# SEASONAL INCIDENCE OF INSECT PESTS, BIO-EFFICACY AND DISSIPATION PATTERN OF SELECTED INSECTICIDES IN CAULIFLOWER


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**DOCTOR OF PHILOSOPHY IN AGRICULTURE**
**(ENTOMOLOGY)**

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**BY**

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**THESIS SUBMITTED TO THE PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF**

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# DECLARATION

I, **N. JEMIMAH** hereby declare that the thesis entitled **"SEASONAL INCIDENCE OF INSECT PESTS, BIO-EFFICACY AND DISSIPATION PATTERN OF SELECTED INSECTICIDES IN CAULIFLOWER"** submitted to the **Professor Jayashankar Telangana State Agricultural University** for the degree of **Doctor of Philosophy in Agriculture** is the result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier in any manner.

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**Date:** **I.D. No. RAD/17-16**

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**Mrs. N. JEMIMAH** has satisfactorily prosecuted the course of research and that thesis entitled **"SEASONAL INCIDENCE OF INSECT PESTS, BIO-EFFICACY AND DISSIPATION PATTERN OF SELECTED INSECTICIDES IN CAULIFLOWER"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any University.

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This is to certify that the thesis entitled **"SEASONAL INCIDENCE OF INSECT PESTS, BIO-EFFICACY AND DISSIPATION PATTERN OF SELECTED INSECTICIDES IN CAULIFLOWER"** submitted in partial fulfillment of the requirements for the degree of **'Doctor of Philosophy in Agriculture (Entomology)'** of the Professor Jayashankar Telangana State Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Mrs. N. JEMIMAH** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

**Thesis approved by the Student's Advisory Committee**

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| | | |
|---|---|---|
| % | : | Per cent |
| μg $g^{-1}$ | : | Microgram per gram |
| μl | : | Micro litre |
| *a.i.* | : | Active ingredient |
| ADI | : | Acceptable Daily Intake |
| AINP | : | All India Network Project |
| AOAC | : | Association of Official Agricultural Chemists |
| APEDA | : | Agricultural and Processed Food Products Export Development Authority |
| BDL | : | Below Detectable Level |
| Bt | : | *Bacillus thuriengenesis* |
| CAC | : | Codex Alimentarius Commission |
| CRM | : | Certified Reference Materials |
| CD (P = 0.05%) | : | Critical Difference at 5 per cent level |
| CF | : | Correction Factor for censoring |
| CFU | : | Colony forming unit per millilitre |
| Cm | : | Centimeter |
| DAS | : | Days After Spraying |
| DMRT | : | Duncan's Multiple Range Test |
| EC | : | Emulsifiable Concentrate |
| *et al.* | : | And others |
| FYM | : | Farm Yard Manure |
| FSSAI | : | Food Safety and Standards Authority of India |
| g *a.i.* $ha^{-1}$ | : | Gram active ingredient per hectare |
| HPLC | : | High Performance Liquid Chromatography |
| hrs | : | Hours |
| i.e. | : | That is |
| kg $ha^{-1}$ | : | Kilogram per hectare |
| LC-MS/MS | : | Liquid Chromatograph-Mass Spectrometer |
| LOD | : | Limit of determination |
| LOQ | : | Limit of quantitation |
| $m^2$ | : | Metre square |
| mg $kg^{-1}$ | : | Milligram per kilogram |

| | | |
|---|---|---|
| min | : | Minute |
| ml $l^{-1}$ | : | Millilitre per litre |
| mm | : | Millimetre |
| MRL | : | Maximum Residue Limit |
| No. | : | Number |
| $^{o}C$ | : | Degree Celsius |
| PHI | : | Pre Harvest Interval |
| ppm | : | Parts per million |
| PTFE | : | Polytetrafluoroethylene |
| q $ha^{-1}$ | : | Quintals per hectare |
| RBD | : | Randomized Block Design |
| SD | : | Standard Deviation |
| SEm | : | Standard Error of mean |
| t | : | Tonne |
| $t_{1/2}$ | : | Residue half-life |
| t $ha^{-1}$ | : | Tonnes per hectare |
| $T_{tol}$ | : | Waiting or safe period |
| TMDI | : | Theoretical Maximum Daily intake |
| *viz.* | : | Namely |
| WP | : | Wettable Powder |

