SPECIES COMPLEX OF APHIDS IN LEGUMES WITH SPECIAL REFERENCE TO BIO-ECOLOGY AND ORGANIC MANAGEMENT OF FIELD BEAN APHID, *Aphis craccivora* (KOCH)

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CERTIFICATE

This is to certify that the thesis entitled **'SPECIES COMPLEX OF APHIDS IN LEGUMES WITH SPECIAL REFERENCE TO BIO-ECOLOGY AND ORGANIC MANAGEMENT OF FIELD BEAN APHID, *Aphis craccivora* (KOCH)'** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL ENTOMOLOGY** to the College of Agriculture, Shivamogga. University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Miss NAMITHA N.V., ID. No. MA1TAF0150** (namithanv.1994@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

Shivamogga
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July, 2018 ***(Namitha N. V.)***

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ABSTRACT

Investigations on **Species complex of aphids in legumes with special reference to bio-ecology and organic management of field bean aphid, *Aphis craccivora* (Koch)** was carried out at College of Agriculture, Navile, UAHS, Shivamogga during 2017-18. During the study, two species of aphids *viz*., *Aphis craccivora* and *Aphis gossypii* Glover were found infesting different legumes in different regions of Shivamogga during 2017-18. The population of bean aphids attained peak during third week of October (15.3 aphids per five centimeter twig) during *Kharif*. During *Rabi* season, the aphid population was maximum during first week of January (224.7 aphids per five centimeter twig). Incidence of bean aphid, *Aphis craccivora* had non-significant negative correlation with total rainfall, non-significant positive correlation with maximum temperature, significant negative correlation with minimum temperature and non- significant positive correlation with relative humidity during *Kharif* 2017, while during *Rabi* 2017-18, aphid showed non-significant negative correlation with total rainfall, maximum temperature, minimum temperature and positive correlation with relative humidity. Biological studies of *Aphis craccivora* on *Lablab purpureus* revealed that the total life cycle of the bean aphid under laboratory condition ranged from 14.20 to 20.80 days with a mean of 17.50 ± 1.91 days. Total nymphal period ranged from 4.20 to 7.70 days with a mean of 5.43 ± 1.05 days and fecundity was 29 ± 4.34 nymphs per female in laboratory. Among the organic molecules, *V. lecanii* 2×10^8 cfu/g (1.5ml/lt) was found more effective in the management of bean aphid. It was significantly superior (with 79.63 mean per cent reduction of aphids) over untreated control. Among all organic molecules, tested *V. leccanii* 2×10^8 cfu/g (1.5ml/lt) recorded highest C: B ratio of 1: 3.11 by recording highest green pod yield (24.14 q / ha).

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ದ್ವಿದಳ ಧಾನ್ಯ ಬೆಳೆಗಳಲ್ಲಿ ಕಂಡುಬರುವ ಸಸ್ಯಹೇನುಗಳು ಹಾಗೂ ಅವರೆ ಸಸ್ಯಹೇನು, *ಅಫಿಸ್ ಕ್ರಾಕ್ಸಿವೋರ* (ಕೋಚ್)ದ ಜೀವಪಾರಿಸರಿಕ ಅಧ್ಯಯನ ಮತ್ತು ಸಾವಯವ ನಿರ್ವಹಣೆ

(ನಮಿತ ಎನ್. ವಿ.)

ಸಾರಾಂಶ

ದ್ವಿದಳ ಧಾನ್ಯ ಬೆಳೆಗಳಲ್ಲಿ ಕಂಡುಬರುವ ಸಸ್ಯಹೇನುಗಳು ಹಾಗೂ ಅವರೆ ಸಸ್ಯಹೇನು, *ಅಫಿಸ್ ಕ್ರಾಕ್ಸಿವೋರ* (ಕೋಚ್)ದ ಜೀವಪಾರಿಸರಿಕ ಅಧ್ಯಯನ ಮತ್ತು ಸಾವಯವ ನಿರ್ವಹಣೆ ಕುರಿತು ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾಲಯ ಶಿವಮೊಗ್ಗದಲ್ಲಿ ೨೦೧೭–೧೮ ಸಾಲಿನಲ್ಲಿ ಸಂಶೋಧನೆ ಕೈಗೊಳ್ಳಲಾಯಿತು. ದ್ವಿದಳ ಧಾನ್ಯ ಬೆಳೆಗಳಲ್ಲಿ ಒಟ್ಟು ೨ ಜಾತಿಯ ಸಸ್ಯಹೇನುಗಳು, *ಅಫಿಸ್ ಕ್ರಾಕ್ಸಿವೋರ* ಮತ್ತು *ಅಫಿಸ್ ಗೊಸಿಪಿ* ದಾಖಿಲಾದವು. ಮುಂಗಾರು ಋತುಗಳಲ್ಲಿ ಸಸ್ಯಹೇನಿನ ಸಂಖ್ಯೆಯು ಅಕ್ಟೋಬರ್ ತಿಂಗಳ ಮೂರನೆಯ ವಾರದಲ್ಲಿ (೧೫.೩ ಪ್ರತಿ ಐದು ಸೆಂಟಿ ಮೀಟರ್ ರೆಂಬೆಗೆ) ಗರಿಷ್ಠವಾಗಿ ಕಂಡುಬಂದಿದೆ ಹಾಗೂ ಹಿಂಗಾರು ಋತುವಿನಲ್ಲಿ ಜನವರಿ ತಿಂಗಳ ಮೊದಲನೆ ವಾರದಲ್ಲಿ ಅಧಿಕ ಸಂಖ್ಯೆಯಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಮುಂಗಾರು ಋತುಗಳಲ್ಲಿ ಸಸ್ಯಹೇನು ಗಮನಾರ್ಹವಲ್ಲದ ಋಣಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಮಳೆಯೊಂದಿಗೆ, ಗಮನಾರ್ಹವಲ್ಲದ ಧನಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಗರಿಷ್ಠ ಉಷ್ಣಾಂಶ, ಗಮನಾರ್ಹ ಋಣಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಕನಿಷ್ಠ ಉಷ್ಣಾಂಶ ಹಾಗೂ ಗಮನಾರ್ಹವಲ್ಲದ ಧನಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಆರ್ದ್ರತೆಯೊಂದಿಗೆ ಹೊಂದಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಹಿಂಗಾರು ಋತುವಿನಲ್ಲಿ ಸಸ್ಯಹೇನು ಗಮನಾರ್ಹವಲ್ಲದ ಋಣಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಮಳೆಯೊಂದಿಗೆ, ಗರಿಷ್ಠ ಉಷ್ಣಾಂಶ, ಕನಿಷ್ಠ ಉಷ್ಣಾಂಶ ಹಾಗೂ ಆರ್ದ್ರತೆಯೊಂದಿಗೆ ಧನಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹೊಂದಿರುವುದು ಸಹ ಸಂಬಂಧ ಅಧ್ಯಯನದಿಂದ ಕಂಡುಬಂದಿರುತ್ತದೆ. ಅವರೆ ಸಸ್ಯಹೇನಿನ ಜೀವನ ಚಕ್ರದ ಅಧ್ಯಯನವನ್ನು ಪ್ರಯೋಗಾಲಯದಲ್ಲಿ ಅವರೆ, *ಲ್ಯಾಬ್‌ಲ್ಯಾಬ್ ಪರ್‌ಪ್ಯೂರಿಯಸ್* ನಲ್ಲಿ ನಡೆಸಲಾಯಿತು. ಕೀಟದ ಒಟ್ಟು ಜೀವನ ಚಕ್ರವು ೧೪.೨೦ ರಿಂದ ೨೦.೮೦ ದಿನಗಳವರೆಗೆ ದಾಖಿಲಾಗಿದ್ದು, ಸರಾಸರಿ ೧೭.೫೦ ± ೧.೯೧ ದಿನಗಳೆಂದು ಕಂಡುಬಂದಿದೆ. ಅಪ್ರಾಪ್ತ ಹಂತದ ಒಟ್ಟು ಕಾಲಾವಧಿ ೪.೨೦ ರಿಂದ ೭.೭೦ ದಿನಗಳವರೆಗೆ ದಾಖಿಲಾಗಿದ್ದು, ಸರಾಸರಿ ೫.೪೩ ± ೧.೦೫ ದಿನಗಳು ಹಾಗೂ ಕೀಟದ ಸಂತಾನಶಕ್ತಿ ೨೯ ± ೪.೩೪ ಮರಿಗಳು ಪ್ರತಿ ಹೆಣ್ಣು ಕೀಟಕ್ಕೆ ದಾಖಿಲಾಗಿರುತ್ತದೆ. ಪ್ರಯೋಗಕ್ಕೆ ಒಳಪಡಿಸಿದ ಎಲ್ಲಾ ಸಾವಯವ ಕೀಟನಾಶಕಗಳಲ್ಲಿ *ವರ್‌ಟಿಸಿಲಿಯಮ್ ಲೆಕಾನಿ* ೨ X ೧೦^{೮} ಸಿಎಫ್‌ಯು ಪ್ರತಿ ಗ್ರಾಂ (೧.೫ ಮಿ.ಲಿ ಪ್ರತಿ ಲೀಟರ್) ಅವರೆ ಹೇನಿನ ಹತೋಟಿಯಲ್ಲಿ ಗಮನಾರ್ಹವಾಗಿ ಫಲಕಾರಿಯಾಗಿತ್ತು (ಉಪಚರಿಸದೇ ಇದ್ದುದಕ್ಕಿಂತ ಶೇ. ೭೯.೬೩ ರಷ್ಟು ಕಡಿಮೆ ಸಂಖ್ಯೆಯ ಹೇನುಗಳೊಂದಿಗೆ). ಅಲ್ಲದೇ ಅತ್ಯಧಿಕ ಹಸಿರುಕಾಳಿನ ಇಳುವರಿಯ (೨೪.೧೪ ಕ್ವಿಂಟಾಲ್ ಪ್ರತಿ ಹೆಕ್ಟೇರ್) ಮೂಲಕ ಇದು ೧ : ೩.೧೧ ಗರಿಷ್ಠ : ವೆಚ್ಚ ಲಾಭದ ಅನುಪಾತವನ್ನು ದಾಖಿಲಿಸಿದೆ.

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INTRODUCTION

I INTRODUCTION

The dolichos bean, *Lablab purpureus* (Linnaeus) Sweet, belongs to the family leguminacae is an important pulse cum vegetable crop. In India, it is cultivated for its tender and mature pods, seeds and also for fodder. The crop is cultivated in dry tropical parts of Asia, Africa, East and West Indies, Central America and China. In India, it is being cultivated in Karnataka, Tamil Nadu, Andhra Pradesh and Kerala. Karnataka state contributes a major share by producing about 0.58 lakh tones with a productivity of 1039 kg / ha from an area of 0.59 hectares (Anon., 2014). Though the crops is cultivated in almost all regions of Karnataka, it is largely grown as a mixed crop with finger millet and sorghum in many parts of Karnataka. However, it is also grown as pure crop under rain fed as well as irrigated conditions.

Lablab is a climbing or erect perennial herbaceous crop often grown as an annual. It grows up to 40 inches tall with long stems of climbing types extending as much as 25 feet from base of the plant. The leaves are trifoliate and the flowers are purple or white. It has a strong tap root with many lateral and adventitious roots. It grows rapidly in fertile soil. It grows fast with beautiful fragrant flowers that attract butterflies. Field bean is primarily grown for its green pods that are consumed as cooked or fried vegetable. Its immature seeds are also consumed after cooking. Field bean is an important source of proteins, minerals and dietary fibers. Its pods have a characteristic aroma and the pod walls have high fiber content.

Green pods of field bean have high nutritive value because it has small amount of vitamin A, vitamin C, proteins, iron and calcium in raw state. It contains 4.5 per cent protein in pod, 25 per cent protein in dry seed (Rashid, 1976). It also contains appreciable amount of vitamin, phosphate, calcium and sodium (Gopalan *et al.*, 1982). Its mature dark colored seeds contain trypsin inhibitor which will be broken down into water soluble cyanogenic glucoside and can only be eaten after prolonged boiling (Floridata, 2008). This crop is also important for its atmospheric nitrogen fixation (Karla, 1979).

Insect pests are major constraints in reducing the productivity of field bean. The crop is attacked by a number of insect pests, *viz.*, *bean* aphid, *Aphis craccivora* Koch, leaf hopper, *Empoasca fabae* Harris, *Empoasca krameri* Ross & Moore, *Empoasca kerri* Pruthi, pod borer, *Etiella zinckenella* Treitschke, whitefly, *Bemisia tabaci* Gennadius, stem fly, *Ophiomyia phaseoli* Tryon, hairy caterpillars, *Ascotis imparta* Walker, Bihar hairy caterpillar, *Spilosoma obliqua* Walker *etc*. Among these, *A. craccivora* has been reported as the major sucking pests infesting this crop. Both nymphs and adults cause damage by sucking the cell sap from tender parts of the plants including lower surface of the leaves.

Bean aphid, *Aphis craccivora* Koch (Homoptera: Aphididae) was first described by Koch in 1854 and is commonly known as cowpea aphid, black bean aphid, legume aphid and oriental pea aphid. Aphids are the major insect pests both in tropical and temperate regions (Francis *et al*., 2000). It is a cosmopolitan species. Throughout the world it is causing direct and indirect (as vectors) damage to the cultivated crops. The aphid, *A. craccivora* is highly polyphagous as it is recorded feeding on plants belonging to 80 plant families. It is a serious pest of leguminous crop, suck the sap from tender shoots, inflorescence and pods resulting in drying up of tender shoot and premature fall of flower buds, flowers and tender pods. Crops that are attacked by this aphid include cowpea, field bean, groundnut, chickpea, mung bean, urdbean, pigeon pea, brassicas, cucurbits, beetroot, cotton, *etc.* (Anon., 2013).

In case of severe infestation, these pests attack all parts of the plants including pods which results in stunted growth and decreased yield. The honey dew secretion of the aphids provides a suitable media for the development of sooty mould and fungi which ultimately hampers the process of photosynthesis (David and Kumaraswami, 1982). It acts as a vector of many plant viruses such as rosette, mottle, stunt and stripe (Porter *et al*., 1984).

Bean aphid is polymorphic (with apterous and alate form), viviparous and in the tropics parthenogenetic reproduction occurs throughout the year. The pest is highly difficult to manage because of its polyphagous nature with very short life cycle and high reproduction rate.

Thorough understanding of the insect ecology forms a basis for effective pest management and conservation of natural enemies. Major parts of insect ecology can be understood if the factors influencing its population are thoroughly investigated. Among these factors, weather parameters are the important and there is a need to understand their influences (Speight *et al*., 1999).

Further, for management of bean aphid, *A. craccivora* many systemic insecticides are being used intensively and indiscriminately by the farmers. Though chemicals gained lots of importance and proved their positive effects in targeting food security, their continuous and injudicious use has led to several problems such as development of resistance in insects, health hazards, environmental effects adverse effects on non-target organisms and destruction of natural enemies. Therefore, it is necessary to search for alternative methods to manage the bean aphid in an ecofriendly manner. Hence the present research study on **Species complex of aphids in legumes with special reference to bio-ecology and organic management of field bean aphid, *Aphis craccivora* Koch** was undertaken with the following objectives.

