CHAPTER IV
EXPERIMENTAL FINDINGS

The findings of the present investigation carried out on the “Incidence of insect and mite pests of french bean, Development and validation of different IPM modules and evaluation of organic pesticides against aphid and mite” has been presented in this chapter under following headings

4.1. Incidence of the insect and mite pests of french bean.
4.2. Development and Validation of different IPM module against the major pests
4.3. Evaluation of certain organic pesticides against aphid and mite attacking french bean crop.

4.1 Incidence of insect and mite pests in french bean during 2013-14 and 2014-15

During the present investigation, eight insects pests viz., black aphid, *Aphis craccivora* Koch.; thrips, *Scirtothrips dorsalis* Hood.; cutworm, *Agrotis ipsilon* Hufn.; pod borer, *Helicoverpa armigera* Hubner.; whitefly, *Bemesia tabaci* Gennadius.; leaf miner, *Liriomyza sativae* Blanchard.; red ant, *Dorylus orientalis* Westwood.; leaf beetle, *Monolepta signata* Olivier. and one mite species i.e. two spotted spider mite, *Tetranychus urticae* Koch. were observed infesting french bean crop in the field. Out of the nine pests, cutworm, aphid, two spotted spider mite, thrips, pod borer and whitefly were recorded as the major pest where as leaf miner, flea beetle and red ant were recorded as minor pest (Table 4.1 and Plate 29 to 38).

4.1.1 Incidence of major pest of french bean during 2013-14

The seasonal incidence of the major pests was recorded on french bean crop from last week of October, 2013 to January, 2014 at weekly interval by Plant Inspection Method. The incidence was recorded on the basis of number of pest per leaf, per twig or per plant at different stages of crop growth. The results are presented in table 4.2 and fig.4.1.
Incidence of cutworm was observed from the 46th Standard Meteorological Week (SMW) i.e. a mean population of 0.47 cutworms per plant was recorded. The peak period of activity was recorded during the month of December, with a mean population of 1.13 cutworms per plant. Thereafter the population showed a steady fall from 51st SMW. No further incidence of cutworm was recorded during the later stages of crop growth. During the month of December highest incidence (11.33%) was recorded (Fig.4.2).

Incidence of aphid was observed from the 45th SMW. The aphid population reached its peak in 47th SMW, with a mean population of 1.43 aphids per twig. Later there was a decline in the population of aphids and no aphids were recorded in 52nd SMW. Thereafter activity of the pest was observed to fluctuate at various time intervals. The mean population recorded during the later weeks of observations was low with 0.13 numbers of aphids per twig. The highest incidence recorded was 14.33 per cent during the month of November. The seasonal incidence of aphid is presented in Fig.4.3.

Two spotted spider mite was observed from 46th SMW. The mean number of mites recorded was 0.47 per leaf during November, which was steadily increased thereafter. The highest population of mite was recorded in the 52nd SMW with a mean population of 1.23 numbers of mites per leaf. Thereafter activity of the pest was observed to fluctuate at various time intervals. Incidence of mite recorded in later weeks of observation when the crop was ageing towards maturity was zero. The highest incidence recorded was 12.33 per cent during the month of December (Fig.4.4).

Thrips were observed from the 45th SMW. A mean population of 0.2thrip per leaf was recorded. A mean population of 0.97thrip per leaf i.e. the peak population was recorded in the 52nd SMW. Thereafter activity of the pest was observed to fluctuate at various time intervals and no thrips were recorded in the 1st and 2nd SMW. The highest incidence recorded was 9.7 per cent during the month of December (Fig. 4.5).
Mean population pod borer/plant indicated that, incidence started in 49th SMW in 2013-14. The mean number of pod borer recorded was 0.23 per plant during November, which was steadily increased and highest mean population per plant was observed (1.12/plant) in the 51st SMW. The highest incidence recorded was 11.22 per cent during the month of December (Fig.4.6).

Whitefly appeared in the 46th SMW. The mean number of whitefly recorded was 0.43 per leaf during November and steadily increased through December to January. The highest population of whitefly was recorded in the 52nd SMW with a mean population of 1.23 numbers of whitefly per leaf. The highest incidence recorded was 12.33 per cent during the month of December (Fig.4.7). Thereafter activity of the pest was observed to fluctuate at various time intervals. Incidence of whitefly was recorded to be zero in later weeks of observation when the crop was ageing towards maturity.

4.1.2 Incidence of major pest of french bean during 2014-15

The incidence of the major pests was recorded on french bean crop from last week of October, 2014 to January, 2015 at weekly interval by Plant Inspection Method. The incidence was recorded on the basis of number of pest per leaf or per twige or per plant. The results are presented in table 4.3 and fig.4.8.

Incidence of cutworm was observed from the 45th SMW and a mean population of 0.33 cutworms per plant was recorded. The peak period of activity was recorded during the month of December, with a mean population of 1.33 cutworms per plant. Thereafter the population showed a steady fall from 51st SMW. No further incidence of cutworm was recorded during the later stages of crop growth. The highest incidence recorded was 13.33 per cent during the month of December (Fig.4.9).

Incidence of aphid was observed from the 45th SMW. The aphid population reached its peak in 49th SMW, with a mean population of 1.0 aphid per leaf. Later on no aphids were recorded. Thereafter activity of the pest was observed to fluctuate at various time intervals. The mean population recorded during the later
weeks of observations was low with 0.2 to 0.70 numbers of aphids per leaf. The highest incidence recorded was 10.0 per cent during the month of December. The seasonal incidence of aphid is presented in fig.4.10.

Two spotted spider mite (TSSM) was observed from 46th SMW. The mean number of mites recorded was 0.23 per leaf during November, which steadily increased. The highest population of the pest was recorded in the 52nd SMW with a mean population of 1.13 numbers of TSSM per leaf. Thereafter activity of the pest was observed to fluctuate at various time intervals. Incidence of TSSM recorded in later weeks of observation when the crop was ageing towards maturity was zero. The highest incidence recorded was 11.33 per cent during the month of December (Fig.4.11).

