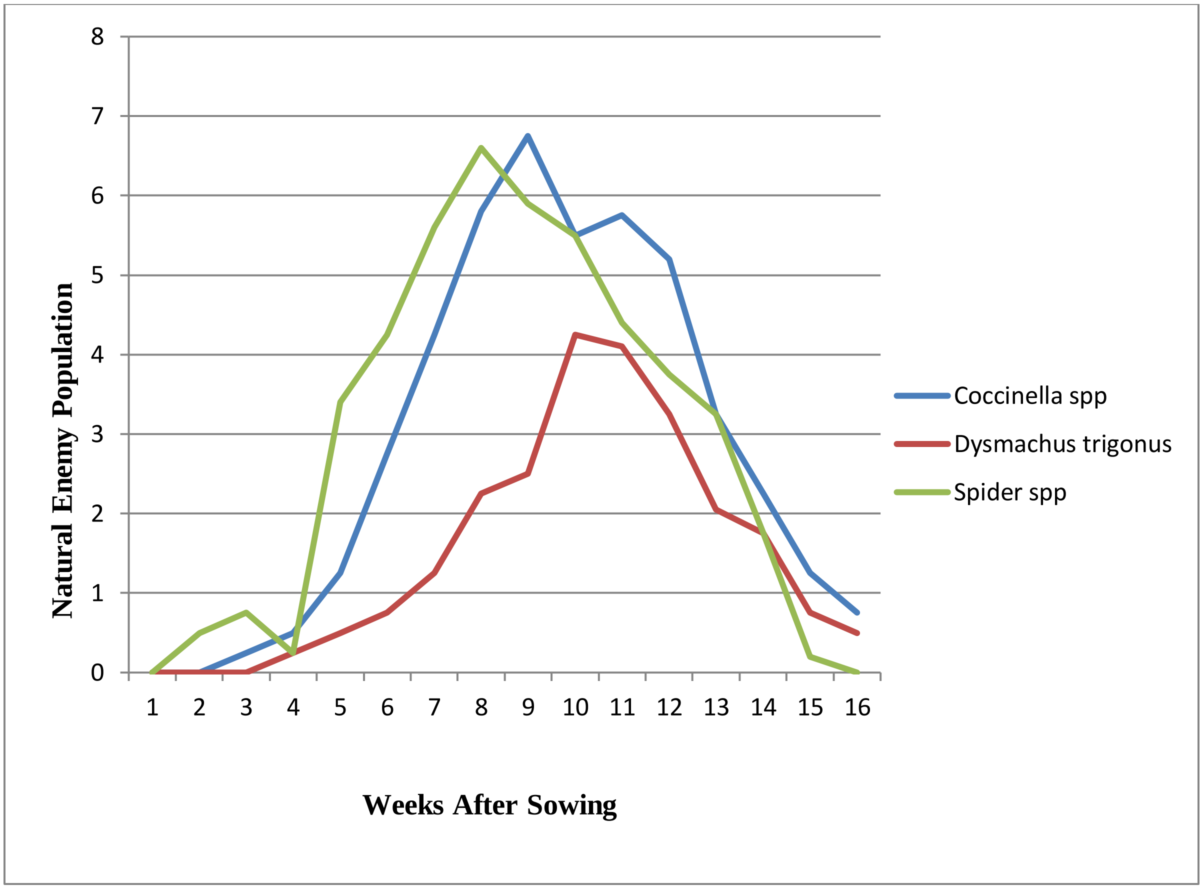

Fig. 4.6 Natural enemy complex of French bean, *Phaseolus vulgaris* L.

Plate 9: Adult and larva of *Coccinella septempunctata*

Plate 10: Adult *Chilomenes sexmaculata*

Plate 11: *Dysmachus trigonus*

Plate 12: Adult spider species

craccivora populations along with crop development and found that coccinellid populations peaked at the same period of aphid population.

From the Table 4.3 and Fig 4.6 the first incidence of rober fly (*Dysmachus trigonus*) was observed in 4th week after sowing *i.e.* on 42nd SMW (0.25/ 6 plants). The highest attended density was observed in 10th week after sowing *i.e.* 48th SMW (4.25/ 6 plants).

In the Table 4.3 and Fig 4.6, the first incidence of spiders was observed in 2nd week after sowing *i.e.* on 40th SMW (0.5/ 6 plants). The highest attended density was observed in 8th week after sowing *i.e.* 46th SMW (6.60/ 6 plants). The peak period ranged from 5th to 13th week after sowing and the population gradually decreases in the later weeks of the cropping period. Dawar *et al*. (2022**)** higher population of spider was noted during 8th WAS coinciding from 1st week of September (37thSMW) to 14th WAS coinciding from 3rdweek of October (43rdSMW). Thereafter, spider population started decreasing and completely disappeared from 15thWAS *i.e.* 4th week of October (44thSMW).

Through this experimental study on Natural enemy of the pest it was observed that the natural enemy Coccinellids were highest in population among all the natural enemies (6.75 coccinellids/ 6 plants) followed by spiders in the cropping season. However as per literatures searched there was no literature found under robber fly as natural enemy on sucking pest of French bean but during the field study this natural enemy was observed.

4.2 Bioassay on Toxicity of plant extract on Aphids (*Aphis craccivora* Koch) by dipping method

In the present study from Table 4.4, the mortality at 24, 48 and 72 hours due to direct toxicity of plant extracts, *D. stramonium*, *L. camara* and Dimethoate 30 EC at different concentrations shows variations in per cent mortality ranging from 0 to 100%. From details presented in Table 4.5, *L. camara* and *A. indica* extract @ 3% concentration reported the highest mortality followed by *D. stramonium* extract @ 4 % at 24 hours after treatment. While *E. globules* and *C. winterianus* @ 5 % reported the lowest mortality at 72 hours after treatment. The results show that the per cent mortality increases with the increase in concentration and time after treatment.

Based on the per cent mortality, the concentration mortality line was calculated using probit analysis. The details of the probit analysis for 24, 48 and 72 hours are presented in Table 4.5. The results from the probit analysis at 24, 48 and 72 hours showed that the standard check Dimethoate 30 EC was the most toxic @ 0.01%. For the plant products, at 24 hours *D. stramonium* and *L. Camara* were the most toxic at low concentration followed by *A. indica.* The LC 50 values at 24 hours were *E. globules* 10 %, *L. Camara* 4%, *C. winterianus* 9%, *A. indica* 8 %, *D. stramonium* 4 % and Dimethoate 30EC 0.01 %. Similar results were obtained at 48 hours after treatment where *D. stramonium* showed the lowest concentration mortality value among botanicals @ 1 % (NS), where significant result could not be found. Therefore at 48 hours after treatment the most toxic at lowest concentration was observed in *L. camara* @ 4%. The LC 50 values for 48 hours after treatment were *L. camara* 4 %, *A. indica* 5 %, *E. globules* 6 %, *C. winterianus* 8 % and *D. stramonium* 1% (NS). However at 72 hours, *L. camara and A. indica* was the most toxic at the lowest LC50 value followed by *C. winterianus* and *E. globules.* While in *D. stramonium* and Dimethoate 30 EC significant result could not be found. The LC50 values at 72 hours were *E. globules* 5 %, *L. camara* 3 %, *C. winterianus* 5 %, *A. indica* 3 %, *D. stramonium* 0 % (Non-significant) and Dimethoate 30 EC 0 % (Non-significant). Based on the study the order of toxicity of plant products based on probit analysis was *A. indica* > *L. camara* > *D. stramonium* > *C. winterianus* > *E. globules*. Based on the result of the bioassay study the LC50 value for field efficacy of different botanical extracts against major sucking pests of French bean was determined and the treatment details are presented in Table 3.4.

Table 4.4 Mortality of Aphid (*Aphis craccivora*) at 24, 48 and 72 hours with plant extract treatment

Plant extract	Dose (%)	Insect mortality rate (%)		
		24 HAT	48HAT	72HAT
1. *Eucalyptus globules*	2	10	20	40
	4	16.67	43.33	53.33
	6	26.67	56.67	63.33
	8	40	60	70
	10	60	83.33	83.33
2. *Lantana camara*	2	36.67	36.67	60
	4	46.67	56.67	63.33
	6	60.00	70	73.3
	8	76.67	80	86.67
	10	83.33	86.67	100
3.*Cymbopogan winterianus*	2	10	20	36.67
	4	20	33.33	60
	6	30	46.67	63.33
	8	40	50	73.3
	10	66.67	73.33	83.3
4.*Azadirachta indica*	2	6.67	26.67	46.67
	4	26.67	40	66.67
	6	30.00	63.33	86.67
	8	60.00	66.67	90
	10	63.33	83.33	96.67
5.*Datura stramonium*	2	40	56.67	93.33
	4	43.33	70	100
	6	63.33	76.67	100
	8	86.67	86.67	100
	10	86.67	96.67	100
6.Dimethoate 30 EC	0.03	43.33	83.33	86.67
	0.04	83.33	86.67	93.33
	0.05	96.67	100	100
	0.06	100	100	100
	0.07	100	100	100

*HAT : Hours after Treatment

Table 4.5 Probit analysis for toxicity at 24, 48 and 72 hours of plant extracts against Aphid, *Aphis craccivora*

Name of extract	LC50 (%)	95% fiducial limit	Slope ± SE	Goodness of fit chi squared
A. At 24 hours				
Eucalyptus	10	6.992-72.465	2.48±0.99	0.62
Lantana	4	0.984-6.808	1.94±0.77	0.02
Citronella	9	6.506-36.286	2.57±0.98	0.81
Neem	8	5.879-16.416	2.96±1.02	0.68
Datura	4	1.205-5.726	2.05±0.77	1.49
Dimethoate	0.01	0.031-0.02	6.53±2.04	0.72
B. At 48 hours				
Eucalyptus	6	6.021-3.878	2.36±0.84	0.53
Lantana	4	1.099-6.205	1.94±0.77	0.02
Citronella	8	5.146-39.221	2.05±0.84	0.53
Neem	5	5.466-3.187	2.20±0.80	0.39
Datura	1(NS)	-	1.58±0.77	0.40
Dimethoate	0.02(NS)	-	2.46±1.76	0.35
C. At 72 hours				
Eucalyptus	5	0.272-26.679	1.53±0.76	0.20
Lantana	3	0.000-4.765	1.52±0.76	1.19
Citronella	5	0.890-11.604	1.64±0.76	0.18
Neem	3	0.381-4.616	1.94±0.78	0.16
Datura	0(NS)	-	0.43±0.90	0.08
Dimethoate	0(NS)	-	1.60±1.66	0.11

*NS : Non significant

4.3 To evaluate the field efficacy of different botanical extracts against major sucking pests of French bean

Field experiment was conducted for studying the field efficacy of different botanical extracts against sucking pests of French bean *viz.*, aphid (*Aphis craccivora* Koch), whitefly (*Bemisia tabaci* Gennadius), thrips (*Megaleurothrips usitatus* Bagnal) and leafhopper (*Empoasca fabae* Harris) during 2018 to 2020 (pooled). The efficacy of the bio pesticides against the pest were recorded after 3rd, 7th and 14th days of 1st and 2nd spray over days after spray. The treatment details are given in the Table 3.3, and the results for two field trial for 2018 to 2019 and 2019 to 2020 (pooled data) of the experiment are discussed as under.

4.3.1 Aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae)

The result of the study from the Table 4.6 and Fig 4.7 showed that there were statistical significance among the treatments after spray. Among different treatments form overall mean with different concentration values the standard check Dimethoate 30 EC recorded the highest reduction percentage in aphid (aphid index) for all the concentrations followed by *D. stramonium* for plant products. Among the botanicals the lowest reduction percentage from overall mean for aphid (aphid index) was observed in *C. winterianus* followed by *E. globules*. The results show that the per cent reduction increases with the increase in concentration and time after 1st and 2nd spray.

From different treatments with different concentration values Table 4.6 and Fig 4.7, the standard check Dimethoate 30 EC recorded the highest reduction percentage from overall mean in aphid (aphid index) for all the concentrations that is @0.01 % (77.67 %), @ 0.02 % (82.14 %) and @ 0.03 % (82.14 %). For the plant products the highest reduction percentage from overall mean for aphids was observed in *D. stramonium* for all the concentration *i.e.* @ 3 % (21.47 %), 4% (25.68 %) and 5 % (29.26 %) followed by *L. camara* for all

Table 4.6 Efficacy of plant extracts against Aphids, *Aphis craccivora* (2018-2020 Pooled data)

Treatments	Conc.	* Reduction % of aphid								
		1st spray				2ndspray				Overall mean
		1DBS	3DAS	7DAS	14DAS	1DBS	3DAS	7DAS	14DAS	
Lantana camara	2%	2.94 (1.85)	11.44^{d} (6.57)	20.34^{d} (18.68)	30.23^{d} (17.59)	2.05 (1.60)	10.77^{d} (6.18)	19.31^{d} (11.13)	27.25^{d} (15.81)	19.71 (11.37)
	3%	2.96 (1.86)	12.30^{c} (7.07)	21.67^{d} (12.52)	27.61^{c} (16.03)	2.13 (1.62)	13.36^{c} (7.68)	24.15^{b} (13.98)	31.10^{b} (18.12)	21.52 (12.43)
	4%	2.89 (1.84)	13.41^{d} (7.70)	22.58^{d} (13.05)	29.03^{c} (16.88)	2.04 (1.59)	17.25^{d} (9.93)	27.69^{d} (16.08)	36.92^{d} (21.66)	24.00 (13.89)
Datura stramonium	3%	2.86 (1.83)	13.09^{d} (7.52)	20.89^{d} (12.06)	28.80^{d} (16.74)	2.09 (1.61)	11.35^{d} (6.52)	23.08^{d} (13.35)	32.08^{c} (18.71)	21.47 (12.40)
	4%	3.03 (1.88)	16.50^{b} (9.50)	23.92^{d} (13.84)	32.47^{b} (18.95)	2.05 (1.60)	16.71^{b} (9.62)	28.26^{a} (16.41)	37.67^{a} (22.13)	25.68 (14.88)
	5%	2.79 (1.81)	15.34^{d} (8.82)	25.67^{d} (14.88)	33.76^{b} (19.73)	1.85 (1.53)	21.84^{c} (12.62)	36.26^{c} (21.26)	49.59^{c} (29.73)	29.26 (17.01)
Azadirachta indica	2%	2.88 (1.84)	6.08^{e} (3.49)	10.84^{e} (6.22)	16.06^{e} (9.24)	2.51 (1.74)	6.08^{e} (3.48)	10.62^{e} (6.10)	17.19^{e} (9.90)	11.08 (6.36)
	3%	3.18 (1.92)	9.09^{d} (5.21)	14.20^{e} (8.16)	18.89^{d} (10.89)	2.58 (1.75)	10.35^{de} (5.94)	14.26^{c} (8.20)	19.56^{c} (11.28)	14.36 (8.26)
	4%	2.78 (1.81)	9.44^{e} (5.42)	14.82^{e} (8.52)	20.65^{d} (11.92)	2.20 (1.64)	15.33^{d} (8.82)	25.64^{d} (14.86)	32.52^{d} (18.98)	19.17 (11.05)
Cymbopogan winterianus	4%	2.79 (1.81)	4.46^{e} (2.56)	9.43^{e} (5.41)	13.53^{e} (7.78)	2.61 (1.76)	4.72^{e} (2.71)	11.17^{c} (6.41)	14.01^{e} (8.06)	9.52 (5.46)
	5%	3.19 (1.92)	5.10^{e} (2.92)	10.99^{e} (6.31)	13.73^{e} (7.89)	2.75 (1.80)	4.95^{e} (2.84)	9.59^{d} (5.50)	14.23^{d} (8.18)	9.78 (5.61)
	6%	2.83 (1.82)	7.45^{e} (4.27)	11.94^{e} (6.86)	15.11^{e} (8.69)	2.40 (1.70)	8.39^{e} (4.81)	13.72^{e} (7.89)	18.49^{e} (10.65)	12.43 (7.14)
Eucalyptus globules	4%	2.85 (1.83)	6.11^{e} (3.51)	10.04^{e} (5.76)	14.45^{e} (8.31)	2.58 (1.75)	5.90^{e} (3.38)	9.81^{e} (5.63)	15.75^{e} (9.06)	10.33 (5.93)
	5%	2.79 (1.81)	5.84^{e} (3.35)	11.37^{e} (6.53)	15.45^{ed} (8.89)	2.36 (1.69)	7.70^{ed} (4.42)	11.99^{dc} (6.89)	18.85^{c} (10.86)	11.78 (6.76)
	6%	2.95 (1.86)	8.02^{e} (4.60)	11.85^{e} (6.80)	16.53^{ed} (9.52)	2.46 (1.72)	8.12^{e} (4.66)	13.23^{e} (7.60)	18.33^{e} (10.56)	12.63 (7.26)
Dimethoate 30 EC	0.01%	2.85 (1.83)	52.29^{c} (31.53)	82.01^{c} (55.09)	96.58^{c} (74.97)	0.09 (0.77)	100.00^{c} (90.00)	100.00^{c} (90.00)	100.00^{b} (90.00)	77.67 (50.96)
	0.02%	3.28 (1.94)	57.05^{a} (34.79)	90.47^{c} (64.79)	98.89^{a} (81.47)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{e} (0.00)	0.00^{e} (0.00)	82.14 (55.22)
	0.03%	2.84 (1.83)	54.71^{c} (33.17)	91.72^{c} (66.53)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	82.14 (55.23)
Control	0%	2.99 (1.87)	0	0	0	3.45 (1.99)	0	0	0	0
	0%	2.93 (1.85)	0	0	0	3.23 (1.93)	0	0	0	0
	0%	3.01 (1.87)	0	0	0	3.35 (1.96)	0	0	0	0
S.E.m±		NS	0.14	0.22	0.15	0.00	0.13	0.27	0.29	
S.E.m±		0.00	0.12	0.22	0.27	0.00	0.17	0.22	0.20	
S.E.m±		NS	0.14	0.35	0.32	0.00	0.17	0.51	1.30	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration
*Table figures are mean values, Figures in parentheses are angular transformed values
Within column values with different letter(s) are significantly different (P=0.05) by DMRT