1. To record the species complex of aphid infesting legumes
2. To record the seasonal incidence of *Aphis craccivora* Koch on field bean
3. To study the biology of *Aphis craccivora* Koch and
4. To evaluate the organic molecules against aphid on field bean

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

The research study on **Species complex of aphids in legumes with special reference to bio-ecology and organic management of field bean aphid, *Aphis craccivora* Koch** was conducted at Zonal Agricultural and Horticultural Research Station, University of Agricultural and Horticultural Sciences, Shivamogga. The available literature on aphid pests, their seasonal incidence, laboratory biology and management of aphid in field condition on field bean and other related crops are reviewed and included in this chapter.

2.1 To record the species complex of aphid infesting legumes

Chakrabarthi (1987) reported 250 species of aphid infesting a number of agricultural and forest plants, out of these only 52 species were found to be gall former.

Usmani and Rafi (2009) carried out survey in important agricultural areas in different localities of Aligarh and I.A.R.I. Pusa, New Delhi during 2006 - 2008 for aphid pests on agricultural crops. They reported 58 species of aphids belonging to 36 genera from Uttar Pradesh.

Hasan (2016) identified five aphid species *viz*., in Al-Homra region, *Aphis gossypii* Glover, *Aphis craccivora*, Koch, *Aphis citricola* Van der Goot, *Myzus persicae* Sultz, and *Brachycaudus amygdalinus* colonizing on different cultivated plants.

Singh *et al.* (2016) reported that 73 aphid species colonized on the legumes in India, among which aphid, *Aphis craccivora* was the dominating species, and fed on 83 species of legumes, followed by *Aphis gossypii* (39 species) and *Acyrthosiphon pisum* (20 species). The higher number of aphid species (16 species) were found to colonise on *Cajanus cajan*, followed by *Lablab purpureus* (12 aphid species) and *Vigna unguiculata* (8 aphid species).

Singh and Singh (2017) reported that *Aphis cracciovora* Koch was a polyphagous and was a major pest of legume crops. The host range of *A. craccivora* in India included plants belonging to over 200 species under 46 plant families. Plants belonging to following families Asteraceae, Cucurbitaceae, Fabaceae and Solanaceae were highly infested.

2.2 To record the seasonal incidence of *Aphis craccivora* Koch on field bean

Attia *et al*. (1986) studied the seasonal abundance of aphids infesting cowpea in Egypt during 1985-86. Three aphid species *viz*., *Aphis craccivora* Koch, *A. gossypii* Glover and *Acyrthosiphon pisum* Harris were found infesting cowpea. However,

A. craccivora was the most damaging species. The absolute counts of *A. craccivora* were recorded at the beginning of season. The pest was found active from mid May to end of September reaching peak in mid July.

Srikanth and Lakkundi (1988) reported 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). They also reported that highly significant positive correlation was found between weekly aphid and predator population.

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

The population density of the cowpea aphid, *A. craccivora* and its associated natural enemies, were studied in faba bean in a field experiment conducted in Egypt during 1995 - 97, and it was found that *A. craccivora* had two main periods of activity with highest counts during the third week of December and February in 1995 - 96, and during the fourth week of December and third week of March in 1996 - 97 (El-Defrawi *et al*., 2000)

Salman and Mohamed (2000) determined the occurrence of alate and apterous forms of *A. craccivora* infesting faba beans cv. Giza 843 in five directions (North, South, East, West and East) of the field. The mean number of the alate form of *A. craccivora* was highest (1017.5 and 893.8) in the North and lowest (565 and 292.5) in the West direction during *Kharif* and *Rabi* seasons, respectively. The mean number of the apterous form of the aphid was highest in the East (4458.2) during *Kharif* season and in the North (4797.7) during *Rabi* season. The aphid count positively correlated with relative humidity and negatively correlated with maximum and minimum temperature.

Abou and Salman (2001) investigated the seasonal abundance of faba bean (cv. Giza 2) pests *viz*., *A. craccivora, Myzus persicae* (Sulzur), *B. tabaci, Liriomyza trifolii* (Burgess) and *Empoasca* spp. and associated predators *viz*., *Coccinella undecimpunctata* and *Orius* spp. in Southern Egypt. The population of *A. craccivora* appeared 2-3 weeks earlier *i.e*., during second and third week of January than the population of *M. persicae* which attained its peak between the second and third week of March.

Jat (2004) observed that the effect of biotic factors *viz.*, maximum and minimum temperature were negatively correlated with aphid population, while the relative humidity had positive correlation. The peak infestation was observed at 24.9 °C maximum, 30.5 °C minimum temperature and 57 per cent relative humidity in mustard.

Pandey (2004) conducted an experiment during 2004 in Ladakh to study the spatial distribution of cowpea aphid (*A. craccivora*) and its predator (*Coccinella* sp.) on Lucerne. Observations were recorded at weekly interval from first aphid appearance (last week of May) until its cessation (July). The aphids followed a negative binomial distribution, while its predator followed a positive binomial distribution for all the sampling dates.

Dalwadi *et al.* (2007) studied the population dynamics of major insect pests of Indian bean in relation to abiotic factors at Anand, Gujarat during 2003-04. *A. craccivora* remained active from mid November to the end of March with two distinct peaks. First peak (24.10 aphids / twig) was noticed during second week of December and second peak (123.80 aphids / twig) during last week of January. Activity of predatory coccinellids was noticed from December to the harvest of the crop with maximum population (3.95/plant) during last week of January which coincided with the peak population of aphid. Minimum temperature, mean temperature and vapour pressure showed significant negative association with aphid population. Relative humidity, sunshine hours and wind speed correlated positively with the aphid population.

Rekha and Mallapur (2007) reported that the sucking pests, lablab bug, *Coptosoma cribraria* (Fabricius.) and *Riptortus pedestris* (Fabricius) occurred commonly and found in large numbers throughout the cropping period, and the results indicated that the incidence of aphid, *A. craccivora* was noticed in large number from September to first week of October with a population range of 30.5 to 50.0 and 8.4 to 11.2 aphids per three leaves on crop sown during third week of August and first week of September, respectively.

Angayarkanni and Nadarajan (2008) carried out the biology and seasonal incidence of *A. craccivora* in cowpea crop. The result revealed that the aphid population remained active throughout the year. Three predators, *viz.*, *Menochilus sexmaculatus*, *Micropis* sp. and *Coccinella transversalis* and spiders were observed feeding and breeding on the aphid colonies under the field conditions.

Field experiments were conducted in groundnut to study the effect of abiotic parameters on the activity of *A. craccivora*. Correlation studies revealed that morning and evening relative humidity had significantly positive correlation, while minimum

temperature showed significant by negative correlation during *Rabi*. During *Kharif*, minimum temperature and rainfall had significant negative correlation. During summer, maximum and minimum temperature, morning and evening relative humidity and wind velocity showed significant negative correlation, whereas remaining parameters failed to show any significant correlation with aphid population (Prasad *et al*., 2008).

Thejaswi *et al.* (2008) studied the population dynamics of insect pests of field bean and reported a total of 22 species of insect pests 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 were *Campoletis chlorideae* Uchida, *Bracon* sp. Green bug, *Herpector costalis* (Str.), *Cryptopeltis tenuis* (Mirid), ladybird beetles, mirids, syrphids and carabid predators.

Yadav (2008) studied the population dynamics of major insect pests of cluster bean in relation to abiotic factors. During the first week of August, the infestation of whitefly, jassid and aphid commenced. The population of aphid reached peak population during the last week of August when maximum and minimum temperature was 32.2 and 25.0 °C, respectively with 85.50 per cent relative humidity.

Rakhshani *et al.* (2009) investigated the population dynamics of three alfalfa aphids, *viz*., pea aphid, *Acyrthosiphon pisum*, spotted alfalfa aphid, *Therioaphis trifolii* and *T. maculate*, black alfalfa aphid, *A. craccivora* and their predators and parasitoids for two subsequent years in Isfahan, Iran. The frequency and temporal occurrence of alfalfa aphids and their natural enemies in different regions varied, but natural enemy populations were more or less coincided with aphid population. Populations of aphids were mainly affected by alfalfa harvesting, ambient temperature and coccinellid predators. Parasitoids were found to be effective on low population density of alfalfa aphids. Air, humidity and rainfall did not affect population of alfalfa aphid.

Godwal (2010) studied the population dynamics of *A. craccivora* infesting indian bean at Jobner and reported that the population of aphid appeared on 5th September, 2009 (1.0 aphid / shoot) and reached peak on 10th October, 2009 (194.80 aphids / shoot). Among natural enemies, the population of lady bird beetle, *Monochilus sexmaculatus* was high, whereas, syrphid fly, *Xanthogramma scutellare* Fab. and black ant, *Monimorium* sp. were few in numbers. The maximum temperature and relative humidity showed non-significant correlation, whereas, the minimum temperature depicted negative significant correlation with aphid population. There is a significant positive correlation between mean aphid population and *M. sexmaculatus* population.

Patel *et al.* (2010) reported that peak activity of *A. craccivora* on cowpea was noticed during eleventh meteorological week. The *A. craccivora* first appeared during third week of February, slowly increased in subsequent weeks and reached to its maximum (10.22 aphids per 10 cm twig) level during third week of March. Thereafter, it was not noticed throughout the crop period.

According to Augustine (2011), the aphid infestation in cowpea started from third week after sowing with its peak activity from 7 to 10 weeks, and remained active throughout the crop period.

Prasad *et al.* (2011) reported that the sucking pest population was found throughout the year on HA-4 of dolichos bean. The peak population of aphids (49.00 / 3leaves), pentatomid bug (5.20 / 5 plants) and coreid bugs (11.20 / 5 plants) were observed on 60 days after sowing (DAS), whereas, eurybrachid bugs (5.20 / 5 plants) recorded at 50 DAS. They also observed that activity of predators *viz.*, robberfly, coccinellids, syrphids, green lacewing and dragonfly were high between 40 and 60 DAS and population declined thereafter.

Borah *et al*. (2012) studied the seasonal incidence of *A. craccivora* and its coccinellid and syrphid predators on black gram during Kharif season in 2009 and 2010. Four Coccinellids *viz., C. transversalis*, *Micraspis discolor* (Fabricius), *Lemmnia biplagiata* (Mulsant) and *Cheilomenes sexmaculata* (Fabricius), a syrphid, *Ischiodon scutellaris* (Fabricius) were found predating upon *Aphis craccivora*. Populations of coccinellid and syrphid predators had positive correlation with the aphid attaining population peak simultaneously with their prey. Multiple regression analysis of different predators with the population of *A. craccivora* showed 95.70 and 96.90 per cent relationship with the aphid population during 2009 and 2010, respectively.

Gauns *et al.* (2014) reported that the seasonal abundance of cowpea aphid showed increasing trend up to middle of August, thereafter population of cowpea aphid decreased and lowest population was noticed during last week of August, then the population of cowpea aphid showed increasing trend and reached to its peak during third week of October.

Kumar and Kumar (2014) recorded highest aphids population of 116.20 per 15 cm shoot tip in cowpea field during *Kharif* season. Abiotic factors like temperature, relative humidity, sunshine hour, extent and distribution of rainfall, *etc*., influenced the infestation and stabilization of various insect pests in cowpea. The populations of aphids influenced positively by relative humidity. The negative correlation was found between aphid and maximum temperature, sunshine hour and wind speed.

Swathi *et al.* (2015) reported that the aphid population started from first week after sowing *i.e.* the third week of October with 0.2 aphid index, and the population increased continuously up to 8th week with a peak level of 3.4 aphid index coinciding with peak stage of flowering and pod formation during first week of December. The peak activity of aphids was seen from 7th week to 10th week after sowing. Thereafter, the population decreased but remained active throughout the crop period. Correlation co-efficient values worked out between insect pests of cowpea and weather parameters revealed that aphid population exhibited significant negative correlation with minimum temperature (r = - 0.613) and average temperature (r = - 0.568) and highly significant negative correlation with evening relative humidity (r = - 0.705). All the other factors had no significant correlation with aphid population on cowpea.

Kataria and Kumar (2016) studied the seasonal incidence of *A. craccivora* on bean crop. The result indicated that the maximum population of pest was seen in the month of January to March on bean crop. The aphid population showed positive correlation with high temperature and the population of predators and other associated insect was showing negative correlation with minimum temperature, relative humidity and rainfall.

Kumar and Singh (2016) reported that the aphid was noticed for the first time during 34thstandard week with scanty population of 5.40 aphids per 10 cm twigs per plant followed by a gradual increase, and highest population of 17.00 aphids / 10 cm twigs / plant was recorded during 37th standard week. Population of *A. craccivora* showed significant negative correlation with maximum temperature and significant positive correlation with maximum relative humidity while non significant negative correlation with minimum temperature and sunshine hours and non significant positive correlation with minimum relative humidity and total rainfall.

Initially, population of aphid was 16.20 aphids per three leaves. The population gradually increased and reached its peak in 34th standard meteorological week (SMW) (108.13 aphids / 3 leaves) when the minimum temperature, maximum temperature, mean relative humidity and rainfall were 24.4 $^{\circ}$C, 30.5 $^{\circ}$C, 84 per cent and 17.4 mm, respectively and gradually the population declined thereafter. The population of both the predators, *Coccinella septempunctata* and *Monochilus sexmaculatus* increased with the increase in aphid population (Choudhary *et al.*, 2017).

Kumar *et al.* (2017) reported that among the various sucking pests recorded on cowpea, the aphid (*A. craccivora*) population commenced during early growth stage of cowpea crop. The peak activity of aphid (*A. craccivora*) was noticed during 38th standard meteorological week. The aphid (*A. craccivora*) first appeared during second week of August, slowly increased in subsequent weeks and reached to its maximum

level of 49.95 aphids per 15 cm twig during third week of September. Thereafter, a decline in the aphid population was noticed throughout the crop period.

2.3 To study the biology of bean aphid, *Aphis craccivora* Koch

Srikanth and Lakkundi (1988) reported the biology of *A. craccivora* on cowpea under laboratory conditions. The nymphs survived for 4.84 ±0.04 days and the adult longevity was 10.42 ± 4.55 days. The fecundity and rate of reproduction were 47.50 ± 16.73 and 6.09 ± 2.81, respectively on cowpea.

Laboratory studies on the biology of *A. craccivora* in cowpea (Patel and Srivastava, 1989) revealed that *A. craccivora* undergo four nymphal instars on cowpeas (*Vigna unguiculata*), the average nymphal period was 5.6, 5.1, 5.15 and 4.86 days in May-June, August-September, October-November and March - April, respectively, the corresponding durations of the total life cycle were 11.07, 11.15, 10.79 and 10.42 days, respectively.

Desai (2000) noted the pre-reproduction, reproduction and post-reproduction periods of *A. gossypii* on cotton as 0.24, 15.08 and 1.84 days, respectively whereas on okra it was 0.44, 16.12 and 1.84 days, respectively. The fecundity of *A. gossypii* on cotton and okra was 21.32 and 25.32, respectively. The average life span of *A. gossypii* on cotton and okra were 23.84 and 24.80 days, respectively.