| | | |
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# ABSTRACT

The study entitled "Seasonal incidence of insect pests, bioefficacy and dissipation pattern of selected insecticides in cauliflower" was conducted during *rabi,* 2018-19 and 2019-20 at College Farm, College of Agriculture, Rajendranagar. During both these years, the population of aphids and leaf webber was high while the incidence of other pests *viz*., diamondback moth, painted bug and tobacco caterpillar was very low.

The aphids infestation was recorded during 47$^{th}$ SMW during both these years. A single peak was noticed in the 1$^{st}$ SMW (115/3leaves/plant) during 2018-19 while two peaks were recorded during 2019-20, the first in the 51$^{st}$ SMW (122.2/3leaves/plant) and the second in the 2$^{nd}$ SMW (142.6/3leaves/plant).

The leaf webber incidence was recorded in the 48$^{th}$ SMW during both the years. However, in 2018-19, a single peak was noticed in the 52$^{nd}$ SMW (4.8 larvae/plant) while in 2019-20, two peaks were observed, the first during 51$^{st}$ SMW (5.4 larvae/plant) and the second during 2$^{nd}$ SMW (6.4 larvae/plant), similar to aphids.

The head borer damage was noticed in the 2$^{nd}$ SMW during both the years recording 30 and 38 per cent damage during 2018-19 and 2019-20, respectively. The natural enemy population was also recorded simultaneously during both the years. In 2018-19, coccinellids were observed in the 50$^{th}$ SMW with the population reaching its peak in the 2$^{nd}$ SMW (1.20/plant) while in 2019-20, it peaked during 1$^{st}$ SMW (1.40/plant). The incidence of syrphids initiated during 49$^{th}$ SMW and the population peaked in the 2$^{nd}$ SMW (2.40 and 2.90/plant) during both the years.

Aphids and leaf webber showed a negative correlation with temperature, windspeed and evaporation and positive correlation with morning RH and sunshine. The predators *viz.*, coccinellids and syrphids exhibited a negative correlation with maximum and minimum temperatures and windspeed while showing positive correlation with morning RH and evaporation. The predators were found to be dependent on the density of aphids and showed positive correlation with aphid population.

The bio-efficacy studies revealed that chlorantraniliprole was the most effective insecticide against leaf webber with 84.03 per cent reduction in population followed by spinosad (79.10%), emamectin benzoate (78.99%) and indoxacarb (73.25%). Chlorpyriphos, diafenthiuron and dimethoate were less effective with 52.97, 40.96 and 31.19 per cent reduction over control, respectively. In case of aphids, dimethoate was the most effective with highest overall reduction in population (77.70%) followed by chlorpyriphos (60.14%) while the remaining treatments recorded less than 50 per cent reduction of aphid population. The mean head borer per cent damage was lowest in chlorantraniliprole treated plots (10.36%) while it was highest in control (36.13%).

Among the selected insecticides, the mean highest yield of 19.74 t $ha^{-1}$ was recorded from chlorantraniliprole treated plots while emamectin benzoate (19.16 t $ha^{-1}$), spinosad (18.79 t $ha^{-1}$) and indoxacarb (18.36 t $ha^{-1}$) were found to be on par. Highest incremental cost-benefit ratio of 1:18.63 was also obtained in chlorantraniliprole treatment.