Thrips (T. tabaci) were observed from the 45th SMW. A mean population of 0.43 thrips per leaf was recorded. A mean population of 0.87 thrip per leaf i.e. the peak population was recorded in the 52nd SMW. Thereafter activity of the pest was observed to fluctuate at various time intervals and no thrips were recorded in the 1st and 2nd SMW. The highest incidence recorded was 8.76 per cent during the last week of December (Fig. 4.12).

Mean population of pod borer incidence started in 49th SMW in 2014-15. The mean number of pod borer recorded was 0.23 per plant during November, which steadily increased and highest population was observed (1.13/plant) in the 51st SMW. The highest incidence recorded was 11.33 per cent during the month of December (Fig.4.13).

Whitefly was observed from 46th SMW. The mean number of whitefly recorded was 0.43 per leaf during November, which steadily increased. The highest population of whitefly was recorded in the 51st SMW with a mean population of 1.13 numbers of whitefly per leaf. Thereafter activity of the pest was observed to fluctuate at various time intervals. The highest incidence recorded was 11.33 per cent during the month of December (Fig.4.14). Incidence of whitefly recorded in later weeks of observation when the crop ageing towards maturity was zero.
4.1.3 Correlation studies of the incidence of major pests with the existing meteorological factors, 2013-14

Simple correlation studies were carried out between the population of the major insect pest and two spotted spider mite with weather parameters viz., Maximum temperature, Minimum temperature, Morning relative humidity, Evening relative humidity, Rainfall (RF) and Bright sunshine hours (BSSH) during 2013-14 (Table 4.10).

The coefficients of correlation studies are presented in table 4.4. The data indicated that population build up of cutworm showed non-significant negative correlation with maximum temperature (r=-0.193), minimum temperature (r=-0.206), evening relative humidity (r=-0.213) and rainfall (r=-0.324). However morning relative humidity (r=0.135) and bright sunshine hours (r=0.026) had positively correlated with weather parameters and was not significant.

The results revealed that maximum temperature (r=0.555*) and bright sunshine hours (BSSH) (r=0.671*) showed significant positive association with the aphid population, while morning relative humidity (r=-0.562*) manifested significant negative correlation and rain fall (r=-0.427) as well as evening relative humidity (r=-0.502) exhibited non-significant negative correlation with aphid population during 2013-14 (Table 4.5).

Maximum temperature had significant negative influence on the TSSM population (r=-0.603*), while minimum temperature, BSSH and Average rain fall showed non-significant negative correlation with weather parameters (r = -0.471, r = -0.347 and r =-0.298 respectively) (Table 4.6). Morning relative humidity and evening Relative humidity exerted significant (r = 0.661*) and non-significant (r = 0.265) positive respectively effect on TSSM population.

Relationship between thrips incidence and weather parameters indicated that none of the parameter found playing significant role in build up of the thrips population accept rain fall with significant negative correlation coefficient (0.-589*) (Table 4.7).
The effect of the weather factors and pod borer population revealed that a significant positive correlation existed with morning relative humidity \((r=0.568^*)\) and significant negative correlation was recorded with maximum temperature \((r=-0.706^*)\), where as non significant negative correlation was recorded with minimum temperature \((r=-0.480)\) rainfall \((r=-0.226)\) and bright sunshine hours \((r=-0.534)\) (Table 4.8).

Maximum temperature showed a significant negative correlation \((r= -0.554^*)\) with population of whitefly (Table 4.9). Morning relative humidity exhibited significant positive correlation \((r=0.605^*)\), whereas minimum temperature \((r= -0.356)\), rainfall \((r=-0.251)\) and Sunshine hours \((r=-0.342)\) had non-significant and negative correlation with whitefly. Evening relative humidity showed non-significant \((r = 0.314)\), but positive influence on whitefly population.

### 4.1.4 Regression studies of the incidence of different pests with existing meteorological factors, 2013-14

The analysis of the significant relationship between the pest incidence and weather factors were done by taking the mean values of pest incidence and weekly average of various weather factors viz., temperature (maximum and minimum), relative humidity (morning and evening), rainfall, and bright sunshine hours, to draw the simple linear regression lines mentioned below.

The relationship between weather parameters and cutworm was not found to be significant during 2013-14.

Maximum temperature displayed an increasing trend in aphid population with regression coefficient \((R^2 = 0.308)\) along with statistically significant correlation coefficient \((r = 0.555^*)\) and can be expressed by \(Y= -2.561 + 0.1217x\). Bright sunshine hours also displayed a significant and positive correlation \((r=0.671^*)\) on aphid population with an increasing tendency \((R^2=0.450)\) and the expression of the relationship was \(Y=- 0.2539+0.1673x\). On the other hand, morning relative humidity revealed a very strong opposite trend to aphid population \((R^2=0.316)\) which was
soundly confirmed by a significant negative correlation coefficient ($r= -0.562^*$) and expressed by $Y= 21.63 - 0.2190x$ (Fig. 4.15 a-c).

Morning relative humidity had statistically significant positive correlation coefficient ($r=0.661^*$) and regression coefficient ($R^2 = 0.436$) with TSSM population and can be expressed by $Y= -17.44 - 0.1877x$. On the other hand, Maximum temperature revealed a very strong positive trend to TSSM population ($R^2=0.363$) which was soundly confirmed by a significant negative correlation coefficient ($r= -0.603^*$) and can be expressed by $Y= 3.096 - 0.09633x$ (Fig. 4.16 a & b). This expressed the magnitude of this association.

The relationship between rainfall and thrips was found to be significant, negative and linear ($r= -0.589$). The regression of thrips population could be expressed by the equation $Y= 0.5690 - 0.1117x$ with regression coefficient ($R^2$) was 0.347 that expressed magnitude of this association (Fig. 4.17).