Henneberry and Forlow (2001) conducted the laboratory study on biology of Cotton aphid, *Aphis gossypii* Glover. They found that apterous adult females produced an average of 1.7 nymphs per day and the nymphs (four instars) developed to adults in an average of 4.1 days at 26.7 °C in the laboratory. Average longevity of adult was 16.1 days.

Patel (2002) observed the range of pre-reproduction, reproduction and post-reproduction periods of *A. gossypii* on isabgol as 0.54 to 1, 9 to 19 and 1 to 3 days, respectively. The adult of *A. gossypii* produced 13 to 42 nymphs on isabgol during its life period. They noted that the total generation period of the aphid on isabgol ranged from 18 to 29 (23.76 ± 0.65) days.

Rathod and Bapodra (2006) found that average pre-reproductive, reproductive and post-reproductive periods of aphid in cotton were 2.19 ± 0.78, 9.19 ± 1.51 and 2.11 ± 0.33 days, respectively. The number of young ones produced by a single adult aphid varied from 12 to 35 nymphs with an average of 25.32 ± 5.78 nymphs. The rate of reproduction of a single adult aphid per day varied from 1 to 12 with an average of 4.32 ± 2.14 nymphs. The entire life span of the aphid varied from 12 to 21 days with an average of 17.98 ± 2.39 days.

Gurjar *et al.* (2007) studied the biology of *A. craccivora* and reported that the total nymphal period and total life period as 5.30 and 19.85 days, respectively.

Manikandan *et al*. (2007) reported that the pre-reproductive, reproductive and post-reproductive periods of both alate and apterous forms were 19.2 ± 6.57 and 21.6 ± 5.37 hrs, 6.6 ± 1.14 and 6.2 ± 0.84 days and 5.8 ± 1.0 and 4.8 ± 0.84 days, respectively. The average fecundity of alate and apterous forms on isabgol was 30.8 ± 2.39 and 30.2 ± 1.92 nymphs per female, respectively.

Angayarkanni and Nadarajan (2008) reported the nymphal period as 7.60 days of and rate of reproduction as 8.07 nymphs per day per adult in cowpea aphid, *A. craccivora*.

Studies on the bio-ecology of cowpea aphid by Rani (2008) revealed that it had a complex life cycle, where both alate and apterous forms were reproduced by parthenogenetic viviparity. The duration of first, second, third and fourth instars were 1.03 ± 0.14, 1.27 ± 0.15, 1.01 ± 0.13 and 1.28 ± 0.11 days, respectively. Total nymphal duration of the aphid was 4.86 ± 0.51 days under laboratory conditions. Pre-reproduction period was 1.01 ± 0.10, reproduction period was 10.31 ± 0.31 and post-reproduction period was 0.70 ± 0.05 days. Adult longevity took an average of 11.82 ± 0.43 days. Aphids laid on an average of 23.37 ± 7.67 nymphs and took 16.75 ± 0.91 days to complete its life cycle.

A study by Shah *et al.* (2009) revealed that the mean duration of first, second, third and fourth instars were 1.14 ± 0.12, 1.17 ± 0.19, 1.16 ± 0.14 and 1.54 ± 0.21 days, respectively on okra and 1.17 ± 0.15, 1.37 ± 0.15, 1.12 ± 0.16 and 1.19 ± 0.16 days, respectively on brinjal. The total nymphal period was more on okra (5.38 ± 0.34 days) than on brinjal (5.09 ± 0.30 days). The pre-reproductive, reproductive and post-reproductive periods were 0.72 ± 0.17, 9.66 ± 0.80 and 1.40 ± 0.06 days, respectively on okra and 0.85 ± 0.11, 7.63 ± 0.87 and 1.03 ± 0.07 days, respectively on brinjal. The adult lived for longer period on okra (11.08 ± 0.85 days) than on brinjal (9.15 ± 0.89 days). The total life span of pest was 16.71 ± 0.74 and 14.45 ± 0.90 days on okra and brinjal, respectively. The number of young ones per generation and birth rate was higher on brinjal than on okra.

Aslam *et al.* (2011) studied the Biology of cabbage aphid, *Brevicoryne brassicae* L. on canola leaves under laboratory conditions. They reported that aphid had a pre-reproductive and reproductive period of 2.34 and 6.25 days, respectively. Number of nymphs produced per female was 30.79 and reproductive rate was 3.85 nymphs per female per day. Longevity of reproductive females was 9.0 days. Nymphs completed three instars in 9.09 days. Mean duration of first, second and third instar was 2.09, 3.50 and 3.50 days, respectively. Mortality of nymphs during

development was 67.85, 17.85 and 14.30 percent in first, second and third instar, respectively. Out of the total nymphs produced, 54.16% reached the reproductive stage.

Patil and Patel (2013) reported that the average duration of first, second, third and fourth instar nymphs as 2.04 ± 0.16, 1.68 ± 0.16, 2.00 ± 0.17 and 1.64 ± 0.13 days, respectively with total nymphal duration of 8.64 ± 0.20 days. The average length of first, second, third and fourth instar nymphs as 0.510 ± 0.007 mm, 0.790 ± 0.014 mm, 1.140 ± 0.012 mm and 1.390 ± 0.013 mm, respectively. The average longevity of adult recorded was 16.36 ± 0.54 days. Adults measured 1.68 ± 0.020 mm in length and 0.890 ± 0.110 mm in breadth. Average pre-reproduction, reproduction and post-reproduction period was 0.68 ± 0.48, 15.50 ± 0.56 and 1.40 ± 0.12 days, respectively. The total life span of *A. gossypii* was 23.76 ± 0.65 days. The reproductive potential of the aphid was 46.50 ± 0.65 nymphs per female for its entire life period and the average rate of birth was 6.50 ± 0.52 nymphs per day per female.

Soffan and Aldawood (2014) studied the biology, colony development and demographic parameters of *A. craccivora* Koch. (Hemiptera: Aphididae) on faba bean, *Vicia faba* L. (family: Fabaceae). Two methods *viz*., whole plant and detached leaf were used in these experiments. After 14 days, the number of apterous adult, nymphs and total cowpea aphids were recorded. It was shown that cowpea aphid performed differently on the whole plant as compared with detached leaves.

Ranila *et al.* (2015) studied the bionomics of *A. gossypii* Glover on coriander in laboratory condition. The results showed that, it passed through four nymphal instars before attaining the adult stage. The oval shaped greenish brown or yellowish brown first instar nymph subsequently changed to yellowish green to bottle green on development. The average developmental periods of first, second, third and fourth nymphal instar were 1.46 ± 0.51, 1.75 ± 0.62, 1.68 ± 0.63 and 1.60 ± 0.64 days, respectively and the total nymphal period was 6.83 ± 1.39 days. The pre-reproductive, reproductive and post-reproductive periods were noted as 1.66 ± 0.47, 8.53 ± 1.97 and 3.53 ± 0.68 days, respectively. Each adult of *A. gossypii* produced 11 to 46 nymphs with an average of 30.76 ± 7.61 nymphs. The average rate of reproduction was 3.86 ± 2.87 nymphs per day. The average longevity of adult aphid was 12.01 ± 1.66 days. The generation period ranged from 18.25 ± 2.97 days.

Dhiman *et al.* (2016) studied the biology of Melon aphid, *A. gossypii* (Glover) on two species of cucurbits *viz*., ridge gourd, *Luffa acutangula* and bottle gourd, *Lagenaria vulgaris* under laboratory condition. The total nymphal period of *A. gossypii* was high (6.31 days) on ridge gourd as compared to (5.66 days) bottle gourd. The average longevity of *A. gossypii* was 18 days on ridge gourd and 16 days on bottle

gourd. The average fecundity of *A. gossypii* was 28 to 74 on ridge gourd and 25 to 71 days on bottle gourd.

Sobkowiak *et al.* (2017) reported that pre-reproduction period ranged from 8 to 19 days. A negative correlation of duration of the pre-reproduction period of *A. craccivora* was found with maximum temperature (R = - 0.598; p = 0.00) and mean daily temperature (R = - 0.576; p = 0.00). The reproduction period was 27 days and the post-reproduction period was rather short and took on average of 1 to 8 days. The entire longevity of *A. craccivora* ranged from 21 to 43 days. They found that the most *A. craccivora* generations were typically highly fertile. The highest fecundity was observed among fundatrices which on average gave birth to 125 nymphs.

2.4 To evaluate the organic molecules against aphid on field bean

Dimetry and El-Hawary (1995) determined the effect of various concentrations of Neem, Azal-F (a commercial product of neem seed kernel extract with five per cent azadirachtin content) on adults and first instar nymphs of *A. craccivora*. They reported that the extract had a aphicidal, deterrent and antifeedent effect which hindered larviposition of the adults and development of the nymphs.

The field efficacy of different formulations and concentrations of *Fusarium pallidoroseum* against *A. craccivora* was investigated in a cowpea crop. The water suspension and diatomaceous earth wettable powder formulations at 7×10^6 spores / ml achieved 100% mortality of *A. craccivora* at 12 and 16 days after treatment, respectively (Sunitha *et al.*, 1999)

Choudhary (2002) evaluated nine insecticides for the control of cowpea aphid. Phosphamidon 0.03 per cent, followed by methyl-o-demeton 0.025 per cent and dimethoate 0.03 per cent were found to be most effective whereas, azadirachtin 0.02 per cent was found to be least effective for the control of aphid.

Thiamethoxam, carbosulfan and pymetrozine were highly effective against *A. craccivora* Koch, while abamectin, azadirachtin and the detergent (Masrol 410) provided a moderate effect (Saad *et al*., 2004).

Santos *et al.* (2004) evaluated the effects of aqueous extract of neem seed powder on the development, survival and fecundity of *A. gossypii.* The treatment consisted of neem seed powder at 23.8, 122.0, 410.00 and 1410.0 mg/100 ml water. The mortality rate during the nymphal development for aphids treated with 410.0 and 1410.0 mg / 100 ml were 60.0 and 100.0 per cent, respectively.

Singh *et al.* (2004) studied the preliminary efficacy of botanicals against cotton aphid, *A. gossypii*, on cotton. Five botanicals *viz.*, multineem (Azadirachtin 9.55 %), econeem (Azadirachtin 0.3 %), neemgold (Azadirachtin 0.03 %), neemazal

(Azadirachtin 1 %) and eucalyptus oil were tested each at 0.2, 0.5 and 1 per cent, respectively. These botanicals were compared with oxydemeton methyl which was superior among the treatments in terms of pest control, Azadirachtin showed 60 % control efficacy.

Goncalves and Bleicher (2006) conducted a field experiment where insecticidal effects of azadirachtin (at 12, 192, 684, 768 and 1536 ppm) and imidacloprid at 0.105 g a.i. / lt were applied to the soil to reach root systems of cowpea previously infected by the pest. They reported that azadirachtin at 192-1536 ppm showed efficacy in the range of 39.16 to 83.81 per cent on nymphs of *A. craccivora* and imidacloprid at 0.105 g a.i. / lt showed 99.9 per cent efficacy.

Armarkar and Agarkar (2007) conducted an experiment where all the concentrations, from 10^8 to 10^2 spores /ml, of *Verticillium lecanii* were tested against *A. craccivora*. They reported that, on the basis of effectiveness, economics and persistency, *V. lecanii* at 10^8 spores/ml was found to be effective for the management of *A. craccivora* on cowpea.

Bahar *et al.* (2007) studied the effect of five different botanical extracts *viz*., tobacco, neem, garlic, eucalyptus and mehogony on aphid population on yard long bean. They reported that tobacco leaf extract had the maximum level of aphid mortality of 74-90%. The extract of neem showed 53-64% level of mortality, while garlic showed similar performance to that of neem. Botanical extracts had significant effects on yield of yard long beans. Tobacco extract treated plants produced the greatest number, amount and biomass of yard long beans. The treatment was followed by neem and garlic. The latter two treatments did not show significant effect.

Dalwadi *et al*. (2008) recorded that after first spray, significantly least (12.32 aphids / twigs) incidence of *A. craccivora* was observed *in* plots treated with Neem Seed Kernel Extract (NSKE) @ 5 % than other botanicals. On the other hand highest (21.62) population of pest was found in Vanguard, followed by Gronim (17.39). Plots treated with NLE, Naffatia Leaf Extract (NFLE) (*Ipomoea fistulosa* Mart.), Neem Azal-F and Neemolin plus exhibited more or less same level (14.36 to 16.08) of aphid incidence. Results of the second spray also revealed that NSKE was found to be superior treatment against aphids, followed by NLE, Gronim and NFLE.

Das *et al.* (2008) evaluated the aphidicidal activity of hot and cold water extracts of some indigenous plants *viz*., *Azadirachta indica* A. Juss (Neem), *Calotropis procera* (Aiton) W.T. Aiton (Akanda), *Polygonum hydropiper* L. (Biskatali) and *Ipomoea sepiaria* J. Koenig ex Roxb. (Bankalmi), against the bean aphid, *A. craccivora* Koch. They found that hot water extracts of *P. hydropiper* and *A. indica* were found to be the most effective (87.6–94.5 and 80.47–89.6% mortality

respectively, $P < 0.01$) among all the extracts. Other hot and cold water extracts of botanicals appeared to be useful (59.5–87.5% mortality) as pesticides for *A. craccivora.* The highest yield (3.25 kg per plant) was obtained using hot water extract of *P. hydropiper*, followed by hot water extract of *A. indica* (3.15 kg / plant). The lowest yield (0.32 kg / plant) was recorded from the control block. They showed that all the phyto product treatments had significantly ($P < 0.01$) better yield than the control block.

Hany and Atef (2008) conducted a field experiment and evaluated entomopathogenic fungus, *Verticillium lecanii* (Zimmermann) and the predator, *Chrysoperla carnea* (Stephens). They tested the *V. lecanii* treatments, followed by release of *C. carnea* in faba bean field for controlling cowpea aphid, *A. craccivora* (Koch). They concluded that highest reduction and yield gain was observed in fungus *V. lecanii*.

Azadirachtin 0.03 per cent and Green Miracle (antitranspirant) were tested alone and in combination against *A. craccivora*. Azadirachtin was found to be highly effective compared to antitranspirant at all concentrations tested against this aphid species reported by Hawary and El-Salam (2008).

Singh *et al.* (2009) conducted a field experiment in Rajasthan on the efficacy of *Azadirachta indica* against aphids on *Vigna radiate*, and reported that *A. indica* at first application showed significantly lower number of aphids under sole crop of *V. radiata*.

Boopathy *et al.* (2010) conducted a field experiment to study the neem based insecticides and chemical insecticides against mustard aphid, *Lipaphis erysimi* Kalt. of broccoli. All the treatments such as neem based insecticides and chemical insecticides were found significantly superior to control. The experimental findings showed that application of chemical insecticides recorded cent per cent reduction in the aphid population. Among neem based insecticides, neem oil @ 0.3 per cent EC recorded significantly minimum aphids population (1.50 aphids / plant).