The studies on dissipation pattern of selected insecticides in cauliflower curd revealed that emamectin benzoate persisted for one day in cauliflower head while spinosad and dimethoate persisted for 5-7 days. Persistence of chlorantraniliprole, diafenthiuron and chlorpyriphos were observed for 10 days while the highest persistence was noticed for indoxacarb (15 days). Based on the designated MRL values (Codex/FSSAI), the calculated waiting periods were found to be lowest for dimethoate (1.79 days) followed by chlorpyriphos (6.71 days), spinosad (10.97 days) and indoxacarb. In case of chlorantraniliprole, the initial deposits were less than MRL values.

The decontamination techniques help in bringing down the concentration of pesticides and the extent of reduction depends on the initial deposits at harvest and also on the substrate and the type of pesticide. The per cent reduction of residues of chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, diafenthiuron, chlorpyriphos and dimethoate by cooking in pressure cooker over treated control were 95.66, 91.36, 100, 70.89, 89.59, 50.60 and 73.75, respectively. Boiling in open vessel in case of chlorantraniliprole, spinosad, indoxacarb and diafenthiuron was the next best method for reduction of residues by 79.08, 77.13, 63.09 and 79.89, respectively.

## Chapter I

# INTRODUCTION

Cauliflower (*Brassica oleraceae* L *var. botrytis*) is one of the most important winter vegetables like cruciferous cabbage, Brussels sprout and broccoli. The edible part of cauliflower is known as curd, which consists of a shoot system with short internodes, branches, apices and bracts. It is a native of southern Europe in the Mediterranean region and was introduced into India in 1822 from England (Swarup and Chatterjee, 1972). It requires cold and moist climate.

Cauliflower contains adequate quantities of vitamins A, B and C and minerals like phosphorous, potassium, calcium, sodium, and iron. Raw cauliflower (100 g) provides 25 k calories of energy, 4.97 g of carbohydrates, 0.3 g of fats, and 1.92 g of proteins. It has a high content of vitamin C (48.2 mg), moderate levels of several B vitamins and vitamin K (15.5 μg). It is consumed as vegetable in curries, soups and pickles. It is low in fat and a rich source of dietary fibre (2 g) (USDA, 2018). The inflorescence extract has been used in the treatment of scurvy, as a blood purifier and as an antacid. The seeds have contraceptive properties. Cauliflower extract has been reported to be effective in the inhibition of initiation and promotion of carcinogenesis *in vitro* (Wang *et al.*, 2012). It is also reported to contain potential chemo preventive agents which include ascorbic acid, carotenoids, tocopherols, isothiocyanates, indoles and flavonoids.

During 2017-18, India produces about 8.668 mt of cauliflower per year from 0.452 m ha area with an average productivity of 19.15 mt $ha^{-1}$. Bihar, Uttar Pradesh, West Bengal, Orissa, Assam, Haryana, Rajasthan and Maharashtra are the major cauliflower growing states. In Telangana, the area under cauliflower is 1.58 thousand ha with a total production of 31.83 mt and average productivity of 20.21 mt $ha^{-1}$ (https://www.indiastat.com). It is also cultivated in non-traditional areas of Tamil Nadu, Andhra Pradesh and Kerala.

The major constraints in production are physiological disorders, pests and diseases. Of these, insect pests are important as they cause serious economic damage to the crop. It has been reported that insect pests cause 40 per cent of the total yield loss in vegetables with an average of 60-80 per cent yield loss in cruciferous crops (Tiwari, 2009). The pests such as diamond back moth (DBM) *Plutella xylostella* (Linnaeus), tobacco caterpillar *Spodoptera litura* (Fabricius), leaf webber *Crocidolomia binotalis* (Zeller), stem borer *Hellula undalis* (Fabricius), aphid *Brevicoryne brassicae* (Linnaeus), mustard aphid *Lipaphis erysimi* (Kaltenbach) affect the quality and yield of cauliflower (Yadav and Malik, 2014).