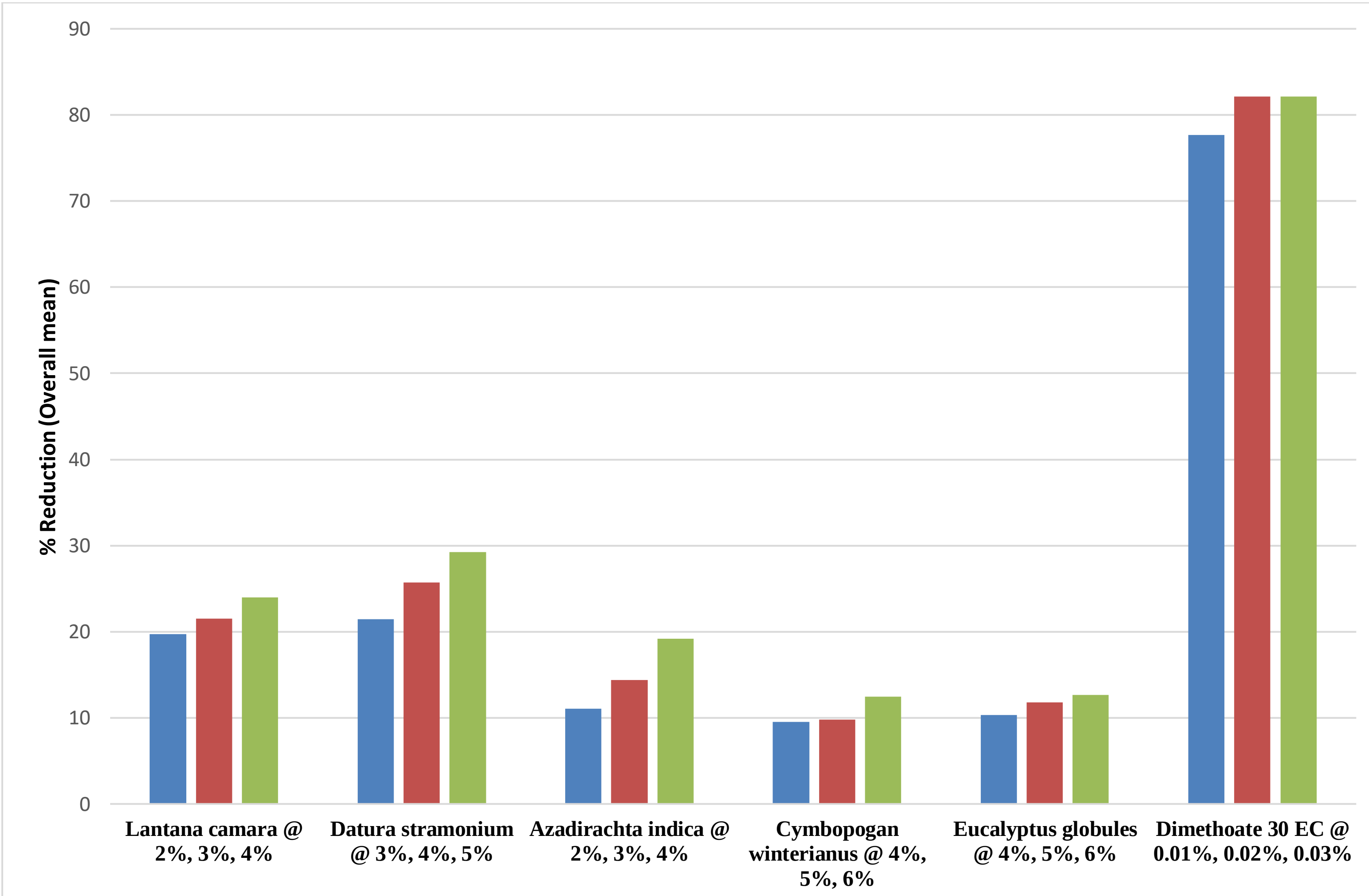

Fig. 4.7 Efficacy of plant extracts against Aphids, *Aphis craccivora* (2018-2020 Pooled data)

Plate 13: Aphids (*Aphid craccivora* Koch)

Plate 14: Thrips (*Megaleurothrips usitatus* Bagnal)

Plate 15: Leafhopper (*Empoasca fabae* Harris)

Plate 16: Whitefly (*Bemisia tabaci* Gennadius)

the concentration *i.e.* @ 2 % (19.71 %), 3% (21.52 %) and 4% (24.0 %) and *A. indica* for all the concentration *i.e.* @ 2 % (11.08 %), 3 % (14.36 %) and 4 % (19.17 %). The lowest efficacy of percentage reduction from overall mean for aphid (aphid index) was seen in *C. winterianus* for all the concentration *i.e.* @ 4 % (9.52 %), 5% (9.78 %) and 6 % (12.43%) followed by *E. globules* @ 4 % (10.33 %), 5% (11.78 %) and 6 % (12.43 %). However, in untreated control from overall mean it was observed that there was no significant reduction percentage of the pest population.

For Aphid in all the 3 concentrations of all the plant extracts used the highest percentage reduction from overall mean was observed in *D. stramonium* @ 5 % (29.26 %) and the lowest percentage reduction from overall mean was observed from *C. winterianus* @ 4 % (9.52 %). Based on the study the highest reduction percentage after 3, 7 and 14 days of 1st and 2nd spray over days after spray was observed in *D. stramonium* @ 5 % (49.59 %) in 14 days after 2nd spray and the lowest reduction percentage was observed in *C. winterianus* @ 4 % (4.46 %) in 3 days after 1st spraying. Based on the study the efficacy order of plant products in percentage reduction from overall mean of aphid population (Aphid index) are as follows *D. stramonium* > *L. camara* > *A. indica* > *E. globules* > *C. winterianus*.

The result of the present findings are comparable to some prior researchers Khan *et al*. (2013) who reported that datura proved to be the most effective botanical for significant reduction of aphid population which was followed by neem oil and the least effective botanical reduction of aphid population was observed in eucalyptus. Similar findings from Choudhary *et al*. (2017) where chemical treatment used for efficacy against *Aphis craccivora*, dimethoate (0.03%) was found to rank in the middle order of efficacy and the treatment neem (0.02%) proved least effective against aphid on cowpea.

4.3.2 Whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)

In the present study from the Table 4.7 and Fig 4.8 revealed that there was statistical significance among the treatments after spray except in *C. winterianus* for 5% concentration of 2nd spray on 3rdday after spraying which was statistically non significant. Among the different treatments with different concentration values the standard check Dimethoate 30 EC recorded the highest reduction percentage from overall mean in whitefly population for all the concentrations followed by *D. stramonium* for plant products. Among the botanicals the lowest reduction percentage from overall mean for whitefly population was observed in *C. winterianus* followed by *E. globules.*The results show that the per cent reduction increases with the increase in concentration and time after 1st and 2nd spray.

From different treatments with different concentration values Table 4.7 and Fig 4.8, the standard check Dimethoate 30 EC recorded the highest reduction percentage from over all mean in whitefly population for all the concentrations that is @ 0.01 % (75.79 %), @ 0.02 % (81.74 %) and @ 0.03% (82.72 %). For the plant products the highest reduction percentage from overall mean for whitefly population was observed in *D. stramonium* for all the concentration *i.e.* @ 3% (26.68 %), 4 % (29.47 %) and 5 % (38.72 %) followed by *L. camara* for all the concentration *i.e.* @ 2 % (25.02 %), 3 % (27.63 %) and 4 % (33.41 %) and *A. indica* for the concentration *i.e.* @ 2 % (14.60 %), 3 % (19.42 %) and 4 % (22.56%). The lowest efficacy of percentage reduction from overall mean for whitefly population was seen in *C. winterianus* for all the concentration *i.e.*@ 4 % (12.76 %), 5 % (13.33 %) and 6 % (16.32 %) followed by *E. globules* @ 4 % (15.75 %), 5 % (18.88 %) and 6 % (18.26 %). Here, only for concentration @ 4 % (15.75 %) in *E. globules* were found to be more effective in percentage reduction in comparison with *A. indica* @ 2 % (14.60 %) concentration. However, in untreated control from overall mean it was observed that there were no significantly reduction percentages of the pest population.

For whitefly in all the 3 concentrations of all the plant extract used the highest percentage reduction from overall mean was observed in *D. stramonium* @ 5 % (38.72 %) and the lowest percentage reduction from overall mean was observed from *C. winterianus* @ 4 % (12.76 %). Based on the study the highest reduction percentage after 3, 7 and 14 days of 1st and 2nd spray over days after spray was observed in *D. stramonium* @ 5 % (68.39 %) in 14 days after 2nd spray and the lowest reduction percentage was observed in *C. winterianus* @ 4 % (5.79 %) in 3 days after 1st spraying. Based on the study the efficacy order of plant products percentage reduction from overall mean of whitefly population are as follows *D. stramonium* > *L. camara* > *A. indica* > *E. globules* >*C. winterianus*.

The result of the present findings are in contrast with the experiment carried out by Shahzad *et al*. (2017) where the results revealed that for whitefly in brinjal the neem spray resulted the highest reduction percentage followed by tobacco and Datura. Also contrasting finding by Iqbal *et al*. (2015) where neem resulted to be the most effective and significant in whitefly population reduction than datura on okra. Here, in this present experiment the result for whitefly pest population reduction *i.e* datura and lantana proved to be the most effective botanical which shows a different result and contrast with other findings. The contrast or difference in these present findings may be noted due to certain reasons that the experiment was carried on different crops where specific reviews cannot be found due to none availability of research materials. Research works done in different geographical area in field condition such as different climate and weather condition could have also been a factor for variation in research findings.

Table 4.7 Efficacy of plant extracts against whitefly, *Bemisia tabaci* (2018-2020 pooled data)