Costa *et al.* (2010) reported that azadirachtin products were efficient to control cowpea black aphid under green house conditions.

Saranya *et al.* (2010) conducted the laboratory bioassay with six different concentrations of *Beauveria basssiana, metarhizium anisopliae, Verticilium lecanii, Hirsutella thompsonii* and *Cladosporium oxysporum* against the adults of *aphis craccivora.* In the high concentration (10^8 spores ml^{-1}), 100% mortality was obtained with *V. lecanii* and *H. thompsonii*, followed by *B. basssiana, M. anisopliae, C. oxysporum.* The lowest LC_{50} value of 2.5×10^4 spores ml^{-1} was recorded with *V. lecanii* and *H. thompsonii* isolates which showed higher virulence compared to other isolates. The LC_{50} values of *B. bassiana, M. anisopliae* and *C. oxysporum* were

4.5×10^4, 8.9×10^5 and 7.4×10^5 spores ml^{-1}, respectively. Among the five entomopathogenic fungi, *V. lecanii, H. thompsonii, B. basssiana* were found to be the promosing virulent isolates. They also reported that after studying their field efficacy, they can be used as potential bio control agent for the management of cowpea aphid.

The results indicated that calendar sprays significantly controlled *A. craccivora* colonies compared to control in the early season. Population of other major insect pests was generally low. During the late season, the various NSKE treatments effectively controlled *A. craccivora*. There were significant differences among the treatments in their effect on the other major insect pests. Grain yields were high in both seasons and significant difference did not exist among the calendar and monitored spray treatments (Egho, 2011).

Habou *et al.* (2011) reported that *Jatropha curcas* oil concentrations at five per cent and 7.5 per cent reduced the level of attack by aphids (*A. craccivora*) by 10 and 50 per cent, respectively as compared to the control. The toxicity increased as the dose of oil is increased. Insect mortality increased during the hours following the treatment and reached a peak after 96 hours.

Salam and Hawary (2011) reported the high virulence of *Lecanicilium lecanii* to both adult and nymphal stage of *A. craccivora*. They observed 100 per cent mortality in adult and nymphs three days after treating with 5×10^6 spores ml^{-1} and 1×10^6 spores ml^{-1}.

According to Baidoo *et al.* (2012), the neem products were effective in reducing the population of *A. craccivora.* Thus application of neem products can be used as an alternative to chemical insecticide to control *A. craccivora.*

El-Salam *et al.* (2012) carried out studies to investigate the effect of entomopathogenic fungi formulations *viz*., *Beauveria bassiana, Verticillium lecanii, Metarhizium anisopliae* and *Paecilomyces fumosoroseus* with botanical insecticide, Nimbecidine against *A. craccivora* in broad bean field. They found that Bio-Catch (*V. lecanii*) was the most effective insecticide with 73.3 per cent reduction, followed by Nimbecidine (67.7 %), Bio-Magic (61.6 %), Priority (50.3 %) and the least effective was Bio- Power (*B. bassiana*) which caused 45.5% reduction in individual aphid populations after two sprayings at 15 days interval between the first and the second sprayings.

Singh *et al.* (2012) carried out laboratory assays to evaluate the repellent property of leaf extracts of three indigenous native botanicals *viz*., *Azadirachta indica, Eucalyptus globules* L. and *Ocimum basilicum* L. against aphids and mealybugs. The result of their experiment revealed that the highest repellency were recorded in *A. indica* leaf extract which gave 99.0 and 97.0 per cent, followed by *E. globules* leaf

extract giving 96.0 and 93.0 per cent, while minimum repulsion were seen in *O. basilicum* leaf extract 91.0 and 88.0 per cent against aphids and mealybugs, respectively. As the dose increased the repellent effect also increased irrespective of the plant extracts.

Suresh *et al.* (2012) tested the virulent fungal entomopathogen, *Verticilium lecanii*-3 (VL-3) under field condition at three different concentrations *viz*., 1×10^7, 1×10^8, 1×10^9 spores/ml. Under field condition VL-3 @ 1×10^9 spores / ml showed higher per cent mortality of aphids (71.62) compared to other two lower concentrations. They finally concluded that there is scope of using *V. lecani* for the management of cowpea aphid under field condition.

Mousa *et al.* (2013) studied the efficacy of garlic, *Allium sativum* oil and eucalyptus *Eucalyptus globulus* oil and their combinations with two organophosphorus pesticides, Dimethoate 30 per cent and Pestban 48 per cent against the sucking pests of faba bean. The results showed that, garlic oil was the best in reducing the population of leafhoppers and plant hoppers with a mean reduction percentage of 68.09 per cent, followed by the two chemical insecticides dimethoate 67.90 per cent, Pestban 64.02 per cent, and Eucalyptus oil was the least in this category with 43.27 per cent. However, in controlling aphids also garlic surpasses again by a mean overall reduction of 90.96 per cent, followed by Pestban 89.44 per cent, while eucalyptus oil came in the third rank as 80.66 per cent before the dimethoate which achieved the least rank in controlling aphids as 76.14 per cent.

Arya *et al.* (2014) evaluated the insecticidal activity of petroleum ether extract of castor (*Ricinus communis*) seeds against mustard aphid *Lipaphis erysimi* Kalt. They found that petroleum ether extract of Ricinus seeds caused 45, 80, 100 and 43, 79, 100 per cent mortality, respectively at 0.5, 1.0 and 1.5 per cent concentration 24 hour after treatments in third instar nymphs and adult apterous viviparous females.

Boruah and Dutta (2014) evaluated *Metarhizium anisopliae* formulation made of 10 per cent glycerol and 0.5 per cent sunflower oil for managing *A. craccivora* in cowpea and observed 50 per cent mortality 15 days after treatment.

Khade *et al.* (2014) reported that effective treatments for cowpea aphid was dimethoate 30 EC 0.003 per cent and difenthiuron 50 WP which recorded 75.29 and 73.95 per cent reduction, respectively followed by neem oil 1 per cent, karanj oil 1 per cent, NSE 5 per cent and *Verticillium lecanii* 2×10^9 cfu / ml @ 4 g / lt which had shown 64.84, 58.74, 57.57 and 54.35 per cent reduction of aphids population, respectively.

Reddy *et al*. (2014) tested the efficacy of chemicals and botanicals against cowpea aphid, *A. craccivora* and revealed that imidacloprid (0.005 %) and acetamaprid

(0.04) caused 98.0 and 96.0 per cent mortality, respectively, whereas, thiamethoxam (0.005 %) and dimethoate (0.06 %) showed more than 80 per cent mortality. Neem oil (1 %) and azadiracthin (0.03 %) caused 69.0 and 50.0 per cent mortality, respectively.

Sreeragand Jayaprakas (2014) conducted an experiment to evaluate the efficacy of Neem oil, surfactant and cassava leaf extract bio pesticide formulation against papaya mealy bug, *Paracoccus marginatus* and cowpea aphid, *A. craccivora* on field crops. They reported that the mortality percentage varied according to formulations, and one per cent formulation which contained 50 ml neem oil, 30 ml surfactant and 20 ml cassava leaf extract proved to be most effective bio pesticide formulation against these sucking pests.

Swarnalata *et al.* (2015) reported that the treatment imidacloprid @ 0.005 per cent (0.19 aphid index / plant) were found to be most effective followed by thiamethoxam 0.01 per cent (0.33 aphid index / plant). *Verticillium lecanii* 0.40 per cent (0.58 aphid index / plant), azadirachtin 0.002 per cent (0.62 aphid index / plant) and dimethoate 0.03 per cent (0.77 aphid index / plant) were the next in order. The highest marketable pod yield (30.37 q / ha) and maximum per cent increase in pod yield of cowpea over the control (84.28 %) were recorded from the plots treated with thiamethoxam 25 WG @ 0.01 per cent.

Abebe (2016) tested the botanical seed extracts against pea Aphids (*Acyrthosiphon pisum* Harris) under laboratory condition. The result revealed that Garlic and 5% Neem induced mortality similar to Endosulfan 35 per cent EC within 24 hours of treatment application.

Field studies were conducted by Ramanujam *et al.* (2016) to test the field efficacy of ten isolates of entomofungal pathogens on the management of cowpea aphid, *A. craccivora*. Three rounds of foliar sprays of oil formulations of entomofungal pathogens at the spore dose of 1×10^8 cfu / ml were given on 30, 45 and 60 days after sowing. The results revealed that there was a lower incidence of aphids (19.37 to 40.81) per plant in the entomofungal pathogen treated plots compared to higher incidence of aphids (88.07) per plant in untreated control. They also reported that Vl-8 isolate of *Lecanicillium lecanii*, Ma-6 isolate of *Metarhizium anisopliae* and Bb-5a isolate of *Beauveria bassiana* showed 78.01, 77.42 and 76.91 per cent reduction of aphid population, respectively over control. Significantly higher yield were recorded in the plots treated with Bb-5a, Ma-6 and Vl-8 isolates (1252, 1225 and 1208 kg / hectare, respectively).

Choudhary *et al*. (2017) reported 76.76 per cent reduction of *A. craccivora* on cowpea when sprayed with dimethoate 0.03 per cent.

Palthiya and Nakat (2017) conducted a field experiment during *Kharif* to study the efficacy of Entomopathogenic fungi against aphids on okra. They tested the three Entomopathogenic fungi for their effect at various combinations with each other at same concentrations and compared with chemical insecticide dimethoate 30 EC. The result indicated that combination of Entomopathogenic fungi as *V. lecanii* 1.15 per cent WP + *M. anisopliae* 1.15 per cent WP was the most effective treatment as compared to standard check dimethoate 30 EC @ 1.5 ml / lit for suppression of aphids population on okra.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The present investigation on **Species complex of aphids in legumes with special reference to bio-ecology and organic management of field bean aphid, *Aphis craccivora* Koch** was carried out during 2017-18 under field condition at Zonal Agricultural and Horticultural Research Station, University of Agricultural and Horticultural Sciences, Shivamogga which belongs to Southern Transitional Agro-climatic Zone (Zone-7) of Karnataka. Geographically, it is situated between 13°27' N latitude and 74°37' to 75°52'E longitude with an altitude of 650 meters from mean sea level (MSL). The places lying in and around receive an average annual rainfall of 842.33 mm distribution well over the season.

The material used and methodologies adopted during the course of investigations on species complex of aphid infesting legumes, seasonal incidence of *A. craccivora* on field bean, biology of aphid, *A. craccivora* and evaluation of organic molecules against aphid, *A. craccivora* on field bean under field conditions are described in this chapter.

3.1 To record the species complex of aphid infesting legumes

3.1.1 Collection and preservation of Aphids

Intensive sampling and collection of aphid occurring on various legume crops were undertaken by conducting survey in different localities in and around Shivamogga regions *viz*., Navile (13°27' N, 75°52'E), Budigere (14°03'N, 75°58'E), Komnalu (14°02'N, 75°59'E), Abbalagere (13°59'N, 75°35'E) and Sogane (14°14'N, 75°56'E) villages from August 2017 to January 2018. Aphids usually feed on the succulent leaves, stem, foliages and pods. Aphids were removed from their host plants with a soft brush soaked in alcohol and preserved in 90 per cent alcohol. The vials were labeled systematically with the information about the host name, locality and date of collection. The collected specimens were sent for identification to National Bureau of Agriculturally Important Insect Resources (NBAIR), Bengaluru. The Geographical position system (GPS) coordinates of the respective locations were noted down.

3.2 To record the seasonal incidence of *Aphis craccivora* Koch on field bean

The studies were conducted to know the seasonal variation of aphids on field bean during *Kharif* and *Rabi* seasons of 2017-18. A bulk plot of 144 square meter with a field bean genotype, HA-4 was raised with spacing of 45 cm × 15 cm and maintained under unprotected conditions. The crop was raised following all the recommended agronomic practices *viz.*, fertilizer application, irrigation, inter-cultivation and disease management except pest management practices (Sravani *et al.,* 2015).

To assess the incidence of aphid, *A. craccivora* the observations were recorded on ten randomly selected plants at weekly intervals commencing from crop germination till harvest by counting the number of aphids per five centimeter.

3.2.1 Natural enemies

Natural enemies of bean aphid, *A. craccivora* were collected from field bean ecosystem, and also various stages of natural enemies were collected while studying seasonal incidence at weekly intervals and brought to the laboratory and kept in cages by providing the food. Emerged predators were collected and sent for identification to National Bureau of Agriculturally Important Insect Resources (NBAIR), Bengaluru.

3.2.2 Data analysis

Results obtained during the study of seasonal incidence of bean aphid were correlated with various weather parameters, *viz*., total rainfall, maximum temperature, minimum temperature and relative humidity. Regression analysis was performed to find out the extent of influence of weather parameters on the seasonal incidence of bean aphids. The weather conditions recorded at the experimental site were obtained from meteorological observatory of College of Agriculture, UAHS, Shivamogga.

3.3 To study the biology of bean aphid, *Aphis craccivora* Koch

The biology of bean aphid, *A. craccivora* was studied under laboratory conditions. The culture was maintained by collecting the aphids from the field bean plant.

The present investigation was carried out at College of Agriculture, Department of Entomology, UAHS, Shivamogga. Large number of apterous aphids were collected from the field and a laboratory stock culture was maintained. Twenty freshly deposited first instar nymphs were collected from the stock culture and each one was transferred into separate petridish with the help of camel hair brush. Tender field bean leaves were provided as food source. Observations on the number, size and duration of different instar, total nymphal period, duration of pre-reproductive, reproductive, post-reproductive, adult longevity, fecundity (nymphs / female) and total period of life cycle were recorded.

The number and duration of nymphal instars were confirmed by the presence of casted exuvia in the petridishes (Plate 2). After last moulting (fourth), the newly developed adults were reared individually in petridishes in order to study the adult longevity and total life span. The pre-reproductive period was considered from the last moulting (adult emergence) to the start of laying of nymphs. The number of days the aphid continued to reproduce was taken as reproductive period.

The post reproductive period was the period between the birth of last young one till adult mortality. The number of young one produced by a single aphid was counted daily during its reproductive period and considered as its reproductive capacity. All the reproductive parameter, adult longevity and total life span were recorded based on the observation on ten newly emerged adult. The morphometric parameters, the length and width of each nymphal instars and adults were recorded by measuring through stereobinocular microscope. The measurement from tip of abdomen to tip of head was considered as length, and width of the thorax as breadth of aphid. During the study period, the average temperature was 25±1.5˚C.

3.4 To evaluate the organic molecules against aphid on field bean

3.4.1 Experimental site

A field experiment was conducted out during *Rabi* 2017-18 at College of Agriculture, Shivamogga to evaluate the efficacy of organic molecules against aphids on field bean. The field experiment was laid out in randomized complete block design (RCBD) with three replications and ten treatments with a plot size of 2.4 x 2 m (Plate 1). In each plot, five plants were selected at randomly and tagged. First spray was given at 20 days after sowing during *Rabi* when aphid population reached to Economic threshold level (ETL). Second spray was given ten days after first spray. The treatment details of the experiment are presented in Table 1 (Plate 3).