The appearance and build-up of population of the above pests from seedling to curd formation stage varies greatly with the prevailing weather conditions. Presence of various pests at higher population at critical growth stages affects the crop growth and may result in considerable qualitative and quantitative loss. Studies on the seasonal incidence of pests provide reliable estimates of field population densities and their seasonal activities. Studies on seasonal incidence of pests on cole crops have been carried out in various parts of the country. Singh *et al.* (2012) reported that the abundance and infestation of mustard aphid had significant and positive correlation with environmental conditions in Uttar Pradesh. Correlation studies of insect pests of cauliflower with abiotic factors showed a significant positive correlation of minimum temperature and evening RH with diamond back moth and non-significant relationship with tobacco leaf eating caterpillar, aphids and painted bugs in Maharashtra (Mishra *et al.* 2018). Studies on severity of insect pests on cauliflower in Ajmer, Rajasthan revealed that the peak population of Spodoptera was observed by the end of September while severity of aphids was higher in winter than in monsoon (Puja and Sabiha, 2016). Studies on the incidence of pests in cauliflower in Telangana region are scanty, hence seasonal incidence of insect pests of cauliflower and their correlation with weather parameters was undertaken.

Knowledge of seasonal incidence of pests helps to formulate a better management strategy with a blend of different practices. Chemical control is considered to be one of the oldest practices for pest control as wide range of chemicals are easily available at reasonable costs and they yield quick results. Farmers are relying on different insecticides as minor damage to the curds may result in major economic loss. Repeated use of chemicals belonging to same group may pose problems of resistance and resurgence hence, more and more insecticides belonging different groups are being developed, promoted and marketed in quick succession. The pest complex in cauliflower is diverse and exclusion of chemical insecticides is impracticable necessitating the use of these new molecules readily. Bio-efficacy studies of new insecticides on DBM (Yadav and Malik, 2014), tobacco leaf eating caterpillar (Khan *et al.,* 2015), mustard aphid (Dotasara *et al.,* 2017b) in various agro-climatic conditions have been carried out. However, there is a need to evaluate the efficacy of these new insecticides against insect pests of cauliflower.

Timely spraying of selected insecticides as per recommended dosage is of utmost importance in pest management. However, usage of massive quantities of synthetic insecticides are giving rise to major concerns about food safety and environmental pollution in addition to the high chemical and labor costs. In many instances, the insecticide sprayed may leave traces of residues in plant produce, soil, water and environment. Also, presence of these residues even after harvest poses risk to the consumers. As vegetables are an essential component of human diet and are basic source of energy, indiscriminate use of pesticides particularly at fruiting stage and non-adoption of safe waiting period leads to accumulation of pesticide residues in consumable vegetables. To reduce the risk to the consumers and ensure safety to the environment, it is essential to know the extent of time pesticides remain on the crop. The rate of dissipation of insecticide varies with several factors like species cultivated, climatic conditions, application parameters like number of applications, penetration rate, volume of water, type of nozzle *etc*., (Rahman *et al.,* 2015). Dissipation pattern of insecticide under a given climatic condition provides an insight on the number of days required for the insecticide to reach below determination level (BDL) and to establish safe waiting periods. Hence studies were undertaken to understand the dissipation pattern of selected insecticides and their half-life values.

When safe waiting periods are not followed there is a problem of residues persisting in the end product. Several workers reported the presence of pesticide residues in vegetables mainly due to their repeated application during entire period of growth in non-prescribed manner to control different pests and to get better yield and quality (Baptista *et al.,* 2008, Lazic *et al.,* 2009). These residues are of great concern to the human health when they are consumed without processing. Removal of these residues is important before consumption of vegetables. To minimize dietary exposure to pesticides, it is pertinent to explore strategies that effectively help in reducing the residue content at individual level. Several simple, labor and cost-effective operations like washing with tap water, washing with acidic and alkaline solutions, peeling and cooking singly or in combination can prove an effective means in reducing dietary consumption of pesticide residues. The effectiveness of different decontamination processes for reduction of different pesticide residues vary with the type of pesticide, its location and age of residues in vegetable and the type of vegetable (Anita *et al.,* 2018).