Treatments	Conc.	*Reduction % of Whitefly								
		1st spray				2nd spray				Overall mean
		1DBS	3DAS	7DAS	14DAS	1DBS	3 DAS	7 DAS	14DAS	
Lantana camara	2%	29.23 (5.45)	11.00^{d} (6.32)	20.19^{d} (11.65)	30.06^{d} (17.50)	20.30 (4.56)	17.24^{c} (9.93)	31.06^{c} (18.09)	46.67^{d} (27.82)	25.02 (14.49)
	3%	34.06 (5.88)	14.08^{d} (8.09)	25.89^{c} (15.00)	34.21^{c} (20.00)	22.34 (4.78)	18.13 (10.45)	34.10^{e} (19.94)	43.97^{e} (26.08)	27.63 (16.04)
	4%	37.20 (6.14)	19.01^{c} (10.96)	31.12^{c} (18.13)	39.79^{c} (23.45)	22.31 (4.78)	24.16^{c} (13.98)	40.78^{c} (24.07)	52.44^{c} (31.63)	33.41 (19.52)
Datura stramonium	3%	33.50 (5.83)	13.06^{d} (7.50)	24.50^{c} (14.18)	32.11^{d} (18.73)	22.61 (4.81)	17.51^{c} (10.08)	32.65^{c} (19.06)	45.20^{d} (26.87)	26.68 (15.47)
	4%	36.03 (6.04)	14.39^{d} (8.27)	26.42^{c} (15.32)	36.25^{c} (21.25)	22.85 (4.83)	18.73 (10.79)	35.70^{e} (20.92)	51.91^{e} (31.28)	29.47 (17.14)
	5%	29.87 (5.51)	20.57^{c} (11.87)	33.71^{c} (19.70)	46.28^{b} (27.57)	15.94 (4.05)	27.24^{b} (15.81)	49.75^{b} (29.84)	68.39^{b} (43.15)	38.72 (22.78)
Azadirachta indica	2%	33.50 (5.83)	7.50^{e} (4.30)	13.62^{e} (7.83)	19.63^{e} (11.32)	26.76 (5.22)	8.36^{e} (4.80)	15.93^{e} (9.16)	23.31^{e} (13.48)	14.60 (8.39)
	3%	36.05 (6.05)	9.88^{e} (5.67)	17.48^{d} (10.06)	22.99^{d} (13.29)	27.71 (5.31)	14.21 (8.17)	23.00^{fe} (13.30)	31.35^{e} (18.27)	19.42 (11.20)
	4%	33.89 (5.86)	12.76^{d} (7.33)	20.21^{d} (11.66)	26.45^{d} (15.34)	24.89 (5.04)	16.42^{d} (9.45)	27.02^{d} (15.68)	35.46^{d} (20.77)	22.56 (13.04)
Cymbopogan winterianus	4%	31.95 (5.70)	5.79^{e} (3.32)	11.85^{e} (6.81)	17.21^{e} (9.91)	26.39 (5.19)	7.25^{e} (4.16)	14.16^{e} (8.14)	21.03^{e} (12.14)	12.76 (7.33)
	5%	36.64 (6.09)	6.76^{e} (3.87)	12.49^{e} (7.17)	17.20^{e} (9.90)	30.28 (5.55)	8.55 (4.90)	14.70^{fe} (8.45)	21.02^{fe} (12.13)	13.33 (7.66)
	6%	33.23 (5.81)	8.65^{e} (4.96)	15.46^{e} (8.90)	20.88^{e} (12.05)	26.24 (5.17)	10.24^{b} (5.88)	18.01^{e} (10.37)	25.73^{e} (14.91)	16.32 (9.39)
Eucalyptus globules	4%	30.93 (5.61)	7.60^{e} (4.36)	14.67^{e} (8.44)	20.98^{e} (12.11)	24.33 (4.98)	10.89^{d} (6.25)	19.42^{d} (11.20)	22.10^{e} (12.77)	15.76 (9.07)
	5%	29.04 (5.43)	9.94^{e} (5.71)	16.70^{d} (9.61)	22.26^{d} (12.86)	22.53 (4.80)	13.10 (7.53)	22.31^{fe} (12.89)	31.19^{e} (18.17)	18.88 (10.88)
	6%	31.80 (5.68)	10.18^{e} (5.84)	16.67^{e} (9.59)	22.72^{e} (13.13)	24.46 (5.00)	12.21^{e} (7.01)	20.90^{e} (12.06)	28.41^{e} (16.51)	18.26 (10.52)
Dimethoate 30 EC	0.01%	34.61 (5.93)	51.90^{c} (31.26)	80.25^{b} (53.37)	93.21^{c} (68.77)	0.96 (1.21)	100.00^{b} (90.00)	100.00^{b} (90.00)	100.00^{c} (90.00)	75.79 (49.28)
	0.02%	32.31 (5.73)	60.27^{c} (37.06)	86.69^{b} (60.10)	97.91^{b} (78.27)	0.21 (0.84)	100.00 (90.00)	100.00^{e} (90.00)	100.00^{e} (90.00)	81.74 (54.83)
	0.03%	32.38 (5.73)	59.77^{b} (36.70)	89.73^{b} (63.81)	98.34^{a} (79.54)	0.20 (0.84)	100.00^{f} (90.00)	100.00^{f} (90.00)	100.00^{f} (90.00)	82.72 (55.81)
Control	0%	32.55 (5.75)	0	0	0	36.61 (6.09)	0	0	0	0
	0%	29.73 (5.50)	0	0	0	33.41 (5.82)	0	0	0	0
	0%	36.09 (6.05)	0	0	0	39.28 (6.31)	0	0	0	0
S.E.m±		0.14	0.12	0.17	0.25	0.14	0.07	0.13	0.93	
S.E.m±		0.14	0.20	0.26	0.13	0.11	(NS)	17.22	17.58	
S.E.m±		0.15	0.07	0.14	0.22	0.14	0.09	0.19	0.33	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Table figures are mean values, Figures in parentheses are angular transformed values

Within column values with different letter(s) are significantly different (P=0.05) by DMRT

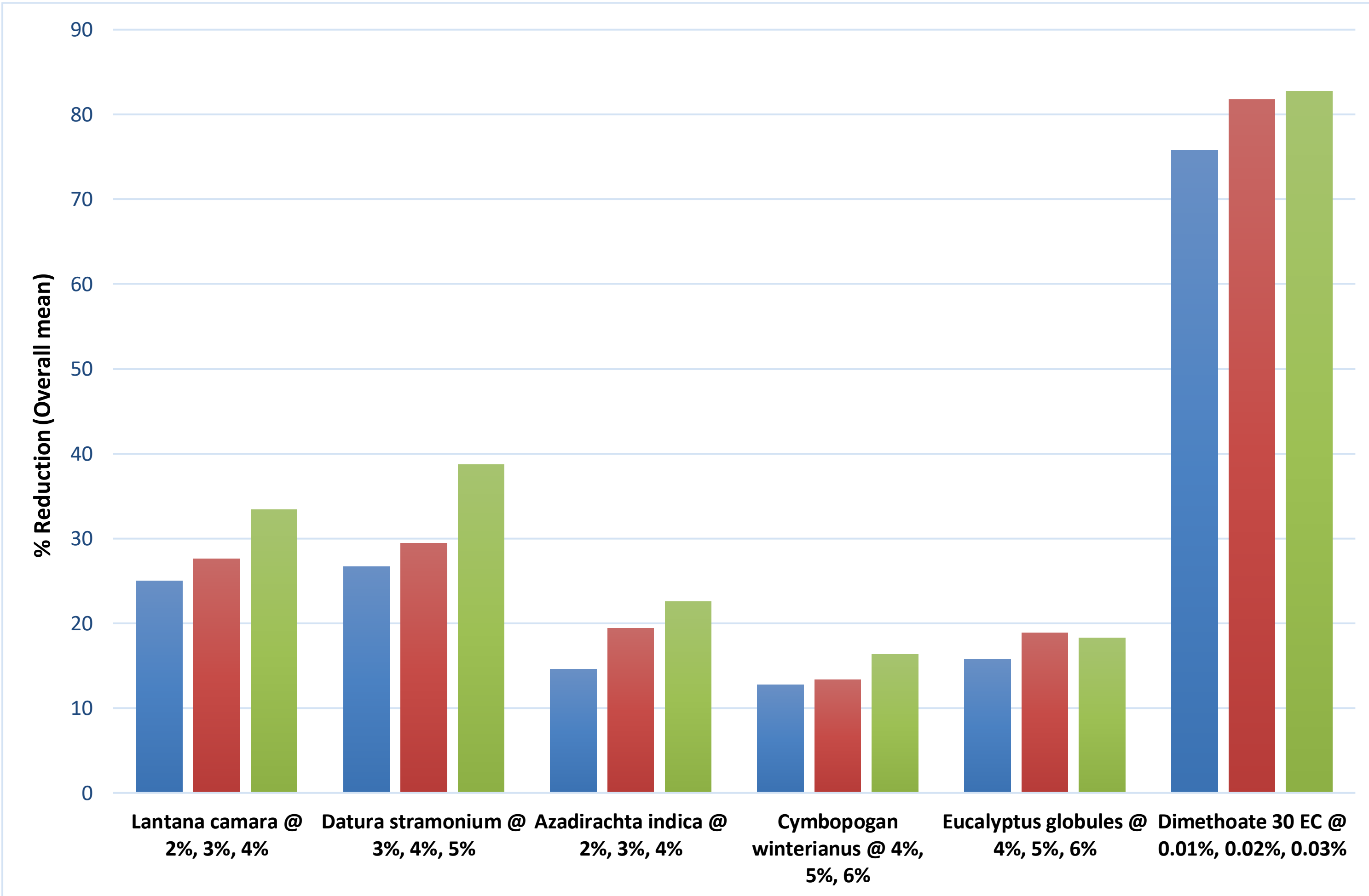

Fig. 4.8 Efficacy of plant extracts against whitefly, *Bemisia tabaci* (2018-2020 pooled data)

4.3.3 Leafhopper, *Empoasca fabae* Harris (Hemiptera: Cicadellidae)

In the present study from the Table 4.8 and Fig 4.9 revealed that there was statistical significance among the treatments after spray except in *E. globules* @6% in all the 1st and 2nd days of spraying which was statistically non significant. Among the different treatments with different concentration values the standard check Dimethoate 30 EC recorded the highest reduction percentage from overall mean in leafhopper population for all the concentrations followed by *D. stramonium* for plant products. Among the botanicals the lowest reduction percent from overall mean for leafhopper population was observed in *C. winterianus* followed by *L. camara.* The results show that the per cent reduction increases with the increase in concentration and time after sprays.

From different treatments with different concentration values Table 4.8 and Fig 4.9, the standard check Dimethoate 30 EC recorded the highest reduction percentage from overall mean in leafhopper population for all the concentrations that is @ 0.01 % (87.17 %), @ 0.02 % (89.12 %) and @ 0.03 % (92.10 %). For the plant products the highest reduction percentage from overall mean for leafhopper population was observed in *D. stramonium* for the concentration *i.e*. @ 3 % (56.65 %), 4 % (58.23 %) and 5 % (64.95 %) followed by *A. indica* for all the concentration *i.e*. @ 2 % (54.46 %), 3 % (62.61 %) and 4 % (63.76 %) and *E. globules* for the concentration *i.e*. @ 4% (48.43%), 5% (58.17 %) and 6 % (63.77 %). The lowest efficacy of percentage reduction from overall mean for leafhopper population was seen in *C. winterianus* for all the concentrations *i.e*. @ 4 % (51.36 %), 5 % (52.29 %) and 6 % (58.62 %) followed by *L. camara* @ 2 % (52.67 %), 3 % (55.54 %) and 4 % (59.36 %). Here, for concentration @ 3 % (62.61 %) in *A. indica* was found to be more effective in percentage reduction from overall mean in comparison with *D. stramonium* @ 4 % (58.23 %) concentration. Also for concentration @

Table 4.8 Efficacy of plant extracts against leafhopper, *Empoasca fabae* (2018-2020 pooled data)

Treatments	Conc.	*Reduction % of leafhopper								
		1st spray				2ndspray				Overall mean
		1DBS	3 DAS	7 DAS	14DAS	1DBS	3DAS	7 DAS	14DAS	
Lantana camara	2%	9.14 (3.10)	26.63^{dc} (15.44)	47.15^{d} (28.13)	62.61^{c} (38.76)	3.36 (1.97)	47.46^{e} (28.33)	75.46^{e} (48.99)	93.80^{d} (69.73)	52.67 (31.78)
	3%	8.74 (3.04)	28.42^{ed} (16.51)	49.98^{d} (29.98)	65.81^{d} (41.15)	2.91 (1.85)	51.79^{e} (31.19)	82.12^{e} (55.20)	100.00^{d} (90.00)	55.54 (33.74)
	4%	9.23 (3.12)	34.30^{c} (20.06)	55.51^{ed} (33.71)	69.90^{e} (44.35)	2.73 (1.80)	54.59^{e} (33.08)	88.84^{e} (62.67)	96.94^{d} (75.79)	59.36 (36.41)
Datura stramonium	3%	8.45 (2.99)	29.03^{c} (16.88)	54.07^{c} (32.73)	71.07^{b} (45.29)	2.36 (1.69)	45.50^{e} (27.07)	84.48^{e} (57.65)	96.47^{d} (74.74)	56.65 (34.51)
	4%	8.71 (3.04)	29.56^{d} (17.19)	56.72^{c} (34.55)	73.22^{c} (47.07)	2.26 (1.66)	52.67^{e} (31.78)	82.69^{e} (55.78)	97.79^{d} (77.93)	58.23 (35.61)
	5%	9.05 (3.09)	39.32^{b} (23.15)	64.13^{b} (39.89)	78.78^{d} (51.98)	1.85 (1.53)	62.61^{ed} (38.76)	93.92^{c} (69.92)	100.00^{c} (90.00)	64.95 (40.50)
Azadirachta indica	2%	9.09 (3.10)	26.55^{dc} (15.40)	47.59^{dc} (28.42)	59.83^{dc} (36.75)	3.61 (2.03)	55.02^{e} (33.38)	85.12^{e} (58.34)	97.23^{d} (76.49)	54.46 (33.00)
	3%	9.69 (3.19)	32.52^{cd} (18.98)	59.10^{c} (36.23)	79.35^{b} (52.52)	1.91 (1.55)	74.51^{c} (48.17)	98.69^{c} (80.73)	100.00^{d} (90.00)	62.61 (38.76)
	4%	9.00 (3.08)	33.33^{c} (19.47)	59.31^{dc} (36.37)	78.33^{d} (51.57)	1.89 (1.55)	88.08^{c} (61.74)	100.00^{c} (90.00)	100.00^{c} (90.00)	63.76 (39.61)
Cymbopogan winterianus	4%	8.13 (2.94)	20.77^{ed} (11.99)	39.54^{e} (23.29)	56.31^{ed} (34.27)	3.53 (2.01)	57.09^{e} (34.81)	86.17^{e} (59.51)	97.16^{d} (76.32)	51.36 (30.90)
	5%	9.41 (3.15)	21.51^{e} (12.42)	41.30^{e} (24.39)	54.05^{e} (32.72)	4.30 (2.19)	58.72^{ed} (35.96)	86.34^{ed} (59.70)	99.42^{d} (83.82)	52.29 (31.53)
	6%	9.19 (3.11)	25.58^{e} (14.82)	53.06^{e} (32.05)	74.15^{ed} (47.86)	2.31 (1.68)	71.35^{d} (45.52)	96.22^{c} (74.19)	100.00^{c} (90.00)	58.62 (35.89)
Eucalyptus globules	4%	7.94 (2.90)	17.80^{e} (10.25)	41.10^{ed} (24.27)	52.13^{e} (31.42)	3.76 (2.06)	47.18^{e} (28.15)	75.42^{e} (48.95)	95.02^{e} (71.84)	48.43 (28.97)
	5%	7.96 (2.91)	26.69^{ed} (15.48)	53.22^{dc} (32.15)	70.49^{dc} (44.82)	2.24 (1.65)	65.92^{dc} (41.24)	94.41^{dc} (70.76)	100.00^{d} (90.00)	58.17 (35.57)
	6%	8.89 (3.06)	30.38 (17.69)	62.87 (38.95)	85.79 (59.09)	1.19 (1.30)	83.16 (56.26)	100.00 (90.00)	100.00 (90.00)	63.77 (39.62)
Dimethoate 30 EC	0.01%	9.68 (3.19)	66.93^{b} (42.01)	94.57^{b} (71.04)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	87.17 (60.65)
	0.02%	7.96 (2.91)	69.23^{c} (43.81)	98.12^{b} (78.86)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	89.12 (63.02)
	0.03%	8.01 2.92	76.29^{a} (49.72)	100.00^{a} (90.00)	100.00^{b} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{e} (0.00)	0.00^{e} (0.00)	92.10 (67.07)
Control	0%	10.04 (3.25)	0	0	0	11.08 (3.40)	0	0	0	0
	0%	8.66 (3.03)	0	0	0	9.79 (3.21)	0	0	0	0
	0%	7.98 (2.91)	0	0	0	9.23 (3.12)	0	0	0	0
S.E.m±		0.02	0.74	0.72	0.51	0.01	2.30	2.80	0.92	
S.E.m±		0.01	0.85	0.60	0.50	0.01	2.18	1.34	0.09	
S.E.m±		0.01	0.15	0.26	0.58	0.01	2.49	0.61	0.10	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Table figures are mean values, Figures in parentheses are angular transformed values

Within column values with different letter(s) are significantly different (P=0.05) by DMRT