3.4.2 Verticillium lecanii and Beauveria bassiana

Verticillium lecanii and *Beauveria bassiana* was procured from Criyagen Agri and Biotech private limited, Bangaluru.

3.4.3 Preparation of 5 per cent lantana leaf extract

Fresh leaves of healthy *Lantana camera* plant were washed with plain water to remove dust from its surface. Leaves were dried under room temperature and grinded into powder using electric grinder. 50 grams of powder was soaked in water and left undisturbed overnight. After 12 hours of soaking, the mixture was stirred well and filtered using muslin cloth and the volume was made up to one liter. One per cent detergent was added to the solution.

3.4.4 Preparation of 2 per cent garlic bulb extract

Two per cent garlic bulb extract was prepared by using 2-3 large sized healthy garlic bulbs, one liter distilled water, electric blender and muslin cloth. Known amount of garlic cloves were grinded using electric blender. 20 grams of grinded garlic paste was soaked in 20 ml of kerosene for overnight. The next day

morning the mixture was stirred well and one per cent detergent was added to the solution. Then the volume was made up to one liter by adding water and was used for spraying.

3.4.5 Preparation of 5 per cent tobacco leaf extract

Fifty gram of tobacco leaves were boiled in one liter of water for 30 minutes. This was filtered and made up to the volume by adding required quantity of water. One per cent soap was added before spray which helped the release of free nicotine.

3.4.6 Preparation of 5 per cent Neem Seed Kernel Extract (NSKE)

Fifty gram of well dried neem seed kernels were powdered using pestle and mortar and soaked overnight in 500 ml of water. Next day morning, the solution was stirred well with wooden stick till solution became milky white. One per cent detergent was added to the solution. Then the solution was filtered through double layered muslin cloth and volume was made to one liter.

3.4.7 Preparation of 5 per cent neem leaf extract

Fresh leaves of healthy *Azadirecta indica* plant were washed with plain water to remove dust from its surface. Leaves were dried under room temperature and grinded into powder using electric grinder. Fifty grams of the powder was soaked in water and left undisturbed overnight. After 12 hours of soaking, the mixture was stirred well and filtered using muslin cloth and the volume was made up to one liter. The solution was used for spraying after addition of one per cent detergent.

3.4.8 Observations

From each tagged plant, five centimeter twig length from free end were selected for counting the number of aphids per twig. With help of magnifying lens, the mean population of aphids per five centimeter twig was counted. Aphid population was recorded at one day before, three, five and seven days after application of organic insecticides. The green pod yield per plant was recorded at each harvest separately for each treatment and yield was converted to quintal/hectare. The data were analyzed using analysis of variance (ANOVA).

3.4.9 Statistical analysis of the experimental data

The statistical analysis of the data obtained from manage mental trials was done using ANOVA using Web Agri Stat Package (WASP-2) developed by Indian Council of Agricultural Research, Research complex, Goa. The standard procedures

Plate 1. Field view of experimental plot of field bean at College of Agriculture, Navile, UAHS, Shivamoga

Plate 2. Culturing of nymphs of bean aphid, *Aphis craccivora* Koch on field bean leaves

in agriculture statistics given by Gomez and Gomez (1976) were followed. The interpretation of data was done by using the critical difference value calculated at 0.05 probability level. The level of significance was expressed at 0.05 probability level.

3.4.10 Cost of cultivation

The cost of cultivation was worked out considering the inputs *viz*., seeds, fertilizers, plant protection chemicals and labour for all the operations. Treatment wise cost of cultivation was worked out. The prevailing price of input materials and labour costs were considered for computing the cost of cultivation which was expressed in Rs / ha.

3.4.10.1 Gross return

The price of field bean prevailing in the market was obtained from Agricultural Produce Market Committee, Shivamogga and was used for the calculation of gross return (Rs / ha).

3.4.10.2 Net Return

Net return (Rs / ha) was calculated by subtracting the cost of cultivation (Rs / ha) from the gross return (Rs / ha).

Net return = Gross return - Cost of cultivation

3.4.10.3 Cost: Benefit ratio

C:B ratio was calculated by dividing the cost of cultivation from gross returns.

$$\text{Cost : Benefit ratio} = \frac{\text{Gross return } \left(\frac{\text{Rs}}{\text{ha}}\right)}{\text{Cost of cultivation } \left(\frac{\text{Rs}}{\text{ha}}\right)}$$

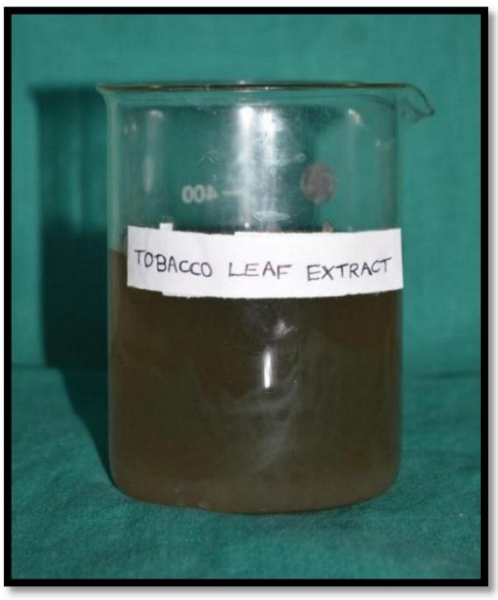
Table 1. Treatment details evaluated against field bean aphid, *Aphis craccivora* Koch

Treatment	Treatment details	Concentration
T_1	*Verticillium lecanii* 2×10^8cfu / g	1.5 ml / lt
T_2	*Beauveria bassiana* 2×10^8 cfu / g	1 g / lt
T_3	Lantana leaf extract	5 %
T_4	Garlic bulb extract	2 %
T_5	Tobacco leaf extract	5 %
T_6	NSKE	5 %
T_7	NLE	5 %
T_8	Lastraw (Potassium salt)	5 ml / lt
T_9	Dimethoate 30EC	1.75 ml / lt
T_{10}	UTC	-

a. Neem leaf extract

b. Lantana leaf extract

c. Garlic bulb extract



d. Tobacco leaf extract

Plate 3. Selected organic molecules tested against bean aphid, *Aphis craccivora* Koch

e. Neem seed kernel extract

f. *Beauveria bassiana*

g. *Veticillium lecanii*

h. Lastraw

Plate 3. Selected organic molecules tested against bean aphid, *Aphis craccivora* Koch

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The results of the research study entitled **"Species complex of aphids in legumes with special reference to bio-ecology and organic management of field bean aphid, *Aphis craccivora* Koch"** conducted at College of Agriculture, Navile, UAHS, Shivamogga during 2017-18 are presented in this chapter.

4.1 To record the species complex of aphid infesting legumes

4.1.1 Aphids species found in and around Shivamogga region on different legume crops

Survey was conducted in and around Shivamogga in order to collect aphids occurring on various legume crops *viz*., field bean, french bean, red gram, green gram, cowpea and yard long bean. The collections depicted the presence of two aphid species *viz*., *Aphis craccivora* Koch and *Aphis gossypii* Glover belonging to the family Aphididae.

In Navile village, *A. craccivora* Koch was collected from green gram, field bean and french bean crop. In these crops aphids were found maximum in population during vegetative and pod development stage. In Budigere village, *A. craccivora* was found on yard long bean crop. In Komnalu *A. craccivora* were recorded from cowpea crop. In red gram crop, *A. craccivora* species were identified in Abbalagere village. In Sogane village, *Aphis gossypii* species were recorded in cowpea crop (Table 2).

4.1.2 Aphis craccivora (Koch)

The aptera of *A. craccivora* is dark brown with a very solid black shiny body and brown to yellow legs. Immatures were slightly dusted with wax and adults were without wax. It had six segmented antennae and distal parts of femur, siphunculi and cauda black (Plate 4a).

4.1.3 Aphis gossypii (Glover)

The aphid was polymorphic with considerable variations in both size and colour. It was pear shaped, small, soft-bodied and slow moving yellow or dark green in colour. The adult aphid varied in colour from light to dark green and had dark siphunculi. The dark siphunculi was the main diagnostic structure in aphids. Siphunculi were tube-like structure in the posterior part of the abdomen (Plate 4b).

4.2 To record the seasonal incidence of *Aphis craccivora* Koch on field bean

The population of aphid, *A. craccivora* recorded during the *Kharif* season 2017 and *Rabi* 2017-18 on variety HA-4 is presented in table 3 and 4 along with

Table 2. Species complex of aphids infesting legumes in and around Shivamogga during study period

Sl.No.	Village	GPS	Species	Family	Hosts	Hosts scientific name
1.	Navile	13°27' N, 75°52'E	*Aphis craccivora*	Aphididae	Green gram	*Vigna radiata*
2.	Budigere	14°03'N,75°58'E	*Aphis craccivora*	Aphididae	Yard long bean	*Vigna unguiculata ssps esquipedalis*
3.	Komnalu	14°02'N,75°59'E	*Aphis craccivora*	Aphididae	Cowpea	*Vigna unguiculata*
4.	Abbalagere	13°59'N,75°35'E	*Aphis craccivora*	Aphididae	Red gram	*Cajanus cajan*
5.	Sogone	14°14'N,75°56'E	*Aphis gossypii*	Aphididae	Cowpea	*Vigna unguiculata*
6.	Navile	13°27' N, 75°52'E	*Aphis craccivora*	Aphididae	Field bean	*Lablab purpureus*
7.	Navile	13°27' N, 75°52'E	*Aphis craccivora*	Aphididae	French bean	*Phaseolus vulgaris*

***a. Aphis craccivora* Koch**

b. *Aphis gossypii* Glover

Plate 4: Species of aphids infesting different legume crops

meteorological parameters, *viz*., total rainfall, minimum and maximum temperature and relative humidity.

4.2.1 Seasonal incidence of Aphis craccivora

4.2.1.1 Seasonal incidence of Aphis craccivora on field bean during Kharif- 2017

Studies were conducted on seasonal incidence of *A. craccivora* on field bean at ZAHRS, Shivamogga from fourth week of July 2017 to fourth week of October 2017. An attempt was made to establish the relationship between aphid population and weather parameters *viz.*, total rainfall, maximum temperature and minimum temperature by correlation and regression statistical analysis.

During *Kharif* season, the incidence of aphid, *A. craccivora* was noticed from 31st standard week (9.2 aphids per five centimeter twig) and continued until 43rd standard week (13.1 aphids per five centimeter twig). However, its occurrence ranged from zero to15.3 aphids per five centimeter twig. The peak incidence was observed during 42nd and 43rd standard week (15.3 and 13.1 aphids per five centimeter twig, respectively (Table 3). The population of aphid was minimum during 39th standard week (1.2 aphids per five centimeter twig).

The aphids preferred to attack the inflorescence, tender pods and also the terminal twigs resulting in twisting of pods and stunted plant growth (Plate 5 and 6).

4.2.1.2 Seasonal incidence of Aphis craccivora on field bean during Rabi 2017-18

The mean population of both nymphs and adults of *A. craccivora* ranged from 75.5 to 224.7 aphids per five centimeter twig. The population started from the 45th standard week (75.5 aphids per five centimeter twig) and continued throughout the cropping period. Peak incidence was observed during 50th, 51st, 52nd and first standard week with 198, 217.6, 216 and 224.7 aphids per five centimeter twig, respectively (Table 4).

4.2.1.3 Correlation and regression between seasonal incidence of Aphis craccivora on field bean with weather parameters.

The incidence of *A. craccivora* on field bean was correlated with various weather parameters *viz.*, maximum temperature, minimum temperature, relative humidity and total rainfall during the study period from July 2017 to February 2018 during *Kharif* and *Rabi* season.

4.2.1.3.1 Kharif 2017

The correlation coefficient between weather parameters and aphid population showed non-significant negative correlation with total rainfall (r = - 0.473), non-

Table 3. Seasonal incidence of bean aphid, *Aphis craccivora* Koch on field bean during *Kharif*- 2017 at Shivamogga

Time		MSW	Average number of aphids per 5 cm twig	Rain fall (mm)	Temperature (°C)		Relative humidity (%)
Month	Week				Maximum	Minimum	
July	IV	30	0	10.8	29.4	21.7	86
August	I	31	9.2	28	30.2	21.8	86
	II	32	8.6	31.8	30	21.9	91
	III	33	4.5	34.4	29.5	21.5	87
	IV	34	3.8	17.6	28.9	21.9	90
September	I	35	4.3	44.2	29.1	21.8	92
	II	36	2.6	70	31.7	22.5	89
	III	37	3.4	45.4	31.9	22.7	88
	IV	38	3.3	7.2	28.7	20.7	87
	V	39	1.2	64	29.5	21.4	89
October	I	40	3.6	62.8	30.6	22	86
	II	41	7.9	17.6	32	22.1	91
	III	42	15.3	0	31	20.8	89
	IV	43	13.1	4.2	32.1	19.3	88

Mean observations of 10 plants

Note: MSW= Mean standard week

Table 4. Seasonal incidence of bean aphid, *Aphis craccivora* Koch on field bean during *Rabi* 2017-18 at Shivamogga

Time		MSW	Average number of aphids per 5 cm twig	Rain fall (mm)	Temperature (°C)		Relative humidity (%)
Month	Week				Maximum	Minimum	
November	II	45	75.5	6.4	31.8	17	78
	III	46	94.4	0	32.5	17.7	77
	IV	47	159.1	0	33.3	19.2	77
December	I	48	174.1	0	29.9	18.3	77
	II	49	156	0	32.3	18.6	78
	III	50	198	0	32.5	16.9	80
	IV	51	217.6	0	31.4	15.8	70
	V	52	216	0	30.7	13	73
January	I	1	224.7	0	31.5	14.3	83
	II	2	185.2	0	32.7	17	73
	III	3	153.2	0	32.1	15	64
	IV	4	136.45	0	32.1	14.9	84
February	I	5	105.7	0	31.9	13.3	56

Mean observations of 10 plants

Note: MSW= Mean standard week

Plate 5. Aphids found on tender twigs

Plate 6. Aphids found on pods and flowers

significant positive correlation with maximum temperature (r = 0.281), significant negative correlation with minimum temperature (r = - 0.537) and non- significant positive correlation with relative humidity (r = 0.074). The equation obtained when the data subjected to multiple linear regression analysis was Y= -13.097 - 0.055 X_1 + 1.207 X_2 - 2.41 X_3 + 0.39 X_4, where X_1= total rain fall, X_2= maximum temperature, X_3= minimum temperature and X_4= relative humidity. The value of coefficient of determination R^2 revealed that the seasonal incidence of bean aphid was influenced by weather parameters to an extent of 43.9 per cent (Table 5).

4.2.1.3.2 Rabi 2017-18

The correlation coefficient between weather parameters and aphid showed non-significant negative correlation with total rainfall (r = - 0.534), maximum temperature (r = - 0.287), minimum temperature (r = - 0.198) and positive correlation with relative humidity (r = 0.177). During *Rabi* season all weather parameters were non-significantly correlated therefore regression analysis was not done (Table 5).