Since cauliflower attracts many pests throughout its growth stages, insecticides are sprayed at regular intervals to protect it. The presence of pesticide residues in raw and cooked vegetable and their chances of passing on to the consumers are of major concern (Raj *et al.,* 1991). Several studies on simple household techniques like washing, peeling and cooking playing a crucial role in reduction of pesticide residues have been reported (Thanki *et al.,* 2012). The efficacy of different decontamination methods depend on the chemical nature, pH and polarity of the insecticide. To minimize the dietary exposure and ensure consumer safety, different decontamination approaches for some of the commonly used insecticides in cauliflower were taken up.

Thus, in the light of the above-mentioned literature, the present investigation titled "Seasonal incidence of insect pests, bio-efficacy and dissipation pattern of selected insecticides in cauliflower" was contemplated with the following objectives:

1. To study the seasonal incidence of insect pests in cauliflower and to correlate with weather factors.
2. To evaluate the bio-efficacy of selected insecticides against insect pest complex in cauliflower.
3. To study the dissipation pattern and residue dynamics of selected insecticides on cauliflower.
4. Evaluation of methods for decontamination of insecticide residues in cauliflower.

## Chapter II

# REVIEW OF LITERATURE

Cauliflower is grown as winter vegetable crop in India. It is affected by a number of insect pests causing substantial losses in yield. A brief review on the seasonal incidence, bioefficacy of certain insecticides, their dissipation and decontamination are given hereunder:

## 2.1 Seasonal Incidence of Insect Pests in Cauliflower and Their Correlation with Weather Factors

Kumar and Yadav (1998) reported seven insect pests in cauliflower among which *P. xylostella,* (Linnaeus) and *S. litura* (Fabricius) were major while *Plusia orichalcea* (Fabricius), *B. cruciferarum* (Kirkaldy), *C. horticola* (Gour), *C. binotalis* (Zeller) and *H. undalis* (Fabricius) were found in low numbers. Diamond back moth was found throughout the crop season and attained peak in 36$^{th}$ SMW (Standard meteorological week) (104 caterpillars/10 plants) whereas the maximum population of *S. litura* was found in 39$^{th}$ SMW (757 caterpillars/10 plants) during the early season crop.

Chaudhuri *et al.* (2001) observed that the population of aphid (*L. erysimi*) reached maximum level during third week of March in spring crop. Aphid population was recorded in both winter and spring seasons but its population was higher in spring crop. Correlation between pest population and important weather parameters showed that in winter, aphid population was negatively correlated with temperature, sunshine and total rainfall, and positively with average relative humidity. During spring season, aphid population showed positive correlation with average relative humidity and total rainfall.

Malik *et al.* (2000) reported that the population of cauliflower aphid, *B. brassicae* fluctuated from 51$^{st}$ meteorological week to 4$^{th}$ meteorological week. Correlation between aphid population and maximum- minimum temperature were negative while with morning relative humidity, it was positive.

Younas *et al.* (2004) carried out studies on population density of aphids on cauliflower cultivars and reported that the density of aphids ranged from 0.00 to 31.76

aphids $cm^{-2}$ leaf area. The lowest and highest average mean population of aphids were recorded on cultivars Snow drift and Meigettsal, respectively.

The peak population of *L. erysimi* was observed during fourth week of January, while that of *P. xylostella* was recorded in the first and second weeks of February during 1997-98 and 1998-99. Maximum and minimum temperatures and relative humidity did not show any significant correlation with the incidence of *L. erysimi* whereas, maximum temperature showed a positive correlation with the population buildup of *P. xylostella* (Rao and Lal, 2005).

Badjena and Mandal (2005) reported the incidence of leaf webber, *C. binotalis* from third week of November to third week of February. The insect attained its peak (25.6 larvae/10 plants) during third week of January.