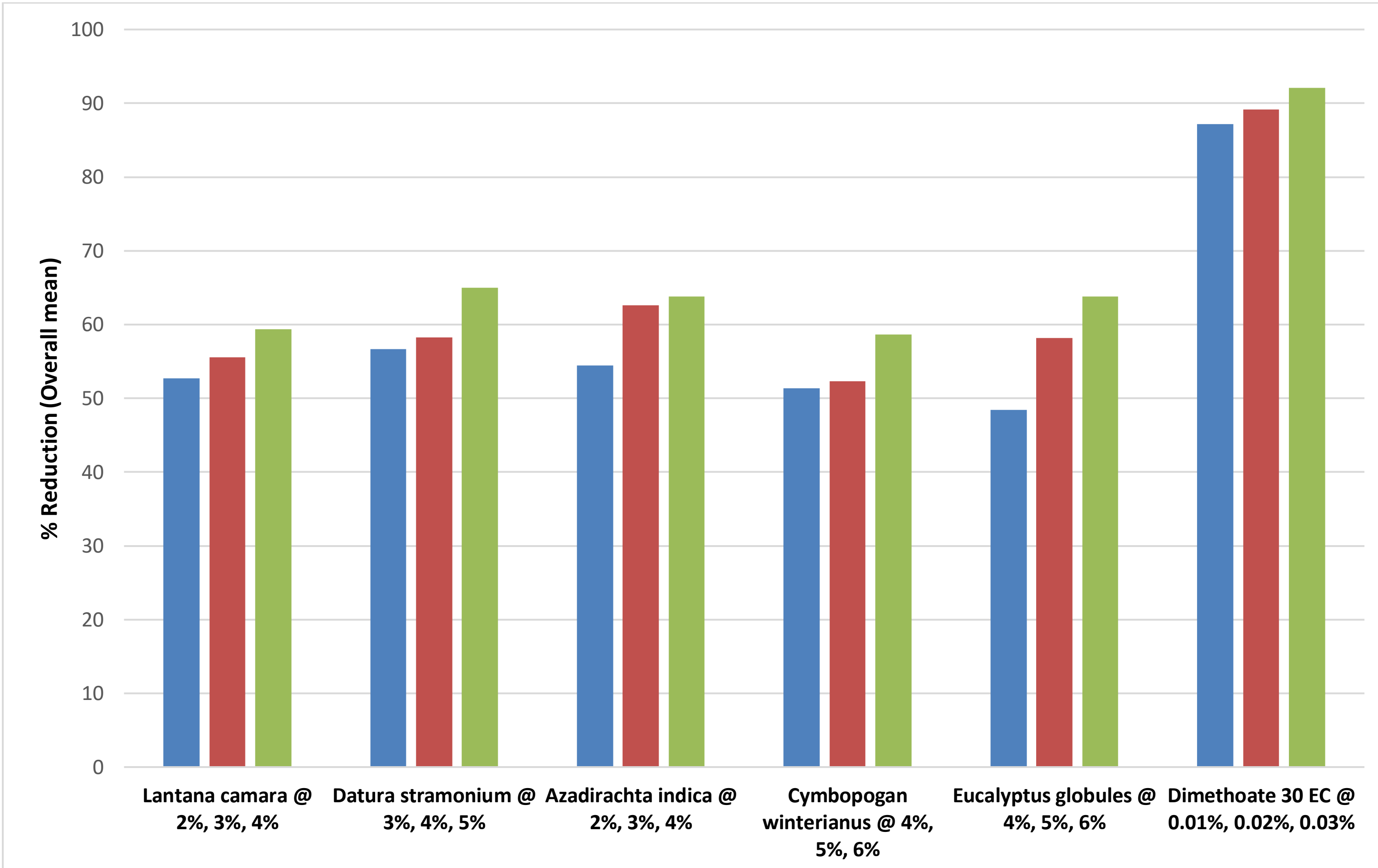

Fig. 4.9 Efficacy of plant extracts against leafhopper, *Empoasca fabae* (2018-2020 pooled data)

6 % (63.77 %) in *E. globules* was found to be more effective in percentage reduction from overall mean in comparison with *A. indica* @ 4 % (63.76 %) concentration. And also concentration @ 2 % (52.67 %) in *L. Camara* was found to be more effective in percentage reduction from overall mean in comparison with *E. globules* @ 4 % (48.43 %) concentration. However, in untreated control from overall mean it was observed that there was no significantly reduction percentage of the pest population.

For leafhopper in all the 3 concentrations of all the plant extract used the highest percentage reduction from overall mean was observed in *D. stramonium* @ 5 % (64.95 %) and the lowest percentage reduction from overall mean was observed from *E. globules* @ 4 % (48.43 %). Based on the study the highest reduction percentage after 3, 7 and 14 days of 1st and 2nd spray over days after spray was observed in *E. globules* @ 6 % (100 %) and *A. indica* @ 4 % (100 %)in 7 days after 2nd spray and *L. camara* 3 % (100 %), *D. stramonium* 5 % (100 %), *A. indica* @ 3 and 4 % (100 %), *C. winterianus* @ 6 % (100 %) and *E. globules* @ % % (100 %) and @ 6 % (100 % NS). The lowest reduction percentage was observed in *E. globules* @ 4 % (17.80 %) in 3 days after 1st spraying. Based on the study the efficacy order of plant products in percentage reduction from overall mean of leafhopper population are as follows *D. stramonium* > *A. indica* > *E. globules* > *L. camara* > *C. winterianus*.

4.3.4 Thrips, *Megaleurothrips usitatus* Bagnal (Thysanoptera: Thripidae)

In the present study from the Table 4.9 and Fig 4.10 revealed that there was statistical significance among the treatments after spray except in *D. stramonium* @ 3 % and 4 % which was non-significant. Among the different treatments with different concentration values the standard check Dimethoate 30 EC recorded the highest reduction percentage from overall mean in thrips population for all the concentrations followed by *D. stramonium* for plant products. Among the plant extract the lowest reduction percentage from overall mean for thrips population was observed in *C. winterianus* followed by *L. camara.*The results show that the per cent reduction increases with the increase in concentration and time after sprays.

From different treatments with different concentration values Table 4.9 and Fig 4.10, the standard check Dimethoate 30 EC recorded the highest reduction percentage from overall mean in thrips population for all the concentrations that is @ 0.01 % (85.97 %), @ 0.02 % (88.60 %) and @ 0.03 % (93.17 %). For the plant products the highest reduction percentage from overall mean for thrips population was observed in *D. stramonium* for the concentration *i.e*. @ 3 % (56.14 %), 4 % (62.01 % NS) and 5 % (66.97 % NS) followed by *E. globules* for the concentration *i.e*. @ 4 % (49.42 %), 5 % (56.79 %) and 6 % (60.51 %) and *A. indica* for the concentration *i.e.* @ 2 % (47.62 %), 3 % (61.41 %) and 4 % (59.95%). The lowest efficacy of percentage reduction from overall mean for thrips population was seen in *C. winterianus* for all the concentrations *i.e.*@ 4% (44.90 %), 5 % (50.64 %) and 6 % (56.26 %) followed by *L. camara* @ 2% (45.61 %), 3 % (57.50 %) and 4 % (58.60 %). Here, for concentration @ 3 % (61.41 %) in *A. indica* was found to be more effective in percentage reduction from overall mean in comparison with *L. camara* @ 3 % (57.50 %) and *E. globules* @ 5 % (56.79 %) concentration. However, in untreated control from overall mean it was observed that there was no significantly reduction percentage of the pest population.

For thrips in all the 3 concentrations of all the plant extracts used the highest percentage reduction from the overall mean was observed in *D. stramonium* @ 5 % (66.97 %) and the lowest percentage reduction from overall mean was observed and recorded in *C. winterianus* @ 4 % (44.90 %). Based on the study the highest reduction percentage after 3, 7 and 14 days of 1st and 2nd spray over days after spray was observed in *A. indica* @ 4 % (100 %) in 7 days after 2nd spray and *D. stramonium* 5 % (100 %), *A. indica* @ 4 % (100 %), *C.*

Table 4.9 Efficacy of plant extracts against Thrips, *Megaleurothrips usitatus* (2018-2020 pooled data)

Treatments	Conc.	*Reduction % of Thrips								
		1st spray				2^{nd}spray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	11.70 (3.49)	20.52^{e} (11.84)	41.11^{e} (24.27)	54.97^{e} (33.35)	5.20 (2.39)	35.18^{e} (20.60)	64.26^{e} (39.99)	82.85^{e} (55.95)	45.61 (27.13)
	3%	8.80 (3.05)	29.86^{dc} (17.38)	53.10^{dc} (32.07)	66.64^{d} (41.79)	2.88 (1.84)	57.10^{ed} (34.82)	88.41^{ed} (62.14)	97.10^{d} (76.17)	57.50 (35.10)
	4%	8.52 (3.00)	32.42^{d} (18.92)	55.35^{d} (33.61)	72.96^{d} (46.85)	2.28 (1.67)	49.45^{e} (29.64)	86.45^{e} (59.82)	96.34^{d} (74.44)	58.60 (35.87)
Datura stramonium	3%	9.53 (3.17)	28.42 (16.51)	53.39 (32.27)	69.13 (43.73)	2.89 (1.84)	52.67 (31.78)	82.11 (55.19)	91.34 (65.98)	56.14 (34.15)
	4%	7.73 (2.87)	33.48 (19.56)	61.29 (37.80)	76.12 (49.57)	1.91 (1.55)	58.39 (35.72)	91.07 (65.60)	97.82 (78.02)	62.01 (38.33)
	5%	9.88 (3.22)	41.77 (24.69)	65.70 (41.07)	80.42 (53.53)	1.89 (1.55)	71.08 (45.30)	98.01 (78.56)	100.00 (90.00)	66.97 (42.05)
Azadirachta indica	2%	10.16 (3.27)	20.79^{e} (12.00)	38.99^{e} (22.95)	51.91^{e} (31.27)	4.80 (2.30)	42.97^{ed} (25.45)	72.66^{e} (46.60)	93.23^{dc} (68.79	47.62 (28.44)
	3%	7.95 (2.91)	29.40^{dc} (17.10)	56.29^{cb} (34.26)	71.86^{dc} (45.94)	2.20 (1.64)	82.39^{c} (55.47)	98.30^{c} (79.41)	100.00^{d} (90.00	61.41 (37.89)
	4%	9.60 (3.18)	31.38^{d} (18.29)	51.04^{d} (30.69)	63.54^{e} (39.45)	3.36 (1.97)	76.58^{ed} (49.98)	100.00^{d} (90.00)	100.00^{c} (90.00)	59.95 (36.83)
Cymbopogan winterianus	4%	10.05 (3.25)	17.91^{e} (10.32)	36.69^{e} (21.53)	51.62^{e} (31.08)	4.79 (2.30)	37.86^{e} (22.25)	67.89^{e} (42.75)	88.77^{ed} (62.59)	44.90 (26.68)
	5%	10.55 (3.32)	22.75^{e} (13.15)	40.17^{e} (23.68)	54.15^{e} (32.78)	4.71 (2.28)	49.34^{e} (29.56)	81.96^{e} (55.05)	98.67^{d} (80.66)	50.64 (30.43)
	6%	9.68 (3.19)	23.39^{e} (13.52)	43.93^{e} (26.06)	57.88^{e} (35.37)	3.98 (2.12)	76.10^{ed} (49.55)	98.74^{d} (80.90)	100.00^{c} (90.00)	56.26 (34.23)
Eucalyptus globules	4%	10.10 (3.26)	21.29^{e} (12.29	38.24^{e} (22.48)	54.08^{e} (32.74)	4.59 (2.26)	44.96^{ed} (26.72)	81.47^{d} (54.56)	98.09^{c} (78.79)	49.42 (29.62)
	5%	10.11 (3.26)	26.95^{ed} (15.63)	46.11^{e} (27.46)	66.63^{d} (41.78)	3.26 (1.94)	68.58^{d} (43.30)	96.93^{c} 75.78)	100.00^{d} (90.00)	56.79 (34.60)
	6%	8.73 (3.04)	29.80^{d} (17.34)	51.58^{d} (31.05)	70.49^{c} (44.82)	2.51 (1.74)	85.07^{c} (58.29)	99.50^{d} (84.28)	100.00^{c} (90.00)	60.51 (37.24)
Dimethoate 30 EC	0.01%	10.66 (3.34)	61.31^{c} (37.82)	96.72^{e} (75.28)	99.88^{c} (87.23)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	85.97 (59.28)
	0.02%	10.49 (3.31)	67.34^{c} (42.33)	98.45^{b} (79.90)	100.00^{c} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	88.60 (62.37)
	0.03%	9.15 (3.11)	80.87^{b} (53.97)	98.63^{b} (80.52)	100.00^{b} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	93.17 (68.70)
Control	0%	8.86 (3.06)	0	0	0	10.11 (3.26)	0	0	0	0
	0%	9.89 (3.22)	0	0	0	10.99 (3.39)	0	0	0	0
	0%	9.14 (3.10)	0	0	0	10.19 (3.27)	0	0	0	0
S.E.m±		0.02	0.22	0.40	0.29	0.01	1.86	1.62	0.85	
S.E.m±		0.01	0.49	0.93	0.65	0.01	3.55	0.64	0.26	
S.E.m±		0.01	0.30	0.64	0.60	0.01	2.52	0.57	0.12	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Table figures are mean values, Figures in parentheses are angular transformed values

Within column values with different letter(s) are significantly different (P=0.05) by DMRT

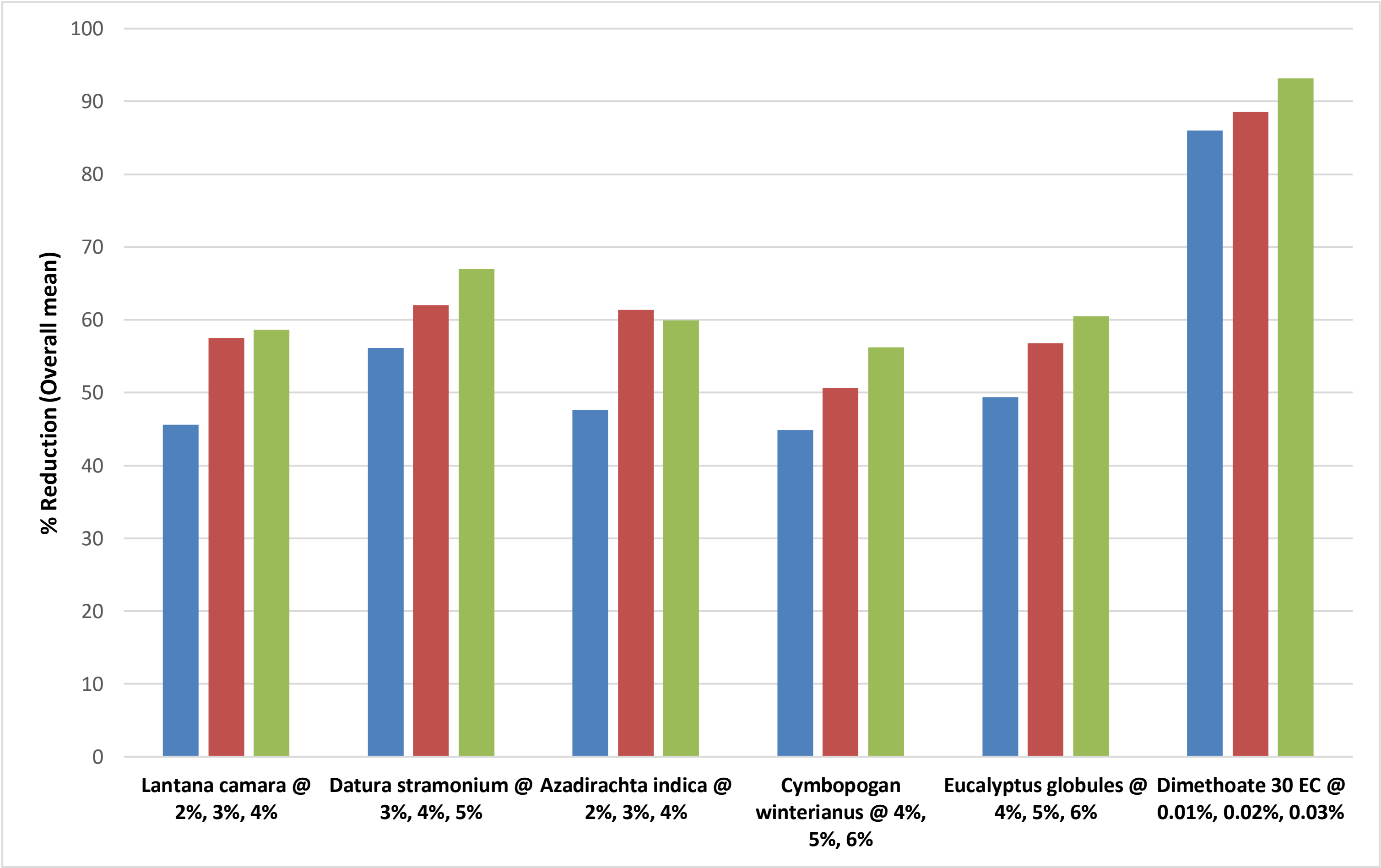

Fig. 4.10 Efficacy of plant extracts against Thrips, *Megaleurothrips usitatus* (2018-2020 pooled data)

winterianus @ 6 % (100 %) and *E. globules* @ 5 % (100 %) and @ 6 % (100 %). The lowest reduction percentage was observed in *C. winterianus* @ 4 % (17.91 %) in 3 days after 1st spraying. Based on the study the efficacy order of plant products in percentage reduction from overall mean of thrips population are as follows *D. stramonium* > *A. indica* > *E. globules* > *L. camara* > *C. winterianus*.