4.2.2 Natural enemies

During the study period two coccinellids *viz*., *Coccinella transversalis* (Fabricius) and *Harmonia* sp. (Plate 7) belongs to the family Coccinellidae and order Coleoptera and predator syrphid fly, *Ishiodon scutellaris* (Fabricius) of family Syrphidae and order Diptera were recorded (Table 6 and Plate 7).

4.3 To study the biology of *Aphis craccivora* Koch

The laboratory rearing was conducted to study the biology of *A. craccivora* on field bean during 2017-18 at Department of Entomology, College of Agriculture, Shivamogga. During the course of investigation, the room temperature was 25 ± 1.5 °C.

4.3.1 Biology of Aphis craccivora

The nymphs of *A. craccivora* moulted thrice and had four instars. The results are presented in the table 6, 7 and 8.

4.3.1.1 First instar nymph

The freshly laid nymphs of apterous form were pale green and had pear shaped bodies. The total body length longer than the body width. The compound eyes were small, situated behind the base of the antenna and were reddish in color with a pair of cornicles (Plate 8a). The length of first instar nymph varied from 0.06 to 0.72 mm with an average of 0.54 ± 0.25 mm and width ranged from 0.26 to 0.36 mm with an average of 0.31 ± 0.03 mm (Table 9).The duration of fist

Table 5. Correlation and regression analysis for incidence of bean aphid, *Aphis craccivora* Koch on field bean with weather parameters during 2017-18

Insect	Correlation coefficient ('r' value)				Coefficient of determination (R^2)	Regression equation
	Total rainfall (mm) X_1	Temperature (°C)		Relative humidity (%) X_4		
		Maximum (°C) X_2	Minimum (°C) X_3			
***Kharif*2017**						
Aphids	-0.473	0.281	-0.537*	0.074	0.439	Y= -13.097-0.055 X_1+1.207 X_2-2.41 X_3+0.39 X_4
***Rabi* 2017-18**						
Aphids	-0.534	-0.287	-0.198	0.177	-	-

*Significant @ 5 per cent level of probability

Note: X_1= Total rainfall (mm) X_2= Maximum temperature (ºC)
X_3= Minimum temperature (ºC) X_4= Relative humidity (%)

Table 6. Natural enemies recorded from bean aphid, *Aphis craccivora* Koch during 2017-18

Sl. No.	Natural enemies	Scientific name	Systemic position (family and order)
1.	Lady bird beetle	*Coccinella transversalis*	Coccinellidae: Coleoptera
2.	Lady bird beetle	*Harmonia* sp.	Coccinellidae: Coleoptera
3.	Syrphid fly	*Ishiodon scutellaris*	Syrphidae:Diptera

Coccinella transversalis

Harmonia **sp.**

Maggot of syrphid fly

Adult syrphid fly

Plate 7. Natural enemies of bean aphid, *Aphis craccivora* Koch

nymphal instar ranged from 1.00 to 2.00 days with an average of 1.47 ± 0.37 days (Table 7).

4.3.1.2 Second instar nymph

The second instar nymphs of apterous form were light green to light brown in color. The compound eyes were similar in structure as compared to first instar nymph (Plate 8b). The nymphal length varied from 0.72 to 1.1 mm with an average of 0.86 ± 0.12 mm and width ranged from 0.04 to 0.52 mm with an average of 0.43 ± 0.15 mm (Table 9). The duration of second nymphal instar ranged from 1.0 to 1.6 days with an average of 1.36 ± 0.47 days (Table 7).

4.3.1.3 Third instar nymph

Third instar aphids were brown in color. The compound eyes were round and slightly bigger than those of the second instar (Plate 8c). Here nymphal length varied from 1.04 to 1.24 mm with an average of 1.13 ± 0.07 mm and width ranged from 0.06 to 0.7 mm with an average of 0.51 ± 0.24 mm (Table 9). The duration of third nymphal instar ranged from 1.0 to 1.5 days with an average of 1.19 ± 0.22 days (Table 7).

4.3.1.4 Fourth instar nymph

Fourth instar nymph was brown to dark brown color with elongated pear shaped body. (Plate 8d). The fourth instar nymphal length varied from 1.52 to 1.64 mm with an average of 1.57 ± 0.03 mm and width ranged from 0.64 to 0.7 mm with an average of 0.71 ± 0.07 mm (Table 9). The duration of fourth nymphal instar ranged from 1.0 to 2.0 days with an average of 1.41 ± 0.39 days (Table 7).

4.3.1.5 Total nymphal duration

The total nymphal duration of the apterous aphid under laboratory conditions ranged from 4.2 to 7.7 days with an average of 5.43 ± 1.05 days (Table 7).

4.3.1.6 Pre- reproductive, reproductive and Post- reproductive period

The mode of reproduction was exclusively through parthenogenesis. The pre- reproductive period varied from 1.0 to 1.6 days with an average of 1.39 ± 0.32 days (Table 8). The reproductive period ranged from 8.0 to 10 days with an average of 9.4 ± 0.77 days (Table 8).The post reproductive period of bean aphid ranged from 1.0 to 1.6 days with an average of 1.28 ± 0.29 days (Table 8). The number of young ones produced by a single female in its lifetime was 23-36 with an average of 29 ± 4.34 (Table 8).

Table 7. Duration of nymphal instars of *Aphis craccivora* Koch reared under laboratory conditions

Nymphal stage	Nymphal developmental period (days)	Mean ± SD (days)
1st instar	1.00 - 2.00	1.47 ± 0.37
2nd instar	1.00 - 1.60	1.36 ± 0.47
3rd instar	1.00 - 1.50	1.19 ± 0.22
4th instar	1.00 - 2.00	1.40 ± 0.39
Total nymphal period	4.20 - 7.70	5.43 ± 1.05

Number of sample, n=10

Table 8. Reproductive parameters of *Aphis craccivora* Koch reared under laboratory conditions

Parameter	Range	Mean ± SD
Pre-reproductive period (days)	1.00 - 1.60	1.39 ± 0.32
Reproductive period (days)	8.00 - 10.00	9.40 ± 0.77
Post- reproductive period (days)	1.00 - 1.60	1.28 ± 0.29
Adult longevity (days)	10.00 - 13.10	12.07 ± 0.86
Fecundity(nymphs/female)	23.00 - 36.00	29.00 ± 4.34
Total life cycle	14.20 - 20.80	17.50 ± 1.91

Number of sample, n=10

Table 9. Morphometric data of field bean aphid, *Aphis craccivora* Koch reared under laboratory conditions

Sl. No.	Insect stage	Length (mm)		Width (mm)	
		Range	Mean ±SD	Range	Mean ±SD
1.	**1st instar**	0.06 - 0.72	0.54 ± 0.25	0.26-0.36	0.31 ± 0.03
2.	**2nd instar**	0.72 - 1.1	0.86 ± 0.12	0.04-0.52	0.43 ± 0.15
3.	**3rd instar**	1.04 - 1.24	1.13 ± 0.07	0.06-0.7	0.51 ± 0.24
4.	**4th instar**	1.52 - 1.64	1.57 ± 0.03	0.64-0.7	0.71 ± 0.07
5.	**Apterous adult**	2.1 - 2.34	2.25 ± 0.08	1.04-1.36	1.16 ± 0.08
6.	**Alate adult**	1.8 - 2.7	2.12 ± 0.27	1.04-1.54	1.17 ± 0.13

Number of sample, n=10

a. First instar

b. Second instar

c. Third instar

d. Fourth instar

e. Apterous adult

f. Alate adult

Plate 8. Different life stages of bean aphid, *Aphis craccivora* Koch

4.3.1.7 Apterous adult

The apterous adult was soft bodied, pear-shaped and shiny black in color with white appendages (Plate 8e). A pair of cornicles were found at posterior end of the abdomen. The longevity of adult ranged from 10.00 to 13.10 with an average 12.07 ± 0.86 days (Table 8). The apterous adult length varied from 2.1 to 2.34 mm with an average of 2.25 ± 0.08 mm and the width ranged from 1.04 to 1.36 mm with an average of 1.16 ± 0.08 mm (Table 9).

4.3.1.8 Alate form

The alate form of bean aphid was pear-shaped and brownish black in color with white appendages (Plate 8f). The body length of alate form ranged from 1.8 to 2.7 mm with an average of 2.12 ± 0.27 mm and width ranged from 1.04 - 1.54 mm with an average of 1.17 ± 0.13 mm (Table 9). The wings were transparent and the veins were green in color.

4.3.1.9 Total life cycle of the apterous bean aphid

Total life cycle of the aphid under laboratory conditions ranged from 14.20-20.80 days with an average of 17.50 ± 1.91 days (Table 8).

4.3.1.10 Mode of reproduction

The aphid reproduced by parthenogenetic viviparity and the total fecundity varied from 23 to 36 nymphs per female with of 29.00 ± 4.34 nymphs per female. No sexual reproduction was noticed in laboratory condition during the course of investigation. Both adult apterous and alate forms directly deposited the young ones parthenogentically.

4.4 To evaluate the organic molecules against aphid on field bean

4.3.1 First spray

4.3.1.1 Pre count

Totally eight organic molecules *viz*., *Verticillium lecanii* 2×10^8 cfu / g @ 1.5 ml / lt, *Beauveria bassiana* 2×10^8 cfu / g @ 1g / lt, lantana leaf extract 5 per cent, garlic bulb extract 2 per cent, tobacco leaf extract 5 per cent, Neem Seed Kernel Extract (NSKE) 5 per cent, Neem leaf extract (NLE) 5 per cent, lastraw @ 5ml / lt were evaluated along with standard check, dimethoate 30EC @ 1.75 ml / lt and an untreated control during *Rabi*- 2017 against the bean aphid, *A. craccivora*. Results of the field trail are presented in Table 10 and 11. Prior to treatment imposition, the population of bean aphids ranged from 23.01 to 27.12 per five centimeter twig in different treatment plots and were statistically non-significant.

4.3.1.2 Three days after first spray

At three days after spray, there were significant differences among the treatments with respect to mean number of aphids per 5 cm twig. Among the organic molecules evaluated, *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt (14.48) was found superior, followed by lastraw @ 5ml / lt (14.83) which were on par with each other. Next best treatments were NSKE 5 per cent (16.38), followed by Garlic bulb extract two per cent (18.60) and *B. bassiana* @ 1g / lt (19.12). Significantly higher aphid population per five centimeter twig was recorded with lantana leaf extract five per cent (21.83), followed by NLE 5 per cent (21.69) and tobacco leaf extract five per cent (19.79).

Standard check dimethoate 30 EC @ 1.75 ml / lt (11.09) was found to be superior over all the treatments and which was on par with *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt and lastraw @ 5ml / lt. In untreated check, the bean aphid population was 27.47 per five centimeter twig which was significantly higher compared to other treatments (Table 10).

4.3.1.3 five days after first spray

There were significant differences among the treatments at five days after spray. All the treatments recorded significantly lower bean aphid population than untreated check. The lowest aphid population per five centimeter twig was recorded with *V. lecanii* 2×10^8 cfu / g @ 1.5 ml/lt (11.29) and lastraw @ 5ml / lt (11.80). The least best treatments were lantana leaf extract 5 per cent (20.86), which was on par with NLE 5 per cent (20.28) and tobacco leaf extract 5 per cent (18.25).

Standard check dimethoate 30 EC @ 1.75 ml/lt recorded lowest aphid population per five centimeter twig (6.92) and found to be superior over all the treatments. In untreated control, aphid population was significantly higher (29.33) compared to other treatments (Table 10).

4.3.1.4 Seven days after first spray

Almost similar trend of results was recorded on seven days after spraying, *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt (13.13) and lastraw @ 5ml / lit (13.62) recorded least number of aphids per five centimeter twig Table 10.

Further, lantana leaf extract 5 per cent with 23.90 aphids per five centimeter twig found to be least effective compared to other treatment, followed by NLE five per cent (23.06) and Tobacco leaf extract 5 per cent (20.34). Standard check dimethoate 30 EC @ 1.75 ml/lt found to be superior over all the treatments and recorded lowest aphid population (7.56). In untreated control, aphid population was significantly higher (32.70) as compared to other treatments.

Table 10. Efficacy of organic molecules against bean aphid, *Aphis craccivora* Koch on field bean during 2017 (First spray)

Tr. No.	Treatment details	Dosage / lit	Mean number of aphids per 5 cm twig				Mean aphids population per 5cm twig	Per cent reduction of aphids over untreated control
			First spray					
			1 DBS	3 DAS	5 DAS	7 DAS		
T1	*Verticillium lecanii*	1.5 ml	23.67 (4.91)	14.48 (3.87)^{de}	11.29 (3.43)^{d}	13.13 (3.68)^{d}	**12.96**	**56.55**
T2	*Beauveria bassiana*	1 g	26.16 (5.16)	19.12 (4.43)^{bcd}	18.06 (4.31)^{bc}	19.75 (4.50)^{bc}	**18.97**	**36.40**
T3	Lantana leaf extract	5%	24.48 (4.99)	21.83 (4.72)^{ab}	20.86 (4.62)^{b}	23.90 (4.87)^{b}	**22.19**	**25.61**
T4	Garlic bulb extract	2%	27.12 (5.23)	18.60 (4.31)^{bcd}	17.04 (4.18)^{bc}	19.05 (4.42)^{bc}	**18.23**	**38.88**
T5	Tobacco leaf extract	5%	24.94 (5.04)	19.79 (4.50)^{bc}	18.25 (4.33)^{bc}	20.34 (4.56)^{bc}	**19.46**	**34.76**
T6	NSKE	5%	23.01 (4.85)	16.38 (4.11)^{cd}	14.42 (3.86)^{cd}	16.81 (4.16)^{cd}	**15.87**	**46.79**
T7	NLE	5%	26.22 (5.12)	21.69 (4.71)^{ab}	20.28 (4.54)^{b}	23.06 (4.85)^{b}	**21.67**	**27.35**
T8	Lastraw	5ml	24.80 (5.02)	14.83 (3.91)^{cde}	11.80 (3.49)^{d}	13.62 (3.75)^{d}	**13.41**	**55.04**
T9	Dimethoate 30EC	1.75ml	25.71 (5.12)	11.09 (3.40)^{e}	6.92 (2.72)^{e}	7.56 (2.82)^{e}	**8.52**	**71.43**
T10	UTC	-	23.78 (4.92)	27.47 (5.28)^{a}	29.33 (5.42)^{a}	32.70 (5.76)^{a}	**29.83**	
	SE. m±		**NS**	**0.20**	**0.20**	**0.22**	**-**	**-**
	CD@ % 0.05		**NS**	**0.59**	**0.60**	**0.66**	**-**	**-**
	CV(%)		**8.94**	**8.00**	**8.62**	**8.87**	**-**	**-**

DBS-Day before spraying; DAS-Day after spraying; Figures in parentheses are $\sqrt{x} + 0.5$ transformed values
Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05)

Among organic molecules the overall mean population of aphids per five centimeter twig was *V. lecanii* 2 × 10^8 cfu / g @ 1.5 m / lt (12.96) and lastraw @ 5ml / lit (13.41). The succeeding best treatments were NSKE 5 per cent, garlic bulb extract 2 per cent and *B. bassiana* 2×10^8 cfu/g @ 1g / lt which recorded the mean aphid population of 15.87, 18.23 and 18.97 per five centimeter twig, respectively. Significantly higher mean aphid population per five centimeter twig was recorded with lantana leaf extract 5 per cent (22.19), NLE five per cent (21.67) and tobacco leaf extract 5 per cent (19.46). Standard check dimethoate 30 EC @ 1.75 ml/lt (8.52) found to be superior treatments over all other treatments. In untreated control, mean aphid population was 29.83 per five centimeter twig which was significantly higher compared to other treatments.