The regression equation $Y= -14.18 + 0.1495x$ fitted to pod borer damage and morning relative humidity. The coefficient of determination ($R^2$) was 0.322 showing thereby that as much as 32.2% variation in the pod borer population was due to the effect of morning relative humidity. Whereas maximum temperature had a significant negative correlation ($r= -0.706^*$) and regression coefficient ($R^2$) was 0.498 with pod borer which indicates 49.8% variation in the population of pod borer and can be expressed as $Y = 2.866 - 0.1046x$ (Fig. 4.18 a & b).

Morning relative humidity had statistically significant positive correlation coefficient ($r=0.605^*$) and regression coefficient ($R^2=0.365$) with whitefly population and can be expressed by $Y= -18.38 + 0.1966x$. On the other hand, Maximum temperature revealed a very strong positive trend to whitefly population ($R^2=0.301$) which was soundly confirmed by a significant negative correlation coefficient ($r= -0.554^*$) and can be expressed by $Y= 3.131 - 0.1012x$ (Fig. 4.19 a & b). This expressed the magnitude of this association.
4.1.5 Correlation studies of the incidence of major pests with the existing meteorological factors, 2014-15

Simple correlation studies were carried out between the population of the major pest and two spotted spider mite with weather parameters \textit{viz.}. Maximum temperature, Minimum temperature, Morning relative humidity, Evening relative humidity, Rainfall (RF) and Bright sunshine hours (BSSH) during 2014-15 (Table 4.17).

The coefficients of correlation studies are presented in table 4.11. The data indicated that population build up cutworm had significant positive correlation with morning relative humidity \((r=0.573*)\) and positive non-significant with evening relative humidity \((r=0.189)\). However a non-significant negative correlation with maximum temperature \((r=-0.288)\), minimum temperature \((r=-0.119)\), bright sunshine hours \((-0.313)\) and rainfall \((r=-0.273)\).

The results revealed that maximum temperature \((r=0.167)\) and bright sunshine hours (BSSH) \((r=0.066)\) showed non-significant positive association with the aphid population, while morning relative humidity \((r=-0.378)\) and rainfall \((r=-0.001)\) manifested non-significant negative correlation with aphid population during 2014-15 (Table 4.12).

Maximum temperature had significant negative influence on the two spotted spider mite population \((r=-0.559*)\), while minimum temperature, BSSH and Rain fall showed non-significant negative correlation with mite population \((r=-0.469, \ r=-0.347 \text{ and } r=-0.431 \text{ respectively})\) (Table 4.13). Morning Relative humidity and evening Relative humidity exerted significant \((r=0.617*)\) and non-significant \((r=0.080)\) positive respectively effect on spider mite population.

Relationship between thrips incidence and weather parameters indicated that maximum temperature and bright sunshine hours had a non-significant but positive correlation \((r=0.153 \text{ and } r=0.062 \text{ respectively})\) in buildup of the thrips population. Whereas minimum temperature, morning relative humidity, evening
relative humidity and rainfall showed non-significant negative correlation ($r=-0.099$, $r=-0.123$, $r=-0.132$ and $r=-0.065$ respectively) with thrips population (Table 4.14).

The effect of the weather factors and pod borer population revealed that a significant positive correlation existed with morning relative humidity ($r=0.553^*$) and non-significant negative correlation was recorded with maximum temperature, minimum temperature, rain fall and bright sun shine hours ($r=-0.489$, $r=-0.368$, $r=-0.178$ and $r=-0.258$ respectively) (Table 4.15).

Maximum temperature showed a significant negative correlation ($r=-0.553^*$) with population of whitefly (Table 4.16). Morning relative humidity exhibited significant positive correlation ($r=0.674^*$), whereas minimum temperature ($r=-0.313$), rainfall ($r=-0.374$) and Sunshine hours ($r=-0.456$) had non-significant and negative correlation with whitefly. Evening relative humidity showed non-significant ($r=0.095$), but positive influence on whitefly population.

### 4.1.6 Regression studies on the incidence of different pests with existing meteorological factors, 2014-15

The analysis of the significant relationship between the pest incidence and weather factors were done by taking the mean values of pest incidence and weekly average of various weather factors viz., temperature (maximum and minimum), relative humidity (morning and evening), rainfall, and bright sunshine hours, to draw the simple linear regression lines mentioned below.

The relationship between morning relative humidity and cutworm was found to be significant with correlation coefficient ($r=0.573^*$) and regression coefficient ($R^2=0.328$) in an increasing tendency during 2014-15 and can be expressed by $Y=-11.92+0.1492x$ that is the magnitude of the relationship (Fig.4.20).

During 2014-15, none of the weather parameters displayed statistically significant correlation coefficient with aphid population.

Morning relative humidity had statistically significant positive correlation coefficient ($r=0.617^*$) and regression coefficient ($R^2=0.381$) with TSSM
population and can be expressed by \( Y=12.47+0.1360x \). On the other hand, Maximum temperature revealed a very strong positive trend to TSSM population \( (R^2=0.312) \) which was soundly confirmed by a significant negative correlation coefficient \( (r=-0.559^*) \) and can be expressed by \( Y=2.963-0.09224x \) (Fig.4.21 a & b). This expressed the magnitude of this association.

The relationship between weather parameters and thrips population build up displayed statistically none significant correlation coefficient during 2014-15.

The regression equation \( Y=-11.90+0.1270x \) fitted to pod borer damage and morning relative humidity with significant positive correlation coefficient \( (r=0.553^*) \). The coefficient of determination \( (R^2) \) was 0.306 showing thereby that as much as 30.6% variation in the pod borer damage was due to the effect of morning relative humidity (Fig.4.22).

Morning relative humidity had statistically significant positive correlation coefficient \( (r=0.674^{**}) \) and regression coefficient \( (R^2=0.454) \) with whitefly population and can be expressed by \( Y=-15.40+0.1667x \). On the other hand, Maximum temperature revealed a very strong positive trend to whitefly population \( (R^2=0.306) \) which was soundly confirmed by a significant negative correlation coefficient \( (r=-0.553^*) \) and can be expressed by \( Y=3.233-0.1025x \) (Fig.4.23 a & b). This expressed the magnitude of this association.