The result of the present findings are comparable to some prior researchers Khan *et al*. (2013) reported that datura proved to be the most effective botanical for significant reduction for thrips population which was followed by neem oil and eucalyptus. More or less similar findings by Singh *et al*. (2014) reported that the most effective biopesticides against thrips on garlic was observed in kalmegh and the efficacy was similar to 0.03% dimethoate followed by *Lantana camara* and *Azadirachta indica*.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The result of the present investigation carried on "**Biorational management against sucking pests of French bean (*Phaseolus vulgaris* L.)**" was conducted in the field and laboratory of department of Entomology, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus during 2017 to 2020. The result on the study of seasonal incidence of sucking pests of French bean and their natural enemies, bioassay of different botanical extracts against the aphids in laboratory conditions, evaluate the field efficacy of different botanicals extract against sucking pests of French bean are summarized in this chapter. The significant findings from this experiment are summarized below:

1. A local cultivar French bean named Jiphu Yak kholar was collected from Kiphire and Tuensang districts of Nagaland for the experimental study.
2. In seasonal incidence of major sucking pest, during 2017 to 2018 the major sucking pest observed were aphids (*Aphis craccivora* Koch), thrips (*Megaleurothrips usitatus* Bagnal) and whitefly (*Bemisia tabaci* Gennadius).
3. In seasonal incidence of aphid (*Aphis craccivora* Koch), pest population was observed from the 2nd week of sowing (WAS) *i.e.* the 1st week of October with 1.13 aphid index, and the population continuously kept on increasing till the 9th week after sowing and reached to a peak level of 3.85 aphid index on the 10th weeks after sowing, where generally coinciding with the peak stage of flowering and pod formation in the last week of November to 1st week of December.
4. For seasonal incidence of thrips (*Megaleurothrips usitatus* Bagnal), pest population was observed from the 5th week after sowing (WAS) *i.e.* the 4thweek of October with 0.63 on 3 leaves per plant and population

continuously kept on increasing till the 9^{th} week after sowing reaching to a peak level of 7.38 (3 leaves per plant) on the 10^{th} weeks after sowing. The peak activity of thrips pest population was seen from 5^{th} to 12^{th} weeks after sowing. And thereafter, the thrips population gradually decreased and eventually decreases to zero when the pods were matured for harvest.

5. For seasonal incidence of whitefly (*Bemisia tabaci* Gennadius), the pest population was observed from the 4^{th} week after sowing (WAS) *i.e*. the 3^{rd} week of October with 1.13 on 3 leaves per plant. Further the population continuously increased till the 9^{th} week after sowing and reached to a peak level of 9.25 (3 leaves per plant) on the 10^{th} weeks after sowing. The peak activity of whitefly pest population was seen from 4^{th} to 12^{th} weeks after sowing.
6. For correlation of weather parameters with the pest population viz. aphid (*Aphis craccivora* Koch), thrips (*Megaleurothrips usitatus* Bagnal) and whitefly (*Bemisia tabaci* Gennadius). Rainfall parameters (r = -0.544* and r = -0.503*) showed negatively significant correlation for both Aphids and thrips population in French bean.
7. Coccinellids were observed with highest population density in 9^{th} week after sowing *i.e*. 47^{th} SMW (6.75 coccinellids / 6 plants) and for rober fly (*Dysmachus trigonus*) the highest attended density was observed in 10^{th} week after sowing *i.e*. 48^{th} SMW (4.25 / 6 plants). The highest attended density for spiders was observed in 8^{th} week after sowing *i.e*. 46^{th} SMW (6.60 / 6 plants).
8. For the bioassay on toxicity of plant extracts on aphid (*Aphis craccivora* Koch), the results from the probit analysis at 24, 48 and 72 hours showed that the standard check dimethoate 30 EC was the most toxic @ 0.01 %.

9. In bioassay toxicity of plant extracts for aphid, *L. camara* and *A. indica* extract @ 3 % concentration reported the highest mortality followed by *D. stramonium* extract @ 4 % at 24 hours after treatment. While *E. globules* and *C. winterianus*@ 5% reported the lowest mortality at 72 hours after treatment.
10. Based on the study the order of toxicity of plant products based on probit analysis was *A. indica* > *L. camara* > *D. stramonium* > *C. winterianus* > *E. globules*.
11. For evaluation of field efficacy on different botanical extracts among the different treatments with different concentration values the standard check dimethoate 30 EC recorded the highest reduction percentage from overall mean for all the sucking pest *i.e*. aphid @ 0.01 % (77.67 %), @ 0.02 % (82.14 %) and @ 0.03 % (82.14 %), Whitefly @ 0.01 % (75.79 %), @ 0.02 % (81.74 %) and @ 0.03 % (82.72 %), Leafhopper @ 0.01 % (87.17 %), @ 0.02 % (89.12 %) and @ 0.03 % (92.10 %) and Thrips @ 0.01 % (85.97 %), @ 0.02 % (88.60 %) and @ 0.03 % (93.17 %).
12. For the plant products the highest reduction percentage from overall mean for aphids was observed in *D. stramonium* for all the concentration *i.e*. @ 3 % (21.47 %), 4 % (25.68 %) and 5 % (29.26 %) and lowest efficacy of percentage reduction from overall mean for aphid (aphid index) was seen in *C. winterianus* for all the concentration *i.e*. @ 4 % (9.52 %), 5 % (9.78 %) and 6 % (12.43 %).
13. Based on the study the efficacy order of plant products in percentage reduction from overall mean of aphid population (Aphid index) were as follows; *D. stramonium* > *L. camara* > *A. indica* > *E. globules* > *C. winterianus*.
14. For the plant products the highest reduction percentage from overall mean for whitefly population was observed in *D. stramonium* for all the concentration *i.e.* @ 3 % (26.68 %), 4 % (29.47 %) and 5 % (38.72 %)

followed by *L. camara* and *A. indica*. The lowest efficacy of percentage reduction from overall mean for whitefly population was seen in *C. winterianus* for all the concentration *i.e.* @ 4 % (12.76 %), 5 % (13.33 %) and 6 % (16.32 %) followed by *E. globules.* The concentration @ 4 % (15.75 %) in *E. globules* was found to be more effective in percentage reduction in comparison with *A. indica* @ 2 % (14.60 %).

15. Based on the study the efficacy order of plant products in percentage reduction from overall mean of whitefly population were as follows; *D. stramonium* > *L. camara* > *A. indica* > *E. globules* > *C. winterianus*.

16. For the plant products the highest reduction percentage from overall mean for leafhopper population was observed in *D. stramonium* for the concentration *i.e*. @ 3 % (56.65 %), 4 % (58.23 %) and 5 % (64.95 %) followed by *A. indica* and *E. globules*. The lowest efficacy of percentage reduction from overall mean for leafhopper population was seen in *C. winterianus* for all the concentration *i.e*. @ 4 % (51.36 %), 5 % (52.29 %) and 6 % (58.62 %) followed by *L. camara*. Here, for concentration @ 3 % (62.61 %) in *A. indica* was found to be more effective in percentage reduction in comparison with *D. stramonium* @ 4 % (58.23 %). Similarly concentration @ 6 % (63.77 %) in *E. globules* was found to be more effective in percentage reduction then with *A. indica* @ 4 % (63.76 %). And also concentration @ 2 % (52.67 %) in *L. Camara* was found to be more effective in percentage reduction in comparison with *E. globules* @ 4 % (48.43 %) concentration.

17. Based on the study the efficacy order of plant products in percentage reduction from overall mean of leafhopper population were as follows; *D. stramonium* > *A. indica* > *E. globules* > *L. camara* > *C. winterianus*.

18. For the plant products the highest reduction percentage from overall mean for thrips population was observed in *D. stramonium* for the

concentration *i.e.* @ 3 % (56.14 %), 4 % (62.01 % NS) and 5 % (66.97 % NS) followed by *E. globules* and *A. indica*. The lowest efficacy of percentage reduction from overall mean for thrips population was seen in *C. winterianus* for all the concentration *i.e.*@ 4 % (44.90 %), 5 % (50.64 %) and 6 % (56.26 %) followed by *L. camara* @ 2 % (45.61 %), 3 % (57.50 %) and 4 % (58.60 %). Here, for concentration @ 3 % (61.41 %) in *A. indica* was found to be more effective in percentage reduction in comparison with *L. camara* @ 3 % (57.50 %) and *E. globules* @ 5 % (56.79 %)concentration

19. Based on the study the efficacy order of plant products in percentage reduction from overall mean of thrips population were as follows; *D. stramonium* > *A. indica* > *E. globules* > *L. camara* > *C. winterianus*.

CONCLUSION

The following conclusion are taken up as per the current above experimental findings

1. The major sucking pests on French bean observed in this experiment were aphid (*Aphis craccivora* Koch), thrips (*Megaleurothrips usitatus* Bagnal), whitefly (*Bemisia tabaci* Gennadius) and leafhopper (*Empoasca fabae* Harris).
2. From the present study the most abundant sucking pest observed was aphid.
3. Aphid and whitefly population showed negative significant correlation with rainfall parameter.
4. On bioassay of aphid (*Aphis craccivora*) the most effective treatment was observed in Dimethoate 30 EC / Rogor (0.01 %) followed by Botanicals Neem (3 %) and Lantana (3 %) followed by Datura (4 %)

and the least effective treatment was seen in Eucalyptus (5 %) and Citronella (5 %).

5. For field efficacy experiment the most effective treatment was observed in Dimethoate 30 EC/ Rogor and for Botanicals the most effective treatment was observed in Datura followed by Lantana and Neem.
6. The least effective treatment for field efficacy was observed in Citronella and Eucalyptus.
7. Through these experiment carried out it can be concluded that locally available botanicals such as Datura, Neem and Lantana prove as good biopesticides and their plant extract can be prepared and use locally for maximum reduction of sucking pests in French bean. Hence reducing use of chemical pesticides by farmers which are likely more expensive and are hazardous to environment, human and animals.

FUTURE LINE OF WORK

1. Screening of local cultivar of French bean in Nagaland to evaluate the level of resistance in local cultivar kholar to major pests of French bean can be taken up
2. To study the efficacy of botanicals and biopesticides against major pest of French bean.
3. Identification of active ingredient of Datura, *Datura stramonium* L. and its insecticidal action on different insect pests can be taken up

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APPENDIX

APPENDIX – A

ANOVA and DMRT test for seasonal incidence of sucking pest during 2017-2018

Aphid incidence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	183.935	15	12.262	55.391	.000
Within Groups	24.794	112	.221		
Total	208.729	127			

Aphid incidence

Duncan

	N	Subset for alpha = .05									
week	1	2	3	4	5	6	7	8	9	10	1
1.00	8	.0000									
16.00	8		.5000								
2.00	8		.5625								
15.00	8			1.0625							
3.00	8			1.3875	1.3875						
14.00	8			1.5375	1.5375	1.5375					
13.00	8				1.6875	1.6875					
4.00	8					1.9750	1.9750				
12.00	8						2.3125	2.3125			
5.00	8							2.5500			
6.00	8								3.1250		
7.00	8								3.2750	3.2750	
11.00	8								3.2750	3.2750	
8.00	8								3.5138	3.5138	3.5138
9.00	8									3.6750	3.6750
10.00	8										3.8500
Sig.		1.000	.791	.058	.233	.081	.154	.315	.135	.124	.181

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 8.000.

ANOVA

Thrips incidence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	888.125	15	59.208	35.894	.000
Within Groups	184.750	112	1.650		
Total	1072.875	127			

Duncan

	N	Subset for alpha = .05			
week	1	2	3	4	1
1.00	8	.0000			
2.00	8	.0000			
3.00	8	.0000			
4.00	8	.0000			
16.00	8	.0000			
15.00	8	.1250			
14.00	8	.3750			
5.00	8	.6250			
13.00	8	1.2500			
12.00	8		3.0000		
6.00	8		3.1250		
7.00	8			5.2500	
11.00	8			5.5000	
8.00	8			5.7500	
9.00	8			6.1250	6.1250
10.00	8				7.3750
Sig.		.104	.846	.220	.054

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 8.000.

ANOVA

Whitefly incidence

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1135.555	15	75.704	73.970	.000
Within Groups	114.625	112	1.023		
Total	1250.180	127			

Duncan

	N	Subset for alpha = .05						
week	1	2	3	4	5	6	7	1
1.00	8	.0000						
2.00	8	.0000						
3.00	8	.0000						
16.00	8	.0000						
15.00	8	.2500						
14.00	8	.8750	.8750					
4.00	8	1.1250	1.1250					
13.00	8		1.8750					
5.00	8			3.1250				
6.00	8			3.7500	3.7500			
12.00	8				4.3750			
7.00	8					5.8750		
8.00	8					6.3750	6.3750	
11.00	8					6.5000	6.5000	
9.00	8						7.0000	
10.00	8							9.2500
Sig.		.056	.063	.219	.219	.248	.248	1.000

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 8.000.