The decreasing order of the treatments with their efficacy was dimethoate 30 EC @ 1.75ml / lt > *V. lecanii* 2 × 10^8 cfu / g @ 1.5m / lt > lastraw @ 5m / lt > NSKE 5 per cent > garlic bulb extract 2 per cent > *B. bassiana* 2 × 10^8 cfu / g @ 1g / lt > tobacco leaf extract 5 per cent > NLE 5 per cent > lantana leaf extract five per cent (Table. 10).

4.3.2 Second spray

When the aphids in different treatments reached ETL second spray was taken up *i.e.* 10 days after first spray (Table 11).

4.3.2.1 Pre count

Prior to treatment imposition, the population of bean aphids ranged from 10.43 to 36.23 per five centimeter twig and spraying was taken up 10 days after first spray (Table 11).

4.3.2.2 Three days after second spray

The data pertaining to three days after second spray against bean aphid is presented in Table 11. Similar trend was observed in the second spray as in first spray with respect to mean number of aphid per five centimeter twig. Among the organic molecules evaluated, lowest incidence of bean aphid (10.14) was recorded in *V. lecanii* 2 × 10^8 cfu / g @ 1.5 ml / lt followed by lastraw @ 5ml / lt (10.75), which were on par with each other. Next best treatments were NSKE 5 per cent (15.67), followed by Garlic bulb extract 2 per cent (17.85), *B. bassiana* @ 1 g / lt (21.00). Significantly higher aphid population per five centimeter twig was recorded with lantana leaf extract five per cent (24.24), followed by NLE five per cent (21.91) and tobacco leaf extract five per cent (21.78).

Table 11. Efficacy of organic molecules against bean aphid, *Aphis craccivora* Koch on field bean during 2017 (Second spray)

Tr. No.	Treatment details	Dosage/ lit	Mean number of aphids per 5cm twig				Mean aphids population per 5cm twig	Per cent reduction of aphids over untreated control
			Second spray					
			1 DBS	3 DAS	5 DAS	7 DAS		
T1	*Verticillium lecanii*	1.5 ml	14.12 (3.82)^{ef}	10.14 (3.26)^{ef}	7.36 (2.8)^{d}	9.2 (3.11)^{e}	**8.9**	**79.63**
T2	*Beauveria bassiana*	1 g	21.46 (4.69)^{bc}	21.00 (4.64)^{bc}	16.51 (4.12)^{bc}	18.75 (4.39)^{bcd}	**18.75**	**57.09**
T3	Lantana leaf extract	5%	26.91 (5.24)^{b}	24.24 (4.95)^{b}	20.97 (4.54)^{b}	23.98 (4.95)^{b}	**23.06**	**47.23**
T4	Garlic bulb extract	2%	19.9 (4.52)^{cd}	17.85 (4.28)^{cd}	14.69 (3.9)^{bc}	17.48 (4.24)^{cd}	**16.67**	**61.85**
T5	Tobacco leaf extract	5%	24.51 (5.00)^{bc}	21.78 (4.7)^{bc}	19.19 (4.44)^{b}	22.32 (4.70)^{bc}	**21.09**	**51.73**
T6	NSKE	5%	19.39 (4.46)^{cde}	15.67 (4.02)^{d}	11.31 (3.44)^{cd}	13.64 (3.76)^{de}	**13.54**	**69.01**
T7	NLE	5%	26.19 (5.11)^{bc}	21.91 (4.73)^{bc}	19.88 (4.51)^{b}	23.55 (4.9)^{bc}	**21.78**	**50.16**
T8	Lastraw	5ml	14.61 (3.89)^{def}	10.75 (3.35)^{e}	7.74 (2.87)^{d}	11.18 (3.42)^{e}	**9.89**	**77.36**
T9	Dimethoate 30EC	1.75ml	10.43 (3.31)^{f}	6.83 (2.71)^{f}	2.49 (1.73)^{e}	4.58 (2.25)^{f}	**4.63**	**89.40**
T10	UTC	-	36.23 (6.02)^{a}	40.57 (6.37)^{a}	43.61 (6.61)^{a}	46.94 (6.86)^{a}	**43.70**	
	SE. m±		**0.22**	**0.19**	**0.26**	**0.24**	**-**	**-**
	CD@ % 0.05		**0.66**	**0.58**	**0.77**	**0.71**	**-**	**-**
	CV(%)		**8.41**	**7.80**	**11.56**	**9.72**	**-**	**-**

DBS-Day before spraying; DAS-Day after spraying; Figures in parentheses are $\sqrt{x} + 0.5$ transformed values

Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05)

Standard check dimethoate 30 EC @ 1.75ml/lt (6.83) was found to be superior over all the treatments and which was on par with *V. lecanii* 2×10^8 cfu /g @ 1.5 ml/lt.

In untreated check, the bean aphid population was 40.57 per five centimeter twig which was significantly higher compared to other treatments (Table 11).

4.3.2.3 Five days after second spray

There were significant differences among the treatments at five days after spray. All the treatments recorded significantly lower bean aphid population than untreated check. The lowest aphid population per five centimeter twig was recorded with *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt (7.36) followed by lastraw @ 5ml / lt (7.74) which were on par with each other. The least best treatments were lantana leaf extract 5 per cent (20.97), which was on par with NLE 5 per cent (19.88) and tobacco leaf extract 5 per cent (19.19).

Standard check dimethoate 30 EC @ 1.75ml/lt recorded lowest aphid population per five centimeter twig (2.49) and found to be superior over all the treatments. In untreated control, aphid population was significantly higher (43.61) compared to other treatments (Table 11).

4.3.2.4 Seven days after second spray

Seven days after treatment imposition, the results showed significant differences among the treatments (Table 11). It was observed that among organic molecules *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt (9.20) and lastraw @ 5 ml / lit (11.18). The least aphid population was noticed in lantana leaf extract five per cent (23.98), NLE five per cent (23.55) and tobacco leaf extract five per cent (22.32). Standard check dimethoate 30 EC @ 1.75ml/lt recorded lowest aphid population (4.58) and found to be superior over all the treatments

The highest aphid population (46.94) was observed in untreated check. At seven days after second spray all the treatments recorded significantly lower population of aphids over the untreated check.

The overall mean number of aphids per five centimeter twig in different treatments indicated that *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt was very effective in recording lowest mean number of aphids per five centimeter twig (8.9) among organic molecules. This was superseded by lastraw @ 5 ml / lit (9.89). The next best treatments were NSKE 5 per cent, garlic bulb extract 2 per cent and *B. bassiana* 2×10^8 cfu / g @ 1 g / lt which recorded the mean aphid population of 13.54, 16.67 and 18.75 per five centimeter twig, respectively. Lantana leaf extract five per cent which recorded mean aphid population of 23.06 per five centimeter twig was found

least effective out of all other treatments evaluated. Standard check dimethoate 30 EC @ 1.75 ml / lt (4.63) found to be superior treatment over all other treatment. The highest mean aphid population (43.70) was observed in untreated check (Table 11).

Significantly highest per cent reduction of bean aphid population over the control was recorded in the treatment *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt (76.63 %) among the organic molecules tested, followed by lastraw @ 5m/lt (77.36 %) and NSKE five per cent (69.01 %). The next best treatments were garlic bulb extract two per cent (61.85 %), *B. bassiana* 2×10^8 cfu / g @ 1 g / lt (57.09 %), tobacco leaf extract five per cent (51.73 %), NLE five per cent (50.16 %) lantana leaf extract five per cent (47.23 %) Table 11.

The decreasing order of the insecticides with their efficacy was dimethoate 30 EC @ 1.75 ml / lt > *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt > lastraw @ 5 ml / lt > NSKE five per cent > garlic bulb extract two per cent > *B. bassiana* 2×10^8 cfu / g @ @ 1g / lt > tobacco leaf extract 5 per cent > NLE 5 per cent > lantana leaf extract five per cent (Table 11).

4.3.3 Yield and cost economics

The effect of different organic molecule sprays on yield and cost economics is presented in the Table 12. Among organic molecules *V. lecanii* 2×10^8 cfu/g @ 1.5 ml / lt was most effective with regard to green pod yield (24.14 q / ha), followed by lastraw @ 5 ml / lt (23.83 q / ha), NSKE five per cent (20.21 q / ha), garlic bulb extract two per cent (19.14 q / ha), *B. bassiana* 2×10^8 cfu / g @ 1g / lt (17.35 q / ha). Standard check dimethoate 30 EC @ 1.75 ml / lt recorded highest yield of 28.75 q / ha over all other organic treatments and found to be superior. However, all the treatments recorded higher yield and were found to be superior over the untreated check.

C: B ratio varied from 1: 1.58 to 1: 3.82 among the treatments (Table 12). Among the organic molecules highest cost - benefit ratio of was 1: 3.11 recorded from *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt, followed by lastraw @ 5 ml / lt (1: 3.10), NSKE 5 per cent (1: 2.62), *B. bassiana* 2×10^8 cfu / g @ 1 g / lt (1: 2.30). Standard check dimethoate 30 EC @ 1.75 ml / lt recorded 1: 3.82 cost - benefit ratio, which were found to be superior over all the treatments. C: B ratio in untreated check was the lowest 1: 1.58.

Among organic molecules *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt, lastraw @ 5 ml / lt and NSKE five per cent is the best treatments.

Table 12. Economics of organic molecules tested against bean aphid, *Aphis craccivora* Koch

Tr. No.	Treatment	Dosage/lt	Yield q/ha	Cost per 2 spary		Total cost for pest management (Rs./ha)	Total cost of production (Rs. /ha)	Gross return (Rs./ha)	Net returns (Rs./ha)	C: B ratio
				Insecticides (Rs./ha)	Labour (Rs.)					
T1	*Verticillium lecanii*	1.5 ml	24.14	950.00	400.00	1350.00	19350	60350	41000	1:3.11
T2	*Beauveria bassiana*	1 g	17.35	400.00	400.00	800.00	18800	43375	24575	1:2.30
T3	Lantana leaf extract	5%	15.57	-	400.00	400.00	18400	38925	20525	1:2.11
T4	Garlic bulb extract	2%	19.14	800.00	400.00	1200.00	19200	42850	23650	1:2.23
T5	Tobacco leaf extract	5%	17.42	550.00	400.00	900.00	18900	43550	24650	1:2.30
T6	NSKE	5%	20.21	850.00	400.00	1250.00	19250	50525	31275	1:2.62
T7	NLE	5%	17.13	-	400.00	400.00	18400	42825	24425	1:2.32
T8	Lastraw	5ml	23.83	600.00	400.00	1000.00	19000	59575	40575	1:3.10
T9	Dimethoate 30EC	1.75ml	28.75	410.00	400.00	810.00	18810	71875	53065	1:3.82
T10	UTC	-	11.42	-	-	-	18000	28550	10550	1:1.58

Note: Cost of green pod = 2500 Rs./q
Standard spray volume: 500 lt/ha
Cost of labour: Rs. 200/day
Number of labour required per spray / ha= 2

DISCUSSION

V DISCUSSION

Results of the present investigation **Species complex of aphids in legumes with special reference to bio-ecology and organic management of field bean aphid, *Aphis craccivora* Koch** conducted during 2017-18 at College of Agriculture, Navile, UAHS, Shivamogga are discussed in this chapter.

5.1 To record the species complex of aphid infesting legumes

This experiment was carried out during 2017-18 to study the species complex of aphid infesting legumes in and around Shivamogga.

5.1.1 Aphids species found in and around Shivamogga region

Two species were recorded during the study period from specimens collected from different regions of Shivammoga, on different legume crops. Usmani and Rafi (2009) recorded 58 species of aphids from Uttar Pradesh infesting agricultural crops.

In Navile region of Shivammogga *A. craccivora* species of aphids were recorded infesting field bean, French bean and red gram. Singh *et al.* (2016) reported that 73 aphid species colonised on the legumes in India, among which aphid, *A. craccivora* was the dominating species and fed on 83 species of legumes. In Komnalu and Sogone village *A. craccivora* and *Aphis gossypii* species were noticed infesting cowpea crop. In Budigere, long yard bean was infested with *A. craccivora* species and in Abbalagere village, *A. craccivora* species was observed infesting red gram crop. Singh *et al.* (2016) reported that *A. craccivora* is the dominating species and fed on 83 species of legumes, followed by *A. gossypii* which fed on 39 species of legumes. The higher number of aphid species (16 species) were found to colonise on *Cajanus cajan*, followed by *Lablab purpureus* (12 aphid species) and *Vigna unguiculata* (8 aphid species).

A. craccivora were found as the major aphid species infesting legume crops. Singh and Singh (2017) concluded that *A. craccivora* Koch is a polyphagous and was a major pest of legume crops.

5.2 To record the seasonal incidence of *Aphis craccivora* on field bean

5.2.1 Aphis craccivora (Koch)

The incidence of aphids started on first week of August, 2017. The population of aphids attained peak during third week of October (15.3 mean aphids per five centimeter twig) during *Kharif*. The present findings are in line with Godwal (2010) who reported that population of aphid appeared on fifth September, 2009 (1.0 aphid / shoot) and reached peak on tenth October, 2009 (194.80 aphids / shoot). The

population of aphid was least during 39th standard week because of high rain fall. Total rainfall was negatively correlated with aphid population. As the total rainfall increased aphid population decreased. Rekha and Mallapur (2007) reported that the aphid, *A. craccivora* incidence was noticed in large number from September to first week of October with a population range of 30.5 to 50.0 and 8.4 to 11.2 aphids per three leaves, respectively.

During *Kharif*, maximum temperature and relative humidity had non significant positive (r = 0.281 and r = 0.074) influence on aphid population, whereas, minimum temperature and rain fall had significant negative and non significant negative correlation, respectively (r = - 0.537 and - 0.473) on aphid population. This is in line with the results of Prasad *et al*. (2008) who reported that during *Kharif* season, the population of *A. craccivora* was influenced negatively with minimum temperature and rainfall. Similar results were recorded by Godwal (2010) who reported that minimum temperature depicted negative significant correlation with aphid population. Kumar and Kumar (2014) recorded highest aphid population of 116.20 per 15 cm shoot tip in cowpea field during *Kharif* season and the population of aphid influenced positively by relative humidity. The negative correlation was found between aphid and maximum temperature. This difference might be due to the weather condition prevailing during study period and also due to change in month of planting during *Kharif.*

During Rabi season, aphid population started during second week of November. Correlation studies revealed that maximum population of aphid was observed during first week of January (224.7 aphids/ five centimeter twig). Kataria and Kumar (2016) reported that the maximum population of pest was seen in the month of January to March on bean crop.