Patait *et al.* (2008) reported that the population of *C. binotalis* in cabbage varied from 3.8 to 44.0 and 1.0 to 6.2 larvae per quadrat during rainy and winter seasons, respectively. During rainy season, the population of *C. binotalis* to the maximum extent was influenced positively by forenoon relative humidity and negatively by minimum temperature. During winter season, the population of *C. binotalis* was affected positively due to the action of afternoon relative humidity and maximum temperature and negatively by the action of forenoon relative humidity and minimum temperature.

Green peach aphid population was low in early sown cauliflower ($3^{rd}$ week of September) wherein the pest appeared during $43^{rd}$ standard week and reached its peak of 6.19 aphids/plant during $48^{th}$ SMW while aphid incidence was seen during $44^{th}$ SMW in late planted cauliflower ($3^{rd}$ week of October) and reached peak of 14.42 aphids/plant during $52^{nd}$ SW (Siddiqui *et al.,* 2009).

Studies on seasonal incidence of diamond back moth *P. xylostella* in cauliflower revealed that its density ranged between 0.90 to 2.38 and 0.27 to 5.84 larvae and pupae per plant, respectively in I week of July and the rate of parasitization was quite low. Population buildup of the pest was usually observed in II to IV week of September. *Cotesia plutellae* (Kurdjumov) was found to be a dominant larval parasitoid while *Oomyzus sokolowskii* (Kurdjumov) parasitized relatively few pupae of *P. xylostella*. Rainfall negatively affected the DBM population (Ahmad and Ansari, 2010).

Ramesh (2011) reported the seasonal invasion of DBM and mustard aphid *L. erysimi* on cole crops. DBM incidence was observed from seedling stage and attained average highest population during the first week of September while that of aphid commenced during second fortnight of November and attained peak during fifth week of February. The activity of leaf webber (*C. binotalis*) was witnessed in the first and second week of September and that of the larvae of tobacco caterpillar (*S. litura*) during the third week of November, coinciding with the curd formation stage.

Ahmad *et al.* (2012) investigated the population trend of diamondback moth (*P. xylostella*) larvae in cauliflower and found that the larval density increased with increasing temperature. The population of 2.1 larvae/plant at 23 °C gradually increased along with temperature and reached to 12.9 larvae/plant at 31°C. When temperature reached to the maximum (36°C), then the population increased about 2-fold (21.2 larvae/plant). It was concluded that the pest population drastically increased with increase in environmental temperature and humidity (Mid-August).

Singh *et al.* (2012) conducted studies on seasonal abundance of mustard aphid on cauliflower and revealed that aphids appeared during first week of January and reached peak of 275.12 aphids per plant. The aphid population continued till the end of March. The aphid population showed highly significant positive correlation with minimum (0.441), maximum (0.553) and average relative humidity (RH) (0.525) while rainfall had non-significant positive relation with aphid population and infestation.

Bana *et al.* (2012) reported that the aphid, *L erysimi* infestation started from last week of November and reached maximum (143.75 and 150.75 aphids/plant) in the fourth and third week of January during 2008-09 and 2009-10, respectively, and thereafter started declining. The aphid population had significant negative correlation with maximum and minimum temperatures (r =-0.569 and r =-0.559) and non-significant with relative humidity (r = 0.442) and sunshine hours (r=- 0.379) during first season and showed significant negative correlation with only minimum temperature (r = -0.534) and non-significant with maximum temperature (r = -0.235), relative humidity (r = 0.313) and sunshine hours (r = 0.373) during second season. The incidence of aphid was only affected by temperature. The coccinellid beetle was maximum during 2$^{nd}$ (35.25) and 3$^{rd}$ week (40.00) of January during first and second years, respectively. Increase in temperature and decrease in aphid population lead to decrease in coccinellids.