APPENDIX- B

Efficacy of plant extracts against whitefly *Bemisia tabaci* (2018-19 data)

Treatments	Conc.	Reduction % of whitefly population								
		After 1st spray				After 2nd spray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	29.23 5.45	9.57^{d} (5.49)	19.38^{d} (11.17)	29.43^{c} (17.11)	20.30 4.56	15.05^{f} (8.65)	29.72^{e} (17.29)	47.80^{ed} (28.55)	24.16 (13.98)
	3%	34.06 5.88	15.60^{fe} (8.98)	29.23^{d} (17.00)	38.24^{c} (22.48)	22.34 4.78	19.70^{fe} (11.36)	38.26^{ed} (22.49)	51.46^{ed} (30.97)	31.04 (18.08)
	4%	37.20 6.14	18.21^{c} (10.49)	30.65^{c} (17.85)	40.11^{c} (23.64)	22.31 4.78	19.31^{fe} (11.13)	36.62^{ed} (21.48)	48.06^{ed} (28.73)	31.53 (18.38)
Datura stramonium	3%	33.50 5.83	13.53^{c} (7.78)	25.69^{c} (14.88)	33.33^{c} (19.47)	22.61 4.81	16.37^{fe} (9.42)	32.33^{e} (18.86)	43.85^{ed} (26.01)	26.84 (15.57)
	4%	36.03 6.04	15.33^{fe} (8.82)	27.78^{d} (16.13)	38.89^{c} (22.89)	22.85 4.83	18.08^{f} (10.42)	37.30^{ed} (21.90)	55.58^{d} (33.76)	30.98 (18.05)
	5%	29.87 5.51	18.06^{c} (10.40)	32.28^{c} (18.83)	46.05^{b} (27.42)	15.94 4.05	18.35^{fe} (10.57)	42.34^{ed} (25.05)	63.38^{d} (39.33)	35.35 (20.70)
Azadirachta indica	2%	33.50 5.83	6.47^{ed} (3.71)	11.50^{e} (6.61)	16.80^{ed} (9.67)	26.76 5.22	6.57^{f} (3.77)	12.26^{fe} (7.04)	19.15^{fe} (11.04)	12.07 (6.93)
	3%	36.05 6.05	7.81^{f} (4.48)	13.72^{e} (7.89)	18.04^{d} (10.39)	27.71 5.31	10.70^{f} (6.14)	17.72^{fed} (10.20)	24.73^{fed} (14.32)	15.22 (8.76)
	4%	33.89 5.86	10.02^{d} (5.75)	16.36^{d} (9.42)	21.54^{d} (12.44)	24.89 5.04	11.53^{f} (6.62)	17.91^{fed} (10.32)	24.89^{fe} (14.41)	16.91 (9.74)
Cymbopogan winterianus	4%	31.95 5.70	4.87^{e} (2.79)	9.20^{e} (5.28)	13.11^{e} (7.53)	26.39 5.19	5.46^{f} (3.13)	11.55^{fe} (6.63)	16.69^{fe} (9.61)	10.07 (5.78)
	5%	36.64 6.09	5.83^{f} (3.34)	10.70^{e} (6.14)	14.37^{e} (8.26)	30.28 5.55	6.68^{f} (3.83)	11.18^{fe} (6.42)	16.14^{fe} (9.29)	10.78 (6.19)
	6%	33.23 5.81	6.46^{e} (3.71)	11.82^{e} (6.79)	15.67^{e} (9.01)	26.24 5.17	7.75^{f} (4.44)	13.42^{fe} (7.71)	18.46^{fe} (10.64)	12.18 (7.00)
Eucalyptus globules	4%	30.93 5.61	7.36^{ed} (17.97)	13.89^{e} (16.66)	19.67^{d} (15.52)	24.33 4.98	9.77^{f} (5.61)	17.86^{fe} (10.29)	15.23^{fe} (8.76)	13.93 (8.01)
	5%	29.04 5.43	8.00^{f} (4.59)	12.63^{e} (7.26)	16.80^{ed} (9.67)	22.53 4.80	9.16^{f} (5.25)	15.61^{fed} (8.98)	21.58^{fed} (12.46)	13.82 (7.95)
	6%	31.80 5.68	7.52^{ed} (4.31)	12.16^{e} (6.99)	17.05^{e} (9.82)	24.46 5.00	8.22^{f} (4.71)	14.66^{fed} (8.43)	20.50^{fe} (11.83)	13.25 (7.61)
Dimethoate 30 EC	0.01%	34.61 5.93	52.63^{b} (11.7)	79.22^{b} (5.1)	91.86^{b} (2.0)	0.96 1.21	100.00^{e} (90.00)	100.00^{d} (90.00)	100.00^{d} (90.00)	75.61 (49.12)
	0.02%	32.31 5.73	60.83^{e} (37.47)	86.24^{c} (59.59)	97.34^{b} (76.77)	0.21 0.84	100.00^{e} (90.00)	100.00^{d} (90.00)	100.00^{e} (90.00)	81.66 (54.75)
	0.03%	32.38 5.73	63.29^{b} (39.27)	91.80^{b} (66.64)	97.45^{a} (77.04)	0.20 0.84	100.00^{e} (90.00)	100.00^{d} (90.00)	100.00^{ed} (90.00)	84.36 (57.52)
Control	0%	32.55 5.75	0	0	0	36.61 6.09	0	0	0	0
	0%	29.73 5.50	0	0	0	33.41 5.82	0	0	0	0
	0%	36.09 6.05	0	0	0	39.28 6.31	0	0	0	0
S.E.m±		0.35	0.18	0.36	0.46	0.35	12.83	12.96	14.86	
S.E.m±		0.29	0.21	0.32	0.14	0.23	17.09	17.20	17.31	
S.E.m±		0.43	0.18	0.20	0.27	0.32	17.09	17.27	17.53	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Figures in the table are mean values, Figures in the parentheses are angular transformed values

Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT

APPENDIX- C

Efficacy plant extracts against aphids, *Aphis craccivora* (2018-19 data)

Treatments	Conc.	Reduction % of aphid population								
		After 1st spray				After 2ndspray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	3.37 (1.97)	11.11^{d} (6.38)	20.74^{d} (11.97)	36.30^{d} (21.28)	2.15 (1.63)	8.14^{ed} (4.67)	18.60^{d} (10.72)	27.91^{d} (16.20)	20.79 (12.00)
	3%	3.3 (1.9)	13.69^{c} (7.87)	25.18^{d} (14.58)	32.22^{d} (18.80)	2.2 (1.64)	13.26^{d} (7.62)	27.22^{b} (15.79)	34.84^{b} (20.39)	24.28 (14.05)
	4%	3.18 (1.92)	14.74^{d} (8.47)	25.31^{d} (14.66)	31.68^{c} (18.47)	2.15 (1.63)	18.68^{c} (10.77)	31.46^{c} (18.34)	43.33^{c} (25.68)	26.83 (15.56)
Datura stramonium	3%	3.20 (1.92)	14.62^{d} (8.41)	24.14^{d} (13.97)	33.72^{d} (19.71)	2.13 (1.62)	10.31^{d} (5.92)	23.28^{d} (13.46)	34.02^{c} (19.89)	23.53 (13.61)
	4%	3.48 (1.99)	17.14^{b} (9.87)	14.97^{d} (12.90)	35.26^{d} (20.65)	2.25 (1.66)	16.37^{d} (9.42)	29.75^{b} (17.31)	39.96^{a} (23.55)	27.24 (15.81)
	5%	2.85 (1.83)	16.74^{d} (9.64)	29.01^{d} (16.86)	40.35^{b} (23.80)	1.70 (1.48)	25.04^{b} (14.50)	44.11^{b} (26.17)	60.49^{b} (37.22)	34.13 (19.95)
Azadirachta indica	2%	3.03 (1.88)	4.10^{e} (2.35)	9.09^{e} (5.22)	13.19^{e} (7.58)	2.63 (1.77)	5.83^{e} (3.34)	9.65^{e} (5.54)	15.44^{e} (8.88)	9.50 (5.45)
	3%	3.43 (1.98)	8.79^{d} (5.04)	13.85^{e} (7.96)	18.17^{e} (10.47)	2.80 (1.82)	8.12^{e} (4.66)	11.70^{c} (6.72)	16.14^{dc} (9.29)	12.88 (7.40)
	4%	2.80 (1.82)	8.88^{e} (5.09)	13.31^{e} (7.65)	18.61^{ed} (10.73)	2.28 (1.67)	14.33^{d} (8.24)	24.26^{d} (14.04)	30.83^{d} (17.96)	17.88 (10.30)
Cymbopogan winterianus	4%	3.08 (1.89)	1.91^{e} (1.09)	3.82^{e} (2.19)	5.74^{e} (3.29)	2.70 (1.79)	2.12^{e} (1.22)	6.38^{e} (3.66)	8.52^{e} (4.89)	8.50 (4.88)
	5%	3.33 (1.96)	4.47^{e} (2.56)	11.25^{e} (6.46)	13.51^{e} (7.76)	2.88 (1.84)	4.29^{e} (2.46)	7.78^{dc} (4.46)	13.05^{d} (7.50)	9.11 (5.23)
	6%	2.88 (1.84)	6.86^{e} (3.93)	11.27^{e} (6.47)	13.89^{e} (7.99)	2.48 (1.72)	8.10^{e} (4.65)	13.24^{e} (7.61)	18.34^{e} (10.57)	11.86 (6.81)
Eucalyptus globules	4%	3.08 (1.89)	4.79^{e} (2.74)	8.79^{e} (5.05)	12.96^{e} (7.45)	2.68 (1.78)	4.72^{e} (2.71)	8.48^{e} (4.86)	14.17^{e} (8.15)	8.99 (5.16)
	5%	2.95 (1.86)	5.01^{e} (2.87)	10.20^{e} (5.85)	13.60^{e} (7.82)	2.55 (1.75)	6.98^{e} (4.00)	10.92^{dc} (6.27)	17.83^{c} (10.27)	10.67 (6.13)
	6%	3.13 (1.90)	8.00^{e} (4.59)	11.97^{e} (6.87)	16.04^{ed} (9.23)	2.63 (1.77)	6.75^{e} (3.87)	11.61^{e} (6.67)	16.33^{e} (9.40)	11.80 (6.78)
Dimethoate 30 EC	0.01%	3.18 (1.92)	54.45^{c} (32.99)	82.89^{c} (55.99)	96.97^{c} (75.85)	0.08 (0.76)	100.0^{c} (90.00)	100.0^{c} (90.00)	100.0^{c} (90.00)	78.63 (51.84)
	0.02%	3.43 1.98	59.94^{a} (36.82)	91.31^{c} (65.93)	99.32^{c} (83.34)	0 (0.71)	100.0^{f} (90.00)	100.0^{e} (90.00)	100.0^{e} (90.00)	83.52 (56.64)
	0.03%	2.93 (1.85)	55.58^{c} (33.76)	93.15^{c} (68.66)	100.00^{a} (90.00)	0.71 (0.41)	0.00 (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	82.91 (56.00)
Control	0%	3.40 (1.97)	0	0	0	3.7 (2.05)	0	0	0	0
	0%	3.08 (1.89)	0	0	0	3.38 (1.97)	0	0	0	0
	0%	3.2 (1.92)	0	0	0	3.53 (2.01)	0	0	0	0
S.E.m±		NS	0.23	0.34	0.28	0.00	0.29	0.50	0.47	
S.E.m±		NS	0.13	0.25	0.39	0.00	0.22	0.21	0.23	
S.E.m±		NS	0.16	0.28	0.22	0.00	0.26	0.38	0.61	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Figures in the table are mean values, Figures in the parentheses are angular transformed values

Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT

APPENDIX- D

Efficacy of plant extracts against leaf hopper, *Empoasca fabae* (2018-19 data)

Treatments	Conc.	Reduction % of leafhopper population								
		After 1st spray				After 2ndspray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	10.00 (3.24)	26.67^{fc} (15.47)	46.67^{d} (27.82)	61.67^{d} (38.07)	3.78 (2.07)	31.57^{e} (18.40)	60.26^{e} (37.06)	88.96^{e} (62.83)	49.18 (29.46)
	3%	8.75 (3.04)	30.48^{d} (17.74)	55.24^{dc} (33.53)	74.29^{dc} (47.98)	2.18 (1.64)	38.70^{e} (22.77)	69.35^{e} (43.91)	100.00^{d} (90.00)	48.89 (29.27)
	4%	9.17 (3.11)	26.67^{c} (15.47)	46.67^{d} (27.82)	61.67^{ed} (38.07)	1.78 (1.51)	31.57^{e} (18.40)	60.26^{e} (37.06)	88.96^{d} (62.83)	62.43 (38.63)
Datura stramonium	3%	9.33 (3.14)	27.68^{ec} (16.07)	52.68^{d} (31.79)	74.11^{c} (47.82)	2.38 (1.70)	26.32^{e} (15.26)	75.44^{ed} (48.97)	92.98^{e} (68.41)	54.2 (32.83)
	4%	9.25 (3.12)	32.43^{d} (18.92)	63.06^{b} (39.10)	81.98^{b} (55.07)	1.60 (1.45)	42.71^{e} (25.28)	79.17^{ed} (52.34)	100.00^{d} (90.00)	57.50 (35.10)
	5%	9.25 (3.12)	47.75^{b} (28.52)	73.87^{c} (47.62)	90.09^{c} (64.28)	0.88 (1.17)	61.90^{d} (38.25)	100.00^{d} (90.00)	100.00^{c} (90.00)	72.02 (46.07)
Azadirachta indica	2%	9.28 (3.13)	28.03^{c} (16.28)	48.25^{d} (28.85)	59.84^{d} (36.75)	3.68 (2.04)	55.10^{d} (33.44)	84.35^{d} (57.52)	96.60^{e} (75.01)	54.83 (33.25)
	3%	10.15 (3.26)	32.51^{d} (18.97)	59.36^{cb} (36.41)	80.05^{cb} (53.18)	1.93 (1.56)	70.13^{d} (44.53)	97.40^{b} (76.91)	100.00^{d} (90.00)	57.63 (35.19)
	4%	9.10 (3.10)	34.07^{d} (19.92)	59.62^{d} (36.59)	78.57^{e} (51.79)	1.90 (1.55)	88.16^{b} (61.83)	100.00^{d} (90.00)	100.00^{c} (90.00)	64.09 (39.86)
Cymbopogan winterianus	4%	8.65 (3.02)	20.23^{ed} (11.67)	39.88^{e} (23.51)	55.20^{d} (33.51)	3.85 (2.09)	57.14^{d} (34.85)	83.77^{d} (56.89)	96.10^{e} (73.95)	50.93 (30.62)
	5%	10.10 (3.26)	22.52^{d} (13.02)	40.84^{e} (24.11)	52.48^{e} (31.65)	4.80 (2.30)	60.42^{ed} (37.17)	84.38^{d} (57.54)	98.96^{d} (81.72)	52.96 (31.98)
	6%	9.30 (3.13)	26.08^{e} (15.11)	53.23^{e} (32.16)	73.92^{e} (47.67)	2.35 (1.69)	69.15^{dc} (43.75)	94.68^{d} (71.23)	100.00^{c} (90.00)	58.51 (35.81)
Eucalyptus globules	4%	9.18 (3.11)	16.35^{e} (9.41)	40.05^{e} (23.61)	47.68^{e} (28.48)	4.75 (2.29)	46.84^{d} (27.93)	72.11^{ed} (46.14)	93.16^{e} (68.68)	46.98 (28.02)
	5%	8.75 (3.04)	27.14^{d} (15.75)	52.57^{d} (31.72)	67.71^{d} (42.62)	2.73 (1.80)	63.30^{d} (39.27)	92.66^{b} (67.91)	100.00^{d} (90.00)	49.09 (29.40)
	6%	9.08 (3.09)	30.58^{ed} (17.81)	64.19^{d} (39.93)	86.78^{dc} (60.20)	1.13 (1.27)	84.44^{cb} (57.61)	100.00^{d} (90.00)	100.00^{c} (90.00)	64.30 (40.01)
Dimethoate 30 EC	0.01%	10.03 (3.24)	68.08^{b} (42.91)	94.51^{c} (70.93)	100.00^{b} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	87.53 (61.08)
	0.02%	7.58 (2.84)	70.30^{c} (44.67)	99.01^{a} (81.93)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{a} (0.00)	0.00^{e} (0.00)	89.77 (63.86)
	0.03%	8.85 (3.06)	74.29^{a} (47.98)	100.00^{b} (90.00)	100.00^{b} (90.00	0.00 (0.71)	0.00^{e} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	91.43 (66.11)
Control	0%	10.05 (3.25)	0	0	0	11.00 (3.39)	0	0	0	0
	0%	8.73 (3.04)	0	0	0	9.78 (3.21)	0	0	0	0
	0%	8.13 (2.94)	0	0	0	9.35 (3.14)	0	0	0	0
S.E.m±		NS	0.72	0.78	0.80	0.02	1.55	3.96	1.86	
S.E.m±		0.01	0.56	0.48	0.65	0.01	5.99	2.20	0.07	
S.E.m±		NS	0.36	0.40	0.74	0.01	5.56	1.54	0.32	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Figures in the table are mean values, Figures in the parentheses are angular transformed values

Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT

APPENDIX-E

Efficacy of plant extracts against thrips, *Megaleurothrips usitatus* (2018-19 data)

Treatments	Conc.	Reduction % of thrips population								
		After 1st spray				After 2ndspray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	12.42 (3.59)	18.12^{e} (10.44)	41.61^{d} (24.59)	55.03^{c} (33.39)	5.53 (2.45)	29.11^{e} (16.92)	60.78^{e} (37.43)	80.39^{e} (53.51)	43.95 (26.07)
	3%	8.83 (3.06)	29.25^{ed} (17.00)	59.43^{d} (36.47)	74.53^{cb} (48.18)	2.18 (1.64)	46.36^{e} (27.62)	80.84^{e} (53.94)	92.34^{e} (67.42)	58.11 (35.53)
	4%	8.42 (2.99)	32.67^{d} (19.07)	60.40^{c} (37.15)	81.19^{c} (54.28)	1.58 (1.44)	36.51^{e} (21.41)	73.54^{e} (47.35)	89.42^{d} (63.40)	59.41 (36.45)
Datura stramonium	3%	10.58 (3.33)	29.92^{d} (17.41)	54.33^{c} (32.91)	68.50^{b} (43.24)	3.25 (1.94)	43.59^{d} (25.84)	74.36^{d} (48.04)	84.62^{ed} (57.80)	54.82 (33.24)
	4%	8.33 (2.97)	33.00^{d} (19.27)	63.00^{d} (39.05)	80.00^{b} (53.13)	1.88 (1.54)	51.11^{e} (30.74)	91.11^{ed} (65.66)	95.56^{e} (72.85)	62.45 (38.64)
	5%	10.75 (3.35)	51.16^{c} (30.77)	74.42^{b} (48.09)	91.47^{b} (66.17)	0.90 (1.18)	53.70^{d} (32.48)	100.00^{d} (90.00)	100.00^{d} (90.00)	73.30 (47.13)
Azadirachta indica	2%	11.15 (3.41)	20.85^{e} (12.04)	38.57^{ed} (22.68)	49.55^{ed} (29.70)	5.53 (2.45)	39.37^{ed} (23.18)	66.97^{ed} 42.04)	90.95^{ed} 65.44)	46.08 27.44)
	3%	8.18 (2.95)	29.66^{d} (17.26)	56.27^{d} (34.24)	70.64^{dc} (44.94)	2.35 (1.69)	79.79^{c} (52.93)	96.81^{d} (75.49)	100.00^{e} (90.00)	61.12 (37.68)
	4%	10.30 (3.29)	29.37^{d} (17.08)	49.27^{e} (29.52)	61.41^{e} (37.88)	3.78 (2.07)	73.51^{d} (47.32)	100.00^{d} (90.00)	100.00^{d} (90.00)	58.61 (35.88)
Cymbopogan winterianus	4%	11.15 (3.41)	16.37^{e} (9.42)	32.96^{e} (19.24)	45.74^{e} (27.22)	5.95 (2.54)	33.19^{ed} (19.39)	65.97^{ed} (41.27)	89.08^{ed} (62.97)	42.50 (25.15)
	5%	10.58 (3.33)	22.70^{e} (13.12)	40.19^{e} (23.70)	54.14^{e} (32.78)	4.65 (2.27)	48.92^{ed} (29.29)	82.26^{e} (55.34)	98.92^{e} (81.59)	50.52 (30.34)
	6%	9.85 (3.22)	23.10^{e} (13.35)	42.64^{e} (25.24)	57.87^{e} (35.36)	4.05 (2.13)	76.54^{dc} (49.95)	98.77^{d} (80.99)	100.00^{d} (90.00)	55.94 (34.01)
Eucalyptus globules	4%	10.28 (3.28)	21.17^{e} (12.22)	38.44^{ed} (22.61)	53.77^{dc} (32.53)	4.65 (2.27)	43.55^{d} (25.82)	79.03^{d} (52.22)	97.85^{ed} (78.10)	48.91 (29.28)
	5%	10.08 (3.25)	26.30^{ed} (15.25)	46.40^{e} (27.65)	66.75^{d} (41.87)	3.20 (1.92)	71.88^{dc} (45.95)	98.44^{d} (79.86)	100.00^{e} (90.00)	57.00 (34.75)
	6%	9.35 (3.14)	28.88^{d} (16.78)	50.80^{d} (30.53)	71.39^{d} (45.55)	2.58 (1.75)	87.38^{c} (60.90)	100.00^{d} (90.00)	100.00^{d} (90.00)	60.17 (36.99)
Dimethoate 30 EC	0.01%	12.13 (3.55)	64.74^{c} (40.35)	96.29^{b} (74.34)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	87.01 (60.47)
	0.02%	10.55 (3.32)	69.91^{c} (44.35)	99.29^{c} (83.16)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	89.73 (63.81)
	0.03%	9.38 (3.14)	81.07^{b} (54.16)	99.20^{a} (82.75)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	93.4 (69.10)
Control	0%	9.15 (3.11)	0	0	0	10.30 (3.29)	0	0	0	0
	0%	10.15 (3.26)	0	0	0	11.08 (3.40)	0	0	0	0
	0%	9.13 (3.10)	0	0	0	10.20 (3.27)	0	0	0	0
S.E.m±		0.04	0.50	0.70	0.38	0.02	2.11	3.13	2.97	
S.E.m±		0.03	0.76	1.16	0.97	0.02	9.46	2.20	1.03	
S.E.m±		0.03	0.57	0.80	0.70	0.01	10.14	1.77	0.63	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Figures in the table are mean values, Figures in the parentheses are angular transformed values

Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT

APPENDIX- F

Efficacy of plant extracts against whitefly, *Bemisia tabaci* (2019-20 data)

Treatments	Con.	Reduction % of whitefly population								
		After 1st spray				After 2ndspray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	23.63 (4.91)	13.12^{c} (7.54)	21.38^{d} (12.34)	31.01^{d} (18.06)	16.18 (4.08)	20.56^{fe} (11.86)	33.08^{e} (19.31)	44.98^{e} (26.73)	26.32 (15.26)
	3%	30.20 (5.54)	12.17^{ed} (6.99)	21.69^{d} (12.53)	29.14^{d} (16.94)	21.33 (4.67)	16.41^{d} (9.45)	29.54^{d} (17.18)	35.76^{ed} (20.95)	23.58 (13.64)
	4%	26.83 (5.23)	20.41^{c} (11.78)	31.97^{dc} (18.64)	39.24^{d} (23.10)	16.23 (4.09)	32.67^{c} (19.07)	48.07^{d} (28.73)	60.09^{d} (36.94)	36.72 (21.54)
Datura stramonium	3%	24.50 (5.00)	12.24^{dc} (7.03)	22.45^{d} (12.97)	30.00^{d} (17.46)	17.03 (4.190	19.38^{e} (11.18)	33.19^{e} (19.38)	47.43^{e} (28.31)	26.39 (15.30)
	4%	28.55 (5.39)	12.96^{d} (7.45)	24.34^{d} (14.09)	32.22^{d} (18.80)	19.25 (4.44)	19.61^{ed} (11.31)	33.51^{ed} (19.58)	46.88^{c} (27.96)	27.27 (15.82)
	5%	22.83 (4.83)	24.64^{c} (14.27)	36.04^{b} (21.12)	46.66^{b} (27.81)	12.08 (3.55)	41.82^{b} (24.72)	61.90^{c} (38.25)	76.60^{c} (50.00)	44.20 (26.23)
Azadirachta indica	2%	28.75 (5.41)	8.87^{edc} (5.09)	16.43^{e} (9.46)	23.39^{e} (13.53)	21.93 (4.74)	10.95^{f} (6.28)	21.21^{fe} (12.24)	29.30^{fe} (17.04)	18.07 (10.41)
	3%	29.83 (5.51)	12.82^{ed} (7.37)	22.80^{d} (13.18)	30.01^{d} (17.46)	20.85 (4.62)	20.02^{dc} (11.55)	31.77^{dc} (18.53)	42.33^{dc} (25.04)	25.79 (14.94)
	4%	24.38 (4.99)	17.64^{dc} (10.16)	27.08^{ed} (15.71)	35.18^{ed} (20.60)	15.73 (4.03)	27.03^{dc} (15.68)	46.74^{d} (27.87)	58.35^{d} (35.69)	33.46 (19.55)
Cymbopogan winterianus	4%	27.48 (5.29)	7.01^{e} (4.02)	15.38^{e} (8.85)	22.66^{e} (13.10)	21.18 (4.66)	9.92^{f} (5.69)	18.06^{fe} (10.41)	27.51^{fe} (15.97)	16.53 (9.51)
	5%	29.10 (5.44)	8.16^{e} (4.68)	15.21^{e} (8.75)	21.48^{e} (12.40)	22.75 (4.82)	11.65^{e} (6.69)	20.55^{e} (11.86)	29.12^{e} (16.93)	17.36 (10.00)
	6%	23.53 (4.90)	12.65^{e} (7.27)	22.10^{e} (12.77)	30.39^{e} (17.69)	16.33 (4.10)	15.77^{e} (9.08)	28.18^{e} (16.37)	41.81^{e} (24.71)	24.53 (14.20)
Eucalyptus globules	4%	28.55 (5.39)	7.88^{ed} (4.52)	15.59^{e} (8.97)	22.50^{e} (13.01)	22.05 (4.75)	12.24^{f} (7.03)	21.32^{fe} (12.31)	30.39^{fe} (17.69)	17.93 (10.33)
	5%	20.28 (4.56)	13.56^{d} (7.80)	24.29^{d} (14.06)	32.43^{d} (18.92)	13.65 (3.76)	22.16^{c} (12.80)	37.73^{c} (22.17)	53.30^{c} (32.21)	29.18 (16.97)
	6%	22.70 (4.82)	14.98^{ed} (8.61)	24.78^{e} (14.35)	32.93^{ed} (19.23)	15.15 (3.96)	21.12^{ed} (12.19)	34.82^{e} (20.38)	46.04^{e} (27.41)	28.14 (16.34)
Dimethoate 30 EC	0.01%	26.53 (5.20)	50.71^{b} (30.47)	81.90^{c} (54.99)	95.38^{c} (72.52)	0.10 (0.77)	100.00^{e} (90.00)	100.00^{e} (90.00)	100.00^{e} (90.00)	76.09 (49.54)
	0.02%	23.20 (4.87)	59.27^{c} (36.35)	87.50^{c} (61.04)	98.92^{c} (81.58)	0.00 (0.71)	0.00^{e} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	81.9 (54.98)
	0.03%	28.45 (5.38)	55.27^{a} (33.55)	87.08^{b} (60.55)	99.47^{b} (84.11)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	80.61 (53.72)
Control	0%	28.70 (5.40)	0	0	0	30.10 (5.53)	0	0	0	0
	0%	24.35 (4.98)	0	0	0	26.40 (5.19)	0	0	0	0
	0%	26.10 (5.16)	0	0	0	28.00 (5.34)	0	0	0	0
S.E.m±		0.20	0.41	0.55	1.30	0.17	3.48	1.40	0.75	
S.E.m±		0.17	0.89	1.21	0.71	0.15	3.38	1.01	0.04	
S.E.m±		0.21	0.50	0.77	1.19	0.20	2.98	0.29	0.00	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration
*Figures in the table are mean values, Figures in the parentheses are angular transformed values
Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT

APPENDIX- G

Efficacy of plant extracts against aphids, *Aphis craccivora* (2019-20 data)