4.2 Development and validation of different IPM modules against certain major insect and mite pests of french bean

Experiments on development and validation of four Integrated Pest Management (IPM) modules in french bean \( (P. vulgaris) \) were conducted at Assam Agricultural University, Jorhat, Assam during 2013-14 and 2014-15 and the results obtained are presented below mentioned subhead.
4.2.1 Development period, feeding potential and stage specific life table of Coccinellid predator (*Coccinella transversalis*)

A laboratory experiment was conducted in the Department of Entomology, Assam Agricultural University, Jorhat, Assam for determination of development period, feeding potential and stage specific life table of *C. transversalis* on *Aphis craccivora*. The results obtained are mentioned below:

**4.2.1a Development period and feeding potential of *C. transversalis* on *Aphis craccivora***

The perusal of data showed that the development duration of first, second, third and fourth instar of *C. transversalis* was 2.40, 2.60, 3.20 and 4.10 days with total larval development period 11.10 days when fed on *Aphis craccivora* (Table 4.18 and Plate 39-45). The feeding behavior of different instars varied significantly with the age and moulting to the next stage. The third and fourth instar were significantly more voracious feeders than second and first instar. The mean feeding rate/day/larvae of first, second, third and fourth instar was 8 and 7.17, 18.67 and 15.83, 26.33 and 23.83, 29.67 and 27.83 on nymphs and adult per day, respectively. The consumption rate of fourth instar differed from all larval stages and adult (Table 4.19 and Plate 46-48).

The result further revealed that the longevity of adults, *C. transversalis* on *Aphis craccivora* was 36.70 days with minimum 30 days and maximum 42 days (Table 4.18). The adult *C. transversalis* devoured 34.17 nymphs/day and 30.33 adults aphid/day in per unit 24 hrs. The per cent feeding potential of adults was significantly more than larval stage and there was significant difference in the feeding rate of adult life at 5% probability level (Table 4.19).

**4.2.1b Stage specific life table of *Coccinella transversalis***

The results showed that in egg stage, apparent mortality was 8% in both November (average temperature 24±1°C) and October (average temperature
While comparing larval instars, the lowest mortality (3.95%) was recorded at third instar stage at 24±1°C, whereas first instar showed highest mortality (12.35%) at 26±1°C (Table 4.20). On the other hand, pre-pupal and pupal mortality was found minimum (1.39 and 2.82%) at 24±1°C (Table 4.21), respectively. Similarly, the corresponding values of maximum mortality (4.92 and 3.45%, respectively) were recorded at 26±1°C (Table 4.20).

At egg stage, the survival fraction was recorded to be 0.92 for both the recording month i.e. November and October. Among larval instars, fourth instar exhibited the highest Sx (0.99) at 24±1°C, whereas the lowest fraction (0.88) was recorded at second instar at 26±1°C. Similarly, at pre-pupal stage, the Sx was found maximum (0.99) at 24±1°C and minimum (0.95) at 26±1°C. *C. transversalis* registered similar value of MSR (0.09) for both the 24±1°C and 26±1°C at egg stage. While considering larval instars, the minimum MRS (0.04) was obtained at fourth instar at 24±1°C as compared to maximum (0.14) at second instar at 26±1°C. However, the pre-pupal stage attained minimum MSR (0.01) at 24±1°C and maximum (0.05) at 26±1°C. On the other hand, at pupal stage minimum MSR was recorded (0.03) at 24±1°C and maximum (0.04) at 26±1°C (Table 4.20).

The lowest (4.87) and highest (6.00) indispensable mortality (IM), at egg stage, was examined at 26±1°C and 24±1°C, respectively. While comparing larval instars, such mortality was recorded minimum (2.84) at third instar at 24±1°C and maximum (7.67) at second instar at 26±1°C (Table 4.20). Nevertheless, a considerable variation was observed at pre-pupal as well as pupal stage. The corresponding lowest value (0.97) for pre-pupal stage was found at 24±1°C, while for pupal period minimum IM (2.00) was observed at 26±1°C. On the other hand, the highest IM (2.90) at pre-pupal stage was recorded at 26±1°C, whereas at pupal stage the mortality was obtained maximum (2.00) at 24±1°C (Table 4.21). At egg stage of *C. transversalis*, k-value was found minimum (0.0362) at 26±1°C and 24±1°C. Among larval instars, it remained lowest (0.006) at fourth instar at 24±1°C as compared to highest (0.068) at second instar at 26±1°C. whereas, the pre-pupal
showed minimum ‘k’ (0.0060) and (0.022) at 24±1°C and 26±1°C, respectively, whereas the maximum ‘k’ value at pupal stage minimum (0.0120) and maximum (0.015) was obtained at 24±1°C and 26±1°C, respectively. Similarly, the total generation mortality (K) was observed lowest (0.1612) at 24±1°C and highest (0.252) at 26±1°C (Table 4.20).

4.2.2. Effect of IPM modules on incidence of french bean pest complex

Data presented in table 4.22 indicated that, significantly lesser per cent incidence of *Aphis craccivora* was seen in Module-I (0.60%) than Module-II (6.0%) and Module-III (2.58%). But highest percentage of aphid incidence (13.40%) was registered in Module-IV. The mean population of thrips varied from 1.04 to 10.0 per cent among the modules. Module-I was found to be superior by recording less incidence of thrips (1.04%) than Module-III (2.6%) and Module -II (4.0%). Considerably higher per cent incidence of thrips was observed in Module-IV (10.0%). The per cent population of TSSM was least (1.0%) in Module-I compared to Module-III (3.0% and Module -II (7.6%). However, maximum incidence of mites was recorded in Module -IV (9.0%). Whitefly incidence was recorded to be minimum in Module -I (1.2%) compared to Module -III (2.80% and Module -II (4.0%). While highest percent incidence of whitefly was registered in Module -IV (10.8%). The mean per cent population of pod borer varied from 0.40 to 8.40% among the different modules. Module-I was found to be superior by recording less incidence of pod borer (0.40%) and was significantly differed from Module -IV (8.4%) (Fig. 4.24).