Population dynamics of insect pests and their natural enemies on cabbage revealed that the peak population of diamondback moth was recorded on 1$^{st}$ March and

23rd February with 13.60 and 14.33 larvae/plant, respectively while the highest parasitized larvae of diamond back moth by *C. plutellae* were found on 15th and 8th March with 10.42 and 10.50 per cent larval parasitisation during 2011-12 and 2012-13 respectively. Cabbage aphid reached its peak on 9th February (14.17 aphids/inch$^2$ leaf) and 16th February (11.03 aphids/inch$^2$ leaf) whereas maximum coccinellid was observed on 23rd February of 2011-12 and 2012-13 crop seasons with 11.67 and 9.67 coccinellids/ 5 plants, respectively. Both maximum and minimum temperature had major role in building up the population of diamond back moth, *C. plutellae* and coccinellid beetles while aphid population was enhanced only by maximum temperature. Relative humidity and rainfall had negative influence on pests and natural enemies (Patra *et al.*, 2013).

Singh and Sundar (2014) conducted pest diversity studies in cauliflower and found maximum population of *S. litura* during 51st SMW (3.75 larvae/10 plants) during 2010-11 while *P. xylostella* larvae reached its peak during 50th SMW. The insect pests were found to have negative correlation with maximum and minimum temperatures.

Ahmad *et al.* (2015) studied the population dynamics of *P. xylostella* in cauliflower and its correlation with weather parameters and reported that the highest mean population of larvae and pupae (4.75±2.14 and 6.7±1.71) per plant were recorded in September whereas the lowest (0.2±0.41 and 0.4±0.71) was recorded in July in two consecutive years. Per cent relative humidity showed a positive significant relationship ($r = 0.79$ and 0.67) with population dynamics whereas a negative correlation ($r = -0.98$ and -0.46) was recorded with total rainfall. Multiple regression models showed 90-98 per cent ($R^2$) interaction between the population of *P. xylostella* and weather parameters.

A study on the population dynamics of major insect pests and their natural enemies in cauliflower revealed that *P. xylostella* occurred during first week of September (2.76 larvae per plant) and reached its peak during first week of November (17.90 larvae per plant) while Spodoptera larva was first noticed in the last week of August (2.0 larvae per plant) and reached its peak by the end of September (8.60 larvae per plant). Severity of aphid incidence was found to be higher in winter season as compared to monsoon season. Highest larval parasitization by *C. plutellae* was recorded during mid-November (9.66%) for the Aug-Nov crop and during April (14.16%) in January-April crop (Puja and Sabiha, 2016).

Shalini *et al.* (2016) reported maximum population of *B. brassicae* (352 aphid/plant) in 9$^{th}$ SMW and showed positive correlation with temperature and wind but negative with relative humidity. In case of DBM, maximum population (11.40/plant) was recorded during 6$^{th}$ SMW and the pest population showed positive correlation with temperatures and relative humidity.

Incidence of *B. brassicae* on cauliflower and its correlation with weather parameters revealed that the mean population of nymphs was 4.56 per leaf with 50.07 per cent infestation of aphid during November 2014 to February, 2015. Minimum and maximum temperatures had significantly negative correlation while relative humidity and rainfall had non-significant negative correlation with aphid population (Sakhrie *et al.*, 2016).

Saranya *et al.* (2017) investigated the seasonal incidence of major insect pests of cauliflower during two seasons *i.e rabi* 2015-16 and 2016-17. Infestation by aphids and DBM initiated in December and that of flea beetles and painted bug in the month of January. The major insect pests reached their peak mean populations during February-March. The population of the major insect pests was positively correlated with the mean atmospheric temperature, wind velocity and sunshine hours; and negatively correlated with relative humidity and rainfall during both the years.

Khan and Talukder (2017) studied the influence of weather factors on the abundance and population dynamics of *S. litura* and *P. brassicae* on cabbage and reported that the peak larval population of *S. litura* (1.57 larvae/plant) and *P. brassicae* (1.98 larvae/plant) was observed during 5$^{th}$ SMW. Both the pests showed positive correlation with temperature (maximum and minimum) and negative correlation with relative humidity in cabbage.