Treatments	Conc.	Reduction % of aphid population								
		After 1st spray				After 2ndspray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	2.5 (1.73)	12.07^{b} (6.93)	16.10^{ed} (9.26)	22.08^{c} (12.76)	2.5 (1.73)	13.98^{c} (8.04)	20.69^{d} (11.94)	27.11^{d} (15.73)	18.43 (10.62)
	3%	2.63 (1.77)	10.54^{ed} (6.05)	17.22^{d} (9.92)	22.01^{d} (12.71)	2.63 (1.77)	13.35^{cb} (7.67)	20.78^{cb} (12.00)	26.94^{cb} (15.63)	18.25 (10.51)
	4%	2.60 (1.76)	11.64a^{ed} (6.69)	19.44^{e} (11.21)	26.11^{c} (15.14)	2.60 (1.76)	15.72^{b} (9.04)	23.41^{d} (13.54)	29.96^{dc} (17.43)	20.77 (11.98)
Datura stramonium	3%	2.53 (1.74)	10.92^{cb} (6.27)	16.98^{d} (9.78)	22.92^{dc} (13.25)	2.53 (1.74)	12.95^{c} (7.44)	20.69^{d} (11.94)	27.11^{d} (15.73)	18.38 (10.59)
	4%	2.25 (1.66)	14.48^{d} (8.33)	19.99^{d} (11.53)	26.79^{c} (15.54)	2.25 (1.66)	16.56^{ba} (9.53)	25.54^{a} (14.80)	33.44^{a} (19.54)	22.44 (12.97)
	5%	2.70 (1.79)	13.11^{d} (7.53)	19.65^{e} (11.33)	23.37^{dc} (13.51)	2.70 (1.79)	16.81^{b} (9.68)	24.16^{d} (13.98)	30.13^{dc} (17.54)	20.93 (12.08)
Azadirachta indica	2%	2.73 (1.80)	8.32^{dc} (4.77)	12.89^{ed} (7.41)	19.35^{ec} (11.16)	2.73 (1.80)	7.89^{ed} (4.52)	14.79^{e} (8.51)	21.66^{e} (12.51)	14.09 (8.10)
	3%	2.45 (1.72)	10.38^{ed} (5.96)	15.52^{ed} (8.93)	21.55^{d} (12.44)	2.45 (1.72)	17.11^{a} (9.85)	22.35^{ba} (12.92)	30.45^{ba} (17.73)	19.10 (11.01)
	4%	2.60 (1.76)	10.61^{ed} (6.09)	17.36^{e} (10.00)	24.04^{dc} (13.91)	2.60 (1.76)	17.84^{b} (10.27)	26.62^{d} (15.44)	34.21^{c} (20.01)	21.16 (12.22)
Cymbopogan winterianus	4%	2.5 (1.73)	4.99^{e} (2.86)	11.07^{e} (6.36)	15.10^{e} (8.68)	2.5 (1.73)	4.75^{e} (2.72)	15.43^{e} (8.88)	18.99^{e} (10.95)	11.61 (6.67)
	5%	2.60 (1.76)	6.67^{e} (3.83)	10.53^{e} (6.05)	15.43^{e} (8.88)	2.60 (1.76)	9.13^{d} (5.24)	15.87^{d} (9.13)	19.19^{d} (11.06)	12.64 (7.26)
	6%	2.45 (1.72)	8.18^{e} (4.69)	15.36^{e} (8.84)	20.45^{ed} (11.80)	2.45 (1.72)	8.90^{d} (5.11)	16.63^{e} (9.57)	21.77^{e} (12.57)	15.16 (8.72)
Eucalyptus globules	4%	2.63 (1.77)	7.63^{ed} (4.38)	11.45^{e} (6.57)	16.23^{ed} (9.34)	2.63 (1.77)	10.25^{dc} (5.89)	14.81^{e} (8.52)	21.60^{e} (12.48)	13.50 (7.76)
	5%	2.25 (1.66)	8.96^{e} (5.14)	15.89^{ed} (9.14)	22.41^{d} (12.95)	2.25 (1.66)	11.59^{dc} (6.66)	17.38^{dc} (10.01)	23.18^{dc} (13.40)	16.47 (9.48)
	6%	2.53 (1.74)	8.87^{e} (5.09)	13.94^{e} (8.01)	18.91^{e} (10.90)	2.53 (1.74)	12.10^{c} (6.95)	18.40^{e} (10.60)	24.56^{ed} (14.22)	15.90 (9.15)
Dimethoate 30 EC	0.01%	2.53 (1.74)	49.62^{a} (29.75)	80.98^{c} (54.07)	96.14^{b} (74.04)	2.53 (1.74)	100.00^{b} (90.00)	100.00^{c} (90.00)	100.00^{c} (90.00)	75.83 (49.32)
	0.02%	2.53 (1.74)	51.62^{c} (31.08)	93.23^{c} (68.80)	99.04^{b} (82.05)	2.53 (1.74)	00.00^{e} (0.00)	00.00^{e} (0.00)	00.00^{e} (0.00)	81.30 (54.39)
	0.03%	2.48 (1.72)	55.72^{c} (33.86)	95.15^{d} (72.09)	100.00^{b} (90.00)	2.48 (1.72)	00.00^{e} (0.00)	00.00^{f} (0.00)	00.00^{f} (0.00)	83.62 (56.74)
Control	0%	2.58 (1.75)	0	0	0	2.58 (1.75)	0	0	0	0
	0%	2.43 (1.71)	0	0	0	2.43 (1.71)	0	0	0	0
	0%	2.50 (1.73)	0	0	0	2.50 (1.73)	0	0	0	0
S.E.m±		NS	0.16	0.37	0.25	0.00	0.22	0.28	0.21	
S.E.m±		0.00	0.27	0.52	0.19	0.00	0.18	0.23	0.51	
S.E.m±		NS	0.24	0.71	0.28	0.00	0.12	0.36	0.52	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Figures in the table are mean values, Figures in the parentheses are angular transformed values

Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT

APPENDIX- H

Efficacy of plant extracts against leafhopper, *Empoasca fabae* (2019-20 data)

Treatments	Conc	Reduction % of leafhopper population								
		After 1st spray				After 2ndspray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	8.28 (2.96)	26.59^{ed} (15.42)	47.73^{ed} (28.51)	63.75^{ed} (39.60)	2.95 (1.86)	67.80^{d} (42.68)	94.92^{e} (71.65)	100.00^{d} (90.00)	56.94 (34.71)
	3%	8.73 (3.04)	26.36^{e} (15.28)	44.70^{ed} (26.55)	57.31^{e} (34.96)	3.65 (2.04)	59.59^{e} (36.58)	89.73^{ed} (63.80)	100.00^{e} (90.00)	54.68 (33.15)
	4%	9.30 (3.13)	29.57^{ed} (17.20)	48.39^{e} (28.94)	59.95^{e} (36.83)	3.68 (2.04)	59.86^{e} (36.77)	92.52^{d} (67.69)	100.00^{d} (90.00)	56.78 (34.59)
Datura stramonium	3%	7.58 (2.84)	30.69^{d} (17.87)	55.78^{d} (33.90)	67.33^{d} (42.32)	2.35 (1.69)	64.89^{d} (40.46)	93.62^{e} (69.42)	100.00^{d} (90.00)	59.53 (36.53)
	4%	8.18 (2.95)	26.30^{e} (15.25)	49.54^{edc} (29.70)	63.30^{d} (39.27)	2.93 (1.85)	58.12^{e} (35.53)	84.62^{e} (57.80)	96.58^{d} (74.97)	55.18 (33.49)
	5%	8.85 (3.06)	30.51^{ed} (17.76)	53.95^{ed} (32.65)	66.95^{ed} (42.03)	2.83 (1.82)	62.83^{e} (38.93)	92.04^{d} (66.98)	100.00^{d} (90.00)	58.82 (36.03)
Azadirachta indica	2%	8.90 (3.07)	25.00^{ed} (14.48)	46.91^{ed} (27.98)	59.83^{ed} (36.75)	3.55 (2.01)	54.93^{ed} (33.32)	85.92^{e} (59.22)	97.89^{d} (78.20)	54.08 (32.74)
	3%	9.23 (3.12)	32.52^{e} (18.98)	58.81^{c} (36.02)	78.59^{d} (51.80)	1.90 (1.55)	78.95^{d} (52.14)	100.00^{c} (90.00)	100.00^{d} (90.00)	62.85 (38.94)
	4%	8.90 (3.07)	32.58^{d} (19.02)	58.99^{dc} (36.15)	78.09^{cb} (51.34)	1.88 (1.54)	88.00^{d} (61.64)	100.00^{c} (90.00)	100.00^{d} (90.00)	63.42 (39.36)
Cymbopogan winterianus	4%	7.60 (2.85)	21.38^{ed} (12.35)	39.14^{d} (23.04)	57.57^{ed} (35.15)	3.20 (1.92)	57.03^{ed} (34.77)	89.06^{e} (62.95)	98.44^{d} (79.86)	51.85 (31.23)
	5%	8.73 (3.04)	20.34^{e} (11.74)	41.83^{e} (24.73)	55.87^{e} (33.97)	3.80 (2.07)	56.58^{e} (34.46)	88.82^{ed} (62.64)	100.00^{e} (90.00)	52.23 (31.49)
	6%	9.08 (3.09)	25.07^{e} (14.52)	52.89^{ed} (31.93)	74.38^{dc} (48.06)	2.28 (1.67)	73.63^{ed} (47.41)	97.80^{c} (77.97)	100.00^{d} (90.00)	58.74 (35.97)
Eucalyptus globules	4%	6.70 (2.68)	19.78^{e} (11.41)	42.54^{e} (25.17)	58.21^{ed} (35.60)	2.78 (1.81)	47.75^{ed} (28.52)	81.08^{e} (54.18)	98.20^{d} (79.11)	50.57 (30.38)
	5%	7.18 (2.77)	68.26^{e} (43.05)	97.31^{dc} (76.67)	100.00^{d} (90.00)	1.75 (1.50)	0.00^{ed} (0.00)	0.00^{dc} (0.00)	0.00^{d} (0.00)	88.52 (62.28)
	6%	8.70 (3.03)	30.17^{ed} (17.56)	61.49^{c} (37.95)	84.77^{b} (57.96)	1.25 (1.32)	82.00^{d} (55.08)	100.00^{c} (90.00)	100.00^{d} (90.00)	63.23 (39.22)
Dimethoate 30 EC	0.01%	9.33 (3.13)	65.68^{c} (41.06)	94.64^{c} (71.15)	100.00^{c} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	86.77 (60.20)
	0.02%	8.35 (2.97)	68.26^{d} (43.05)	97.31^{b} (76.67)	100.00^{c} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	88.52 (62.28)
	0.03%	7.18 (2.77)	78.75^{c} (51.95)	100.00^{b} (90.00)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	92.92 (68.30)
Control	0%	10.03 (3.24)	0	0	0	11.15 (3.41)	0	0	0	0
	0%	8.60 (3.02)	0	0	0	9.80 (3.21)	0	0	0	0
	0%	7.83 (2.89)	0	0	0	9.10 (3.10)	0	0	0	0
S.E.m±		0.04	1.57	1.90	1.15	0.02	3.58	2.35	0.12	
S.E.m±		0.02	2.36	2.10	1.51	0.01	2.82	1.46	0.14	
S.E.m±		0.02	0.64	0.71	0.94	0.01	4.07	0.50	0.09	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Figures in the table are mean values, Figures in the parentheses are angular transformed values

Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT

APPENDIX- I

Efficacy of plant extracts against thrips, *Megaleurothrips usitatus* (2019-20 data)

Treatments	Conc.	Reduction % of thrips population								
		After 1st spray				After 2^{nd}spray				Overall mean
		1DBS	3 DAS	7 DAS	14 DAS	1DBS	3 DAS	7 DAS	14 DAS	
Lantana camara	2%	10.98 (3.39)	23.23^{ed} (13.44)	40.55^{d} (23.92)	54.90^{d} (33.30)	4.88 (2.32)	42.05^{d} (24.87)	68.21^{d} (43.00)	85.64^{d} (58.92)	47.48 (28.34)
	3%	8.78 (3.05)	30.48^{ed} (17.75)	46.72^{d} (27.86)	58.69^{d} (35.94)	3.58 (2.02)	63.64^{c} (39.52)	93.01^{c} (68.45)	100.00^{c} (90.00)	56.42 (34.35)
	4%	8.63 (3.02)	32.17^{c} (18.77)	50.43^{dc} (30.29)	64.93^{dc} (40.49)	2.98 (1.86)	56.30^{d} (34.27)	93.28^{c} (68.87)	100.00^{c} (90.00)	57.90 (35.38)
Datura stramonium	3%	8.48 (3.00)	30.56^{c} (17.79)	55.28^{c} (33.56)	67.22^{c} (42.24)	2.53 (1.74)	76.52^{c} (49.93)	97.39^{c} (76.88)	100.00^{c} (90.00)	57.80 (35.31)
	4%	7.13 (2.76)	34.04^{c} (19.90)	59.30^{c} (36.37)	71.58^{c} (45.71)	1.95 (1.57)	65.38^{c} (40.83)	91.03^{c} (65.54)	100.00^{c} (90.00)	68.11 (42.93)
	5%	9.00 (3.08)	30.56^{c} (17.79)	55.28^{c} (33.56)	67.22^{c} (42.24)	2.88 (1.84)	49.93^{c} (88.89)	76.88^{b} (100.00)	90.00^{c} (100.00)	60.77 (37.42)
Azadirachta indica	2%	9.18 (3.11)	20.71^{d} (11.95)	39.51^{d} (23.27)	54.77^{d} (33.21)	4.08 (2.14)	47.85^{dc} (28.59)	80.37^{c} (53.48)	96.32^{c} (74.41)	49.56 (29.71)
	3%	7.73 (2.87)	29.13^{dc} (16.93)	56.31^{c} (34.27)	73.14^{b} (47.00)	2.05 (1.60)	85.37^{b} (58.61)	100.00^{c} (90.00)	100.00^{c} (90.00)	65.83 (41.17)
	4%	8.90 (3.07)	33.71^{c} (19.70)	53.09^{c} (32.07)	66.01^{dc} (41.31)	2.95 (1.86)	80.51^{c} (53.62)	100.00^{b} (90.00)	100.00^{c} (90.00)	61.53 (37.98)
Cymbopogan winterianus	4%	8.95 (3.07)	19.83^{d} (11.44)	41.34^{d} (24.42)	58.94^{d} (36.11)	3.63 (2.03)	45.52^{d} (27.08)	71.03^{d} (45.26)	88.28^{d} (61.98)	48.18 (28.80)
	5%	10.53 (3.32)	22.80^{d} (13.18)	40.14^{d} (23.67)	54.16^{d} (32.79)	4.78 (2.30)	49.74^{d} (29.83)	81.68^{d} (54.76)	98.43^{c} (79.83)	47.23 (28.18)
	6%	9.50 (3.16)	23.68^{d} (13.70)	45.26^{d} (26.91)	57.89^{d} (35.38)	3.90 (2.10)	75.64^{c} (49.15)	98.72^{b} (80.82)	100.00^{c} (90.00)	56.59 (34.47)
Eucalyptus globules	4%	9.93 (3.23)	21.41^{d} (12.36)	38.04^{d} (22.36)	54.41^{d} (32.96)	4.53 (2.24)	46.41^{d} (27.65)	83.98^{c} (57.12)	98.34^{c} (79.55)	49.94 (29.96)
	5%	10.15 (3.26)	27.59^{ed} (16.01)	45.81^{d} (27.27)	66.50^{c} (41.68)	3.33 (1.96)	65.41^{c} (40.85)	95.49^{c} (72.72)	100.00^{c} (90.00)	48.80 (29.21)
	6%	8.10 (2.93)	30.86^{c} (17.98)	52.47^{c} (31.65)	69.44^{c} (43.98)	2.45 (1.72)	82.65^{c} (55.74)	98.98^{b} (81.81)	100.00^{c} (90.00)	60.90 (37.52)
Dimethoate 30 EC	0.01%	9.20 (3.11)	56.79^{b} (34.61)	97.28^{b} (76.61)	99.64^{b} (85.12)	0.00 (0.71)	0.00^{e} (0.00)	0.00^{e} (0.00)	0.00^{e} (0.00)	83.89 (57.03)
	0.02%	10.43 (3.31)	64.75^{b} (40.35)	97.60^{b} (77.43)	100.00^{a} (90.00)	0.00 (0.71)	0.00^{e} (0.00)	0.00^{e} (0.00)	0.00^{d} (0.00)	85.34 (58.58)
	0.03%	8.93 (3.07)	80.67^{b} (53.78)	98.04^{b} (78.64)	100.00^{b} (90.00)	0.00 (0.71)	0.00^{e} (0.00)	0.00^{d} (0.00)	0.00^{d} (0.00)	92.90 (68.29)
Control	0%	8.58 (3.01)	0	0	0	9.93 (3.23)	0	0	0	0
	0%	9.63 (3.18)	0	0	0	10.90 (3.38)	0	0	0	0
	0%	9.15 (3.11)	0	0	0	10.18 (3.27)	0	0	0	0
S.E.m±		0.02	0.41	0.55	1.30	0.02	3.48	1.40	0.75	
S.E.m±		0.01	0.89	1.21	0.71	0.01	3.38	1.01	0.04	
S.E.m±		NS	0.50	0.77	1.19	0.02	2.98	0.29	0.00	

* DAS: days after spraying *DBS: day before spraying *Conc.: Concentration

*Figures in the table are mean values, Figures in the parentheses are angular transformed values

Within column values followed by different letter(s) are significantly different (P=0.05) by DMRT