4.2.3. Effect of IPM modules in yield and economic returns of french bean

Data on yield of french bean were collected and economic return was calculated for each IPM module and results are presented below:

The resultant data indicated that yield due to different IPM modules has great influenced and highest yield (15.48t/ha) (including both healthy and infested) was recorded in M_I followed by M_{III} (15.12t/ha) and M_{II} (15. However, least yield (15.0t/ha) was registered in M_{IV} (Table 4.23).
Total healthy yield, total infested yield and gross return were significantly influenced by different IPM modules (Table 4.23). Results indicated that the highest healthy bean yield ha\(^{-1}\) (13.99 t ha\(^{-1}\)) was achieved due to effect of MI which was significantly different from all other treatments followed by MIII (13.91 t ha\(^{-1}\)). On the contrary, the lowest healthy bean yield (9.88 t ha\(^{-1}\)) was obtained from control treatment (MIV). The lowest infested bean yield ha\(^{-1}\) (1.21 t ha\(^{-1}\)) was found due to the effect of MIII which differed from all other treatments followed by MI (1.49 t ha\(^{-1}\)). Furthermore, the highest infested bean yield ha\(^{-1}\) (5.12 t ha\(^{-1}\)) was obtained from control treatment (MIV).

From the economic point of view, IPM modules caused effective pest management in french bean crop and has a great gross return. In the present study, applied IPM modules showed variable performance for managing the insect pests of french bean (Table 4.22). The effectiveness of IPM modules were not same but varied significantly and this is why a great variation was occurred in terms of gross return. Results showed that the highest gross return (000, Rs. 41.08 ha\(^{-1}\)) over control was achieved from MI, whereas the lowest gross return (000, Rs. 36.79 ha\(^{-1}\)) over control came from module MII. The second highest gross return (000, Rs. 40.26 ha\(^{-1}\)) over control was observed in MIII which was close to MI. Under the treated plot, the lowest gross return (000, Rs. 36.79 ha\(^{-1}\)) was observed from MII (Fig. 4.25). The effectiveness of IPM Modules in respect to B:C ratio were obtained to be 2.06, 1.95 and 1.97 from Module –I, II and III respectively as compared to control.

**4.3 Evaluation of certain organic pesticides against aphid and TSSM attacking french bean crop**

The preliminary screening is a good means of evaluating the potential insecticidal and acaricidal activity of plant extracts used for this purpose. Insecticidal activity of aqueous and ethanol extracts of seven different plant parts are noted and presented in table 4.24-4.29 and fig. 4.26-4.45. The average mortality data were subjected to probit analysis for calculating LC\(_{50}\) and LC\(_{90}\) at 95% confidence limits of upper as well as lower confidence limit and chi-square values were calculated.
accordingly. For comparison of susceptibility LC$_{50}$ values and regression equation of the test plant extracts against targeted pests were determined. The probit analysis of percent mortalities in all the plant extracts gave chi-square values and the chi-square values were adjusted for heterogeneity test (Table 4.24 - 4.29).

4.3.1 Probit analysis of selected plant extracts

4.3.1a LC$_{50}$ determination against aphid (A. craccivora)

The value of median lethal concentration (LC$_{50}$) of the aqueous and ethanol plant extracts tested, the present results showed the highest A. craccivora percent mortality in the methanol fruit extract of Piper longum (LC$_{50}$= 5.25; LC$_{90}$=14.45) followed by ethanol seed extract of Jatropha curcas (LC$_{50}$=6.17; LC$_{90}$=17.38), aqueous leaf extract of Polygonum hydropiper (LC$_{50}$=7.24; LC$_{90}$=23.44), Phlogacanthus thyrsiflorus (LC$_{50}$=7.76; LC$_{90}$=22.91), Murraya koenigii (LC$_{50}$=8.13; LC$_{90}$=24.55), Pongamia pinnata (LC$_{50}$=8.91; LC$_{90}$=25.70) and Ocimum sanctum (LC$_{50}$=8.91; LC$_{90}$=34.67) after 24 hours (Table 4.24 and Fig. 4.26 - 4.33).

The A. craccivora mortality was highest in ethanol extract of Piper longum (LC$_{50}$=3.39; and LC$_{90}$=10.23) followed by ethanol seed extract of Jatropha curcas (LC$_{50}$= 4.17; LC$_{90}$=12.02), aqueous leaf extract of Polygonum hydropiper (LC$_{50}$=4.37; LC$_{90}$=13.80), Phlogacanthus thyrsiflorus (LC$_{50}$=5.13; LC$_{90}$=15.14), Murraya koenigii (LC$_{50}$=5.25; LC$_{90}$=15.85), Pongamia pinnata (LC$_{50}$=5.25; LC$_{90}$=15.85) and Ocimum sanctum (LC$_{50}$=5.62; LC$_{90}$=20.42) after 48 hours and presented in table 4.25. Similar trend was observed in per cent mortality of A. craccivora after 72 hours of exposure period with LC$_{50}$ value (3.24) and LD$_{90}$ value (9.12) in Piper longum, followed by ethanol seed extract of Jatropha curcas (LC$_{50}$=3.47; LC$_{90}$=9.55), aqueous leaf extract of Polygonum hydropiper (LC$_{50}$=3.72; LC$_{90}$=10.23), Phlogacanthus thyrsiflorus (LC$_{50}$=4.27; LC$_{90}$=14.79), Murraya koenigii (LC$_{50}$=4.37; LC$_{90}$=12.88), Pongamia pinnata (LC$_{50}$=4.47; LC$_{90}$=15.85) and Ocimum sanctum (LC$_{50}$=4.68; LC$_{90}$=13.49) (Table 4.26 and Fig. 4.26-4.33).
4.3.1b LC\textsubscript{50} determination against two spotted spider mite (\textit{T. urticae})

Among the aqueous and ethanol plant extracts tested, the present results showed the highest \textit{T. urticae} per cent mortality was found in the ethanol fruit extract of \textit{Piper longum} (LC\textsubscript{50}= 5.13; LC\textsubscript{90}=16.22) followed by ethanol seed extract of \textit{Jatropha curcas} (LC\textsubscript{50}=7.59; LC\textsubscript{90}=30.20), aqueous leaf extract of \textit{Polygonum hydropiper} (LC\textsubscript{50}=8.51; LC\textsubscript{90}=27.54), \textit{Phlogacanthus thrysiflorus} (LC\textsubscript{50}=8.71; LC\textsubscript{90}=28.18), \textit{Murraya koenigii} (LC\textsubscript{50}=8.91; LC\textsubscript{90}=36.31), \textit{Pongamia pinnata} (LC\textsubscript{50}= 11.22; LC\textsubscript{90}=38.02) and \textit{Ocimum sanctum} (LC\textsubscript{50}= 11.48; LC\textsubscript{90}= 46.77) after 24 hours (Table 4.27 and Fig. 4.34-4.40).