The peak incidence of aphid *B. brassicae* (120/leaf) was observed during 51$^{st}$ SMW, diamondback moth *P. xylostella* (7.82 larvae/plant), leaf webber *C. binotalis* (3.00 larvae/plant), tobacco leaf eating caterpillar *S. litura* (2.0 larvae/plant) and Tussock moth *Orgyia* spp (0.85 larvae/plant) during 2$^{nd}$ SMW, while 3$^{rd}$ and 8$^{th}$ SMW saw peak of green semilooper *Trichoplusia ni* (Hubner) (1.06 larvae/plant) and head borer *H. undalis* (2.50 per cent). The peak activity of maggots of syrphid fly (4.52/plant) and mummified aphids (24.88/plant) were observed during 52$^{nd}$ and 51$^{st}$ SMW, respectively. Aphids and leaf webber populations showed negative significant correlation with minimum temperature while correlation of syrphid fly and mummified aphid were significant with minimum temperature and evening relative humidity. Correlation between DBM and evening relative humidity was negatively significant whereas maximum temperature and evaporation were positively significant in case of head borer (Gaikwad *et al.,* 2018a).

The infestation of various pests *viz.*, DBM, head borer, leaf webber, cabbage semilooper and tobacco leaf eating caterpillar was initiated during 47$^{th}$ SMW and they reached peak during 51$^{st}$, 3$^{rd}$, 48$^{th}$, 49$^{th}$ and 49$^{th}$ SMW, respectively in cabbage during 2016-17 (Aiswarya *et al.,* 2018).

Mishra *et al.* (2018) recorded the seasonal incidence of major insect pests on cauliflower which began from 35$^{th}$ SMW and persisted up to 47$^{th}$ SMW. Peak incidence of DBM was observed in 39$^{th}$ SMW (7.32 larvae/plant) and was found to have had a significant positive correlation with minimum temperature (r=0.6475) and evening RH (r=0.5578). Peak incidence of tobacco leaf eating caterpillar (*S. litura*) (3.12 larvae/plant) and aphids (*B. brassicae)* (44.17 aphids/3 leaves/plant) was in 43$^{rd}$ SMW while painted bugs (*B. cruciferarum*) were observed from 35$^{th}$ to 47$^{th}$ SMW with peak incidence in 42$^{nd}$ SMW (4.23 painted bugs/3 leaves/plants).

Patel and Patel (2018) investigated the incidence of insect pests of cauliflower and found the larval population of DBM during second week of November while aphid (*B. brassicae*), tobacco caterpillar (*S. litura*) and *Helicoverpa armigera* (Hubner) appeared during first week of December. The last week of January saw the incidence of flea beetle, *Phyllotreta cruciferae* (Goeze). Temperature was found to exhibit significant positive influence on cabbage head eating caterpillar and flea beetle, while maximum temperature had significant negative impact on aphid population. Evening and average relative humidity showed significant positive influence on diamond back moth population. Wind velocity exhibited significant positive influence on tobacco caterpillar, cabbage head eating caterpillar and flea beetle population.

Correlation studies on the aphid population and their natural enemies were carried out by Bhede *et al.* (2018). Aphids showed significant negative correlation with minimum temperature. Syrphid fly maggots and coccinellids showed negative correlation with minimum temperature while positive with aphid population. The correlation between aphid and mummified aphid was significantly positive. The weather parameters and biotic factors (natural enemies) were the critical factors for abundance of population of aphids on cauliflower.

## 2.2 Bio-efficacy of Selective Insecticides against Insect Pest Complex in Cole Crops

Sinha *et al.* (2001) found that chlorpyriphos 20 EC was very effective for controlling mustard aphid and giving the maximum yield.

Babu *et al*. (2002a) found that indoxacarb was effective against *P. xylostella* under laboratory conditions followed by abamectin. Further, based on field experiments Babu *et al*. (2002b) stated that indoxacarb @