During *Rabi* season total rainfall, maximum temperature and minimum temperature had non significant negative correlation (r = - 0.534, r = - 0.287 and r = - 0.198) with the occurance of aphid population (Table 5). This result is closely confirmatory with the findings of Dalwadi *et al.* (2007) who also reported that minimum temperature, maximum temperature showed significant negative association with aphid population. Relative humidity correlated positively with the aphid population and Prasad *et al*. (2008) opined that relative humidity had significant positive correlation while minimum temperature showed significant negative correlation during *Rabi*.

Kataria and Kumar (2016) studied thes easonal incidence of *A. craccivora* on bean crop. The result indicated that the maximum population of pest was seen in the month of January to March on bean crop. The aphid population showed positive correlation with high temperature.

5.3 To study the biology of bean aphid, *Aphis craccivora* Koch

The present investigation revealed that the bean aphid *A. craccivora* passed through four nymphal instars before reaching the adult stage. The present observations are in agreement with that of Patel and Srivastava (1989) and Rani (2008) who reported that *A. craccivora* had four nymphal instars.

The total nymphal period on field bean ranged from 4.20 to 7.70 days with mean of 5.43 ± 1.05 days. The mean length of the nymphal instars was 0.54 ± 0.25 mm, 0.86 ± 0.12 mm, 1.13 ± 0.07 mm and 1.57 ± 0.03 mm for first, second, third and fourth instars, respectively. The mean width of nymphal instars was 0.31 ± 0.03 mm, 0.43 ± 0.15 mm, 0.51 ± 0.24 mm and 0.71 ± 0.07 mm for first, second, third and fourth instars, respectively. The duration of larvae ranged from 1.0 to 2.0, 1.0 to 1.6, 1.0 to 1.5 and 1.0 to 2.0 days for first, second, third, fourth and fifth instars, respectively. This is in line with Gurjar *et al.* (2007) who reported the total nymphal period of 5.30 days. However, Rani (2008) noticed shorter developmental period (4.86 days) on cowpea. The duration of average nymphal instar on cowpea was 4.84 ± 0.04 days as reported by Srikanth and Lakkundi, 1988. The nymphal measurement observed in this study are similar to that of Rani (2008). The present observations indicated that the aphid reproduced parthenogentically and viviparously.

Pre-reproductive period ranged from 1.00 to 1.60 days with a mean of 1.39 ± 0.32 days. Reproductive duration lasted for 8.00 to 10 days with a mean of 9.4 ± 0.77 days. Post- reproductive period ranged from 1.00 to 1.60 days with a mean of 1.28 ± 0.29 days and these results are comparable with the results of Rani (2008). However, post- reproductive days was more compared to the reports of Rani (2008). This might be due to variation in climatic conditions.

The longevity of adults was 12.07 ± 0.86 days. Rani (2008) also reported that average longevity of adult was 11.83 ± 0.43 days. The fecundity was 29 ± 4.34 (range 23 to 36 nymphs per female) in the present investigation, it was more compared to reports of Rani (2008) who reported that fecundity was 23.37 ± 7.67 nymphs per female. Srikanth and Lakkundi (1988) reported 47.50 ± 16.73 nymphs per female on cowpea. The difference in the development periods and fecundity might be due to individual innate capacity, food availabilities and also changed climatic conditions.

The total life cycle of the aphid under laboratory condition was 17.50 ± 1.91 days which are in close conformity with Rani (2008) who reported 16.75 ± 0.91 days, and also with Gurjar *et al*. (2007) who reported total life cycle of 19.85 days.

5.4 To evaluate the organic molecules against aphid on field bean

Out of eight organic molecules *viz*., *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt, *B. bassiana* 2×10^8 cfu / g @ 1g / lt, lantana leaf extract 5 per cent, garlic bulb extract 2 per cent, tobacco leaf extract 5 per cent, NSKE 5 per cent, NLE 5 per cent, lastraw @ 5ml / lt were evaluated along with standard check, dimethoate 30EC @ 1.75 ml / lt for the management of bean aphid, *A. craccivora* in the field condition. Among organic molecules, *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt was found superior treatment in reducing bean aphid density. When the per cent control was calculated, it was noticed that *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt could reduce the aphids density to an extent of 56.55 and 79.63 per cent in first and second spray, respectively. The research findings are in line with the findings of Khade *et al.* (2014) who reported that *V. lecanii* 2×10^9 cfu / ml @ 4g shown 54.35 per cent reduction of aphids population over different biorational management of sucking pests of Cowpea, *Vigna sinensis* L.

The present findings are in accordance with the findings of El-Salam *et al.* (2012) who reported that *V. lecanii* was the most effective entomopathogenic fungi formulations against bean aphids, *A. craccivora* in broad bean field achieved 73.3 per cent reduction were superior to other treatments. Salam and Hawary (2011) reported high virulence of *Lecanicilium lecanii* to both adult and nymphal stage of *A. craccivora*. They observed cent per cent mortality in adult and nymphs three days after treated with 5×10^6 spores ml^{-1} and 1×10^6 spores ml^{-1}. Similarly, Suresh *et al.* (2012) reported that effective control of aphid was obtained by spraying *V. lecanii*-3 @1×10^9 spores / ml which recorded 71.62 per cent mortality of aphids.

The lastraw @ 5 ml / lit recorded 77.36 per cent reduction over control was found superior followed by NSKE 5 per cent with 69.01 per cent reduction over control. The next best treatments were garlic bulb extract two per cent, *B. bassiana* 2×10^8 cfu / g @ 1g / lt and tobacco leaf extract five per cent with 61.85, 57.09 and 51.73 per cent reduction over control, respectively. Further, NLE 5 per cent and lantana leaf extract with 50.16 and 47.23 per cent reduction over control.

NSKE 5 per cent was moderately effective. These results are in agreement with the findings of Dalwadi *et al.* (2008) who reported significantly least (12.32 aphids / twigs) incidence of *A. craccivora* was observed in plots treated with NSKE 5 per cent, NLE 5 per cent and Lantana leaf extract 5 per cent recorded higher aphid population thus providing least effective but they were not inferior to untreated check.

Bahar *et al.* (2007) reported that tobacco leaf extract had the maximum level of aphid mortality (74 - 90 per cent). The extract of neem showed 53 to 64 per cent level of mortality, while garlic showed similar performance to that of neem. Lantana

leaf extract 5 per cent (22.63) and NLE 5 per cent (21.72) were least effective compared to other treatments.

Standard check dimethoate 30 EC @ 1.75 ml / lt recorded 89.40 per cent reduction over control and found to be superior treatments over all other treatments. The presents findings were in close agreements with results of Choudhary *et al.* (2017) reported that 76.76 per cent reduction of *A. craccivora* on cowpea when sprayed with dimethoate 0.03 per cent.

Among organic molecules *V. leccanii* 2×10^8cfu/g @ 1.5 ml / lt and lastraw @ 5 ml / lt was found to be superior against *A. craccivora.*

5.4.1 Cost benefit analysis

The C: B ratio of organic molecules was highest in case of *V. lecanii* 2×10^8 cfu / g @ 1.5ml / lt (1: 3.11) due to the higher yield of green pod (24.14 q / ha) obtained and the lowest incidence of bean aphid (Table 12), which is followed by lastraw @ 5ml / lt emerged as a best option for the management of bean aphid which had recorded higher yield (23.83 q / ha) as well as appreciable cost benefit ratio (1: 3.10). Standard check dimethoate 30 EC @ 1.75 ml / lt recorded highest C: B ratio compared to all other organic molecules (1: 3.82) and found to be superior over all the treatments.

Khade *et al.* (2014) reported that cost benefit ratio for management of cowpea aphid was highest in case of *Verticillium lecanii* (2×10^9 cfu / ml) (2.70) this is in close confirmatory with the present result.

Conclusion

- Two species of aphids *viz., A. craccivora* and *A. gossypii* were recorded during the study period on legumes. Among them *A. craccivora* was the dominant species.
- The population of aphids attained peak during third week of October during *Kharif*. During *Rabi* season the aphid population was maximum during first week of January. Correlation study revealed that during *Kharif*-2017 season aphid population showed non-significant negative correlation with total rainfall, non-significant positive correlation with maximum temperature, significant negative correlation with minimum temperature and non- significant positive correlation with relative humidity while, during *Rabi* 2017-18 aphid showed non-significant negative correlation with total rainfall, maximum temperature, minimum temperature and positive correlation with relative humidity.
- The total life cycle of the bean aphid under laboratory condition ranged from 14.20 to 20.80 days with a mean of 17.50 ± 1.91 days. Total nymphal period was

ranged from 4.20 to 7.70 days with a mean of 5.43 ± 1.05 days and fecundity was 29.00 ± 4.34 nymphs per female.

- Detailed biology of *A. craccivora* is quite useful in maintaining the laboratory culture for mass production of aphid predators and also to assess the aphid population build up under field conditions, so that control measures can be planned more precisely.
- Among entomopathogens, *V. lecanii* was found more effective for the management of bean aphid, *A. craccivora.*
- Botanicle insecticides *viz.*, NSKE, lastraw and garlic bulb extract were also found effective in suppressing bean aphids population. Hence, this can be recommended for the management of bean aphid, *A. craccivora* for the organic growers.

Future line of work

- Biology of bean aphid, *A. craccivora* under field condition may be taken up for comparison with that of laboratory condition.
- Field study should be conducted to evaluate the efficacy of natural enemies for the management of *A. craccivora*.
- Field studies are required to work out the ETL and EIL of *A. craccivora* on field bean.
- Large scale demonstration of organic molecule in different locations should be tried to confirm their efficacy for the control of field bean aphid, *A. craccivora.*
- Research study on seasonal incidence and management of other sucking pests also should be conducted and efficacy of organic molecules should be evaluated in field bean.

SUMMARY

VI SUMMARY

Investigations on **Species complex of aphids in legumes with special reference to bio-ecology and organic management of field bean aphid, *Aphis craccivora* Koch** was carried out at the College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga during 2017-18. The research findings of the study are summarized below.

Studies on species complex of aphids infesting different legumes in different regions of Shivamogga during 2017-18 revealed that there are two species of aphids *viz*., *Aphis craccivora* and *Aphis gossypii*.

Seasonal incidence of the bean aphids revealed that the mean population of bean aphid, *A. craccivora* was maximum during third week of October (15.3 aphids / 5cm twig) during *Kharif* season. Aphid population showed non-significant negative correlation with total rainfall (r = - 0.473), non-significant positive correlation with maximum temperature (r = 0.281), signicant negative correlation with minimum temperature (r = - 0.537) and non- significant positive correlation with relative humidity (r = 0.074).

During *Rabi* season the aphid population was maximum during first week of January (224.7 aphids per five centimeter twig). The correlation coefficient between weather parameters and aphid population showed non-significant negative correlation with total rainfall (r = - 0.534), maximum temperature (r = - 0.287), minimum temperature (r = - 0.198), and positive correlation with relative humidity (r = 0.177).

Biological studies of bean aphid, *A. craccivora* on field bean revealed that the total nymphal period ranged from 4.20 to 7.70 days with a mean of 5.43 ± 1.05 days. The morphometric study revealed that the mean length of the nymphal instars was 0.54 ± 0.25 mm, 0.86 ± 0.12 mm, 1.13 ± 0.07 mm and 1.57 ± 0.03 mm for first, second, third and fourth instars, respectively. The mean width of nymphal instars was 0.31 ± 0.03 mm, 0.43 ± 0.15 mm, 0.51 ± 0.24 mm and 0.71 ± 0.07 mm for first, second, third and fourth instars, respectively. The duration of nymphs ranged from 1.0 to 2.0, 1.0 to 1.6, 1.0 to 1.5 and 1.0 to 2.0 days for first, second, third, fourth and fifth instars, respectively.

Pre-reproductive period ranged from 1.00 to 1.60 days with a mean of 1.39 ± 0.32 days reproductive period lasted for 8.00 to 10 days with a mean of 9.4 ± 0.77days, post- reproductive period ranged from 1.00 to1.60 days with a mean of 1.28 ± 0.29 days.

The longevity of adults ranged from 10.00 to 13.10 days with a mean of 12.07 ± 0.86 days. The fecundity ranged from 23 to 36 nymphs per female with a

mean of 29 ± 4.34 nymphs per female in the present investigation. The total life cycle of the bean aphid under laboratory condition ranged from 14.20 to 20.80 days with a mean of 17.50 ± 1.91 days.

Evaluation of organic molecules against bean aphid, *A. craccivora* revealed that *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt and lastraw @ 5 ml / lt were found to be effective against bean aphid by recording the lower aphid population as compared to other organic molecules.

When yield was recorded and cost benefit ratios were worked out for the organic molecules evaluated, *V. lecanii* 2×10^8 cfu / g @ 1.5 ml / lt was found most effective by recording highest green pod yield (24.14 q / ha) and C: B ratio (1: 3.11). All the treatments recorded higher C: B ratio and were found significantly superior over the untreated check.

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APPENDICES

VIII APPENDICES

APPENDIX I

Appendix 1. Weather data of Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga from July to February 2017-18

MSW	Rain fall (mm)	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum	
30	10.8	29.4	21.7	29.4
31	28	30.2	21.8	30.2
32	31.8	30	21.9	30
33	34.4	29.5	21.5	29.5
34	17.6	28.9	21.9	28.9
35	44.2	29.1	21.8	29.1
36	70	31.7	22.5	31.7
37	45.4	31.9	22.7	31.9
38	7.2	28.7	20.7	28.7
39	64	29.5	21.4	29.5
40	62.8	30.6	22	30.6
41	17.6	32	22.1	32
42	0	31	20.8	31
43	4.2	32.1	19.3	32.1
45	6.4	31.8	17	78
46	0	32.5	17.7	77
47	0	33.3	19.2	77
48	0	29.9	18.3	77
49	0	32.3	18.6	78
50	0	32.5	16.9	80
51	0	31.4	15.8	70
52	0	30.7	13	73
1	0	31.5	14.3	83
2	0	32.7	17	73
3	0	32.1	15	64
4	0	32.1	14.9	84
5	0	31.9	13.3	56

APPENDIX II

Appendix 2. Cost of insecticide and organic molecules

1. Verticillium lecanii 2×10^8 cfu / g (lt) - Rs.950.00

2. Beauveria bassiana 2×10^8 cfu / g (Kg) - Rs. 400.00

3. Tobacco leaf - Rs. 550.00

4. Garlic bulb - Rs.40 / Kg

5. NSKE 5% - Rs. 17.00 / Kg

6. Lastraw - Rs. 600.00

7. Dimethoate 30 EC - Rs.410.00

APPENDIX III

Appendix 3. List of abbreviations and symbols used

%	Percentage
°C	Degree Celsius
C.D.	Critical difference
@	at
cm	Centimeter
g	Grams
h	Hours
ha	Hectare
kg	Kilogram
lt	Liter
ml	Milliliter
mm	Millimeter
No	Number
Viz.	Namely
S.Em	Standard error of mean
t/ha	Tonnes per hectare