The \textit{T. urticae} mortality was found highest in methanol extracts of \textit{Piper longum} (LC\textsubscript{50}=3.41; and LC\textsubscript{90}=7.94) followed by ethanol seed extract of \textit{Jatropha curcas} (LC\textsubscript{50}= 4.37; LC\textsubscript{90}=11.48), aqueous leaf extract of \textit{Polygonum hydropiper} (LC\textsubscript{50}=4.57; LC\textsubscript{90}=12.02), \textit{Phlogacanthus thrysiformis} (LC\textsubscript{50}=5.23; LC\textsubscript{90}=13.80), \textit{Murraya koenigii} (LC\textsubscript{50}=5.35; LC\textsubscript{90}=14.79), \textit{Pongamia pinnata} (LC\textsubscript{50}=5.37; LC\textsubscript{90}=13.49) and \textit{Ocimum sanctum} (LC\textsubscript{50}= 5.66; LC\textsubscript{90}= 17.78) after 48 hours and presented in table 4.28. Similar trend was found in per cent mortality of \textit{T. urticae} after 72 hours of exposure period with LC\textsubscript{50} value (3.33) and LD\textsubscript{90} value (7.00) in \textit{Piper longum}, followed by ethanol seed extract of \textit{Jatropha curcas} (LC\textsubscript{50}=3.72; LC\textsubscript{90}=9.33), aqueous leaf extract of \textit{Polygonum hydropiper} (LC\textsubscript{50}=3.80; LC\textsubscript{90}=9.55), \textit{Phlogacanthus thrysiflorus} (LC\textsubscript{50}=4.37; LC\textsubscript{90}=10.47), \textit{Murraya koenigii} (LC\textsubscript{50}=4.40; LC\textsubscript{90}=11.22), \textit{Pongamia pinnata} (LC\textsubscript{50}=4.57; LC\textsubscript{90}=11.22) and \textit{Ocimum sanctum} (LC\textsubscript{50}=4.72; LC\textsubscript{90}=12.30) (Table 4.29 and Fig. 4.34-40).

4.3.2 Efficacy test of plant extracts in mortality of aphid and two spotted spider mite of french bean under laboratory condition

Efficacy of seven locally available plant extracts \textit{viz.} leaf extract of \textit{Polygonum hydropiper}, \textit{Murraya koenigii}, seed extract of \textit{Jatropha curcas}, fruit extract of \textit{Piper longum}, leaf extract of \textit{Ocimum sanctum}, \textit{Phlogacanthus thrysiflorus} and \textit{Pongamia pinnata} at respective concentrations were evaluated against both aphid
(A. craccivora) and two spotted spider mite (T. urticae) during 2013-2014 and 2014-15 on the basis of per cent mortality under laboratory condition.

4.3.2.1 Insecticidal effect of plant extracts on per cent mortality of Aphid (A. craccivora) population

The results obtained from the laboratory evaluation of Polygonum hydropiper, Murraya koenigii, Jatropha curcas, Piper longum, Ocimum sanctum, Phlogacanthus thyrsiflorus and Pongamia pinnata for different exposure periods against aphid (A. craccivora) are presented in the Table 4.30. The plant extract were evaluated for exposure period of 24, 48, 72 and 96 hrs. against adults of aphid (A. craccivora) to determine the significant difference among the plant extracts.

4.3.2.1a 24 hours after treatment:

The data on mean per cent mortality of aphid population recorded 24 hrs. after treatment are presented in Table 4.30 and illustrated in Fig.4.41 The per cent mortality of the aphid population due to the insecticidal effect of plant extract were ranges from 13.33 to 26.67 per cent for exposure period of 24 hrs and analysis of variance showed that the treatments were non-significant at 5 per cent probability level indicating that the application of plant extract at respective concentration were non-significantly differ on per cent mortality of aphid population.

4.3.2.1b 48 hours after treatment

The data on mean per cent mortality of aphid population recorded 48hrs. after treatment along with respective CD values are presented in Table 4.30 and diagrammatically shown in Fig. 4.41. While comparing the significant of difference among the treatment at 5 per cent probability level, the data reveals that none of the treatments differed significantly. The mortality of the aphid due to the insecticidal effect of plant extract were ranges from 38.15 to 51.85 per cent and the highest per cent aphid mortality was recorded in Piper longum (51.85), followed by Jatropha curcas (44.44), Polygonum hydropiper (48.15), Phlogacanthus thyrsiflorus
(40.74), *Murraya koenigii* (38.15), *Pongamia pinnata* (40.74) and *Ocimum sanctum* (47.04).

### 4.3.2.1c 72 hours after treatment

The mortality of the adult aphid due to the insecticidal effect of the plant extracts were ranged from 47.78 to 67.78 per cent. The analysis of variance showed that the treatments were significant at 5 per cent probability level for the exposure period 72 hrs indicating that the treatments were effective on per cent mortality of aphid. The per cent mortality of aphid due to bio-pesticides varies from 47.78 to 67.78 which were higher in comparison to the exposure period of 48 hrs. While comparing the significant of difference of means among the treatments by Least Significant Difference (LSD), Table 4.30 revealed that fruit extract of *Piper longum* (67.78) differs from rest of the treatment and was at par with seed extract of *J. curcas* (64.44) and *P. hydropiper* (60.74) in per cent mortality of aphid. There was difference in the per cent mortality of aphid due to seed extract of *Jatropha curcas* with *Murraya koenigii* (53.33) *Ocimum sanctum* (47.04) and *Pongamia pinnata* (50.00) and effect of *J. curcus* on per cent mortality of aphid was at par with leaf extract of *Polygonum hydropiper* (60.74) and *Phlogacanthus thyrsiflorus* (57.41) (Fig. 4.41).

### 4.3.2.1d 96 hours after treatment

In perusal of the experimental findings the treatments were significant at 5 per cent probability level for the exposure period 96 hrs indicating that the treatments were effective on per cent mortality of aphid. The per cent mortality of aphid due to bio-pesticides varies from 48.61 to 75.46 which were higher in comparison to the exposure period of 72 hrs. While comparing the significant of difference of means among the treatments by LSD, table 4.30 revealed that fruit extract of *Piper longum* (75.46) differs from rest of the treatment and was at par with seed extract of *J. curcas* (65.89) and *P. hydropiper* (63.89) in per cent mortality of aphid. There was difference in the per cent mortality of aphid due to seed extract of *Jatropha curcas* with *Murraya koenigii* (55.56) *Ocimum sanctum* (48.61)
and *Pongamia pinnata* (52.31) and effect of *J. curcas* on per cent mortality of aphid was at par with leaf extract of *Polygonum hydropiper* (63.89) and *Phlogacanthus thyrsiflorus* (60.19).

### 4.3.2.2 Acaricidal effect of plant extracts on two spotted spider mite population

The results obtained from the laboratory evaluation of *Polygonum hydropiper, Murraya koenigii, Jatropha curcas, Piper longum, Ocimum sanctum, Phlogacanthus thyrsiflorus* and *Pongamia pinnata* for different exposure periods against two spotted spider mite (*T. urticae*) are presented in the table 4.31. The plant extract were evaluated for exposure period of 24, 48, 72 and 96 hrs. against adults of two spotted spider mite (*T. urticae*).

#### 4.3.2.2a 24 hours after treatment

The data on mean per cent mortality of two spotted spider mite population recorded 24 hrs. after treatment are presented in table 4.31 and illustrated in Fig. 4.42. The per cent mortality of the two spotted spider mite population due to the insecticidal effect of plant extract were ranges from 16.67 to 23.33 per cent for exposure period of 24 hrs and analysis of variance showed that the treatments were not significant at 5 per cent probability level indicating that the application of plant extract at respective concentration were non-significantly differ on per cent mortality of two spotted spider mite population.

#### 4.3.2.2b 48 hours after treatment

The data on mean per cent mortality of two spotted spider mite population recorded 48hrs. after treatment along with respective CD values are presented in table 4.31 and diagrammatically shown in fig.4.42. While comparing the significant of difference among the treatment at 5 per cent probability level, the data reveals that none of the treatments differed significantly. The mortality of the two spotted spider mite due to the insecticidal effect of plant extract were ranged from 33.70 to 48.15 per cent and the highest per cent two spotted spider mite population mortality was recorded in *Piper longum* (48.15), followed by *Polygonum hydropiper*
(45.19), *Murraya koenigii* (44.44), *Jatropha curcas* (41.11), *Pongamia pinnata* (38.52), *Phlogacanthus thyrsiflorus* (38.15), and *Ocimum sanctum* (33.70) after 48 hrs. of exposure period.

**4.3.2.2c 72 hours after treatment**

The analysis of variance showed that the treatments were significant at 5 per cent probability level for the exposure period of 72hrs. indicating that the treatments were effective on per cent mortality of two spotted spider mite. The per cent mortality of two spotted spider mite due to plant extracts varied from 35.19 to 64.07 which was higher in comparison to the exposure period of 48 hrs. While comparing the significant of difference of means among the treatments, table 4.31 revealed that fruit extract of *Piper longum* (64.07) differs from rest of the treatment and was at par with seed extract of *J. curcas* (57.04) and *P. hydropiper* (54.07) in per cent mortality of mite. There was difference in the per cent mortality of two spotted mite due to seed extract of *Jatropha curcas* with *Murraya koenigii* (46.30) *Ocimum sanctum* (35.19) and *Pongamia pinnata* (43.33) and effect of *J. curcus* on per cent mortality of two spotted mite was at par with leaf extract of *Polygonum hydropiper* (54.07) and *Phlogacanthus thyrsiflorus* (49.63).

**4.3.2.2d 96 hours after treatment**

In perusal of the experimental findings the treatments were significant at 5 per cent probability level for the exposure period of 96 hrs indicating that the treatments were effective on per cent mortality of two spotted spider mite. The per cent mortality of two spotted spider mite due to plant extract varies from 36.57 to 66.85 which was higher in comparison to the exposure period of 72hrs. While comparing the significant of difference of means among the treatments, (Table 4.31) revealed that effect on mortality of two spotted spider mite due to fruit extract of *Piper longum* (66.85) was at par with *J. curcas* (58.89) and *P. hydropiper* (57.31) and differs significantly from rest of the treatment. There were no significant difference in the effect of leaf extract of *Polygonum hydropiper* on the mortality of two spotted
mite with *Murraya koenigii*, *Phlogacanthus thyrsiflorus* and *Pongamia pinnata* except *Ocimum sanctum* that cause only 36.57 per cent spotted spider mite mortality.

4.3.3 Efficacy of plant extract in reduction of aphid and two spotted spider mite of french bean under field conditions

Field efficacy of seven locally available plant extracts viz. leaf extract of *Polygonum hydropiper*, *Murraya koenigii*, seed extract of *Jatropha curcas*, fruit extract of *Piper longum*, leaf extract of *Ocimum sanctum*, *Phlogacanthus thyrsiflorus* and *Pongamia pinnata* at respective concentration were evaluated against aphid (*A. craccivora*) and two spotted spider mite (*T. urticae*) for exposure period of 1, 3, 5 and 7 days during 2013-14 and 2014-15.

4.3.3.1 Insecticidal effect of plant extracts in reduction of aphid (*A. craccivora*) population

4.3.3.1a One day after treatment

The data on mean per cent reduction of aphid population recorded one day after treatment are presented in table 4.32 and illustrated in fig.4.43. The per cent reduction of the aphid population due to the insecticidal effect of plant extract were ranges from 21.21 to 49.98 per cent for exposure period of one day and analysis of variance showed that the treatments were not significant at 5 per cent probability level indicating that the application of plant extract at respective concentration were not significantly differ on per cent reduction of aphid population.

4.3.3.1b Three days after treatment

The data on mean per cent reduction of aphid population recorded three days after treatment along with respective CD values are presented in table 4.32 and diagrammatically shown in fig.4.43. While comparing the significant of difference among the treatment at 5 per cent probability level, the data reveals that none of the treatment differed significantly. The reduction of the aphid due to the insecticidal effect of plant extract were ranges from 27.27 to 65.63 per cent and the highest per cent aphid population reduction was recorded in *Piper longum* (65.63),
followed by *Jatropha curcas* (47.06), *Polygonum hydropiper* (42.42), *Phlogacanthus thyrsiflorus* (40.00), *Murraya koenigii* (37.50), *Pongamia pinnata* (32.50) and *Ocimum sanctum* (27.27).

### 4.3.3.1c Five days after treatment

The per cent reduction of aphid population after five days of treatment were ranges from 30.30 to 81.25 and analysis of variance revealed that all the plant extract has considerable insecticidal effect on the reduction of the aphid population. Among the plant extract the lowest per cent reduction (30.30) was recorded in treatment with *Ocimum sanctum* which was statistically differed with other treatments where as highest per cent reduction (81.25) of aphid was observed in the treatment with *Piper longum* and differs significantly with all other treatments. The treatment with *Jatropha curcus* caused 64.71 per cent reduction of aphid population which defers from the treatment of *Phlogacanthus thyrsiflorus* (48.57), *Murraya koenigii* (46.88), *Pongamia pinnata* (40.0) and *Ocimum sanctum* (30.30) and was at par with the treatment of *Polygonum hydropiper* (60.61) (Table 4.32).

### 4.3.3.1d Seven days after treatment

The data on mean per cent reduction of aphid population recorded seven days after treatment along with respective CD values are presented in table 4.32 and diagrammatically shown in fig.4.43. While comparing the significant of difference among the treatment at 5 per cent probability level by LSD, the data reveals that the treatment differed significantly. The reduction of the aphid due to the insecticidal effect of plant extract were ranges from 39.39 to 84.38 per cent and the highest per cent aphid population reduction was recorded in *Piper longum* (84.38), followed by *Jatropha curcas* (73.53), *Polygonum hydropiper* (72.73), *Phlogacanthus thyrsiflorus* (60.0), *Murraya koenigii* (56.25), *Pongamia pinnata* (45.0) and *Ocimum sanctum* (39.39).
4.3.3.2 Acaricidal effect of plant extracts in reduction of TSSM (*T. urticae*) population

4.3.3.2a One day after treatment

The data on mean per cent reduction of TSSM population recorded one day after treatment are presented in table 4.33 and illustrated in fig. 4.44. The per cent reduction of the TSSM population due to the insecticidal effect of plant extract were ranged from 10.81 to 24.39 per cent for exposure period of one day and analysis of variance showed that the treatments were not significant at 5 per cent probability level indicating that the application of plant extract at respective concentration were not significantly differ on per cent reduction of TSSM population.

4.3.3.2b Three days after treatment

The data on mean per cent reduction of TSSM population recorded three days after treatment along with respective CD values are presented in table 4.33 and diagrammatically shown in fig. 4.44. While comparing the significant of difference among the treatment at 5 per cent probability level by LSD, the data reveals that none of the treatment differed significantly. The reduction of the TSSM due to the insecticidal effect of plant extract were ranges from 24.32 to 51.22 per cent and the highest per cent TSSM population reduction was recorded in *Piper longum* (51.22), followed by *Jatropha curcas* (40.0), *Polygonum hydropiper* (36.84), *Phlogacanthus thrysiflorus* (31.58), *Murraya koenigii* (30.77), *Pongamia pinnata* (30.0) and *Ocimum sanctum* (24.32).

4.3.3.2c Five days after treatment

The per cent reduction of TSSM population after five days of treatment were ranged from 35.14 to 60.98 and analysis of variance revealed that all the plant extract has considerable insecticidal effect on the reduction of the TSSM population. Among the plant extract, the lowest per cent reduction (35.14) was recorded in treatment with *Ocimum sanctum* which was differed with other treatments where as highest per cent reduction (60.98) of two spotted spider mite was observed.
in the treatment with *Piper longum* and differs with all other treatments. The treatment with *Jatropha curcas* caused 50.0 per cent reduction of spider mite population which defers significantly with the mortality in the treatment of *Pongamia pinnata* (37.50) and *Ocimum sanctum* (35.14) and was at par with the treatment of *Polygonum hydropiper* (47.37), *Phlogacanthus thyrsiflorus* (42.11), *Murraya koenigii* (41.03) and depicted in table 4.33.

### 4.3.3.2d Seven days after treatment

The data on mean per cent reduction of TSSM population recorded seven days after treatment along with respective CD values are presented in table 4.33 and diagrammatically shown in fig. 4.44. While comparing the significant of difference among the treatment at 5 per cent probability level by LSD, the data reveals that the treatment differed significantly from the control. The reduction of the TSSM due to the insecticidal effect of plant extract were ranges from 37.84 to 63.41 per cent and the highest per cent TSSM population reduction was recorded in *Piper longum* (63.41), followed by *Jatropha curcas* (52.50), *Polygonum hydropiper* (50.0), *Phlogocanthus thyrsiflorus* (44.74), *Murraya koenigii* (43.59), *Pongamia pinnata* (40.0) and *Ocimum sanctum* (37.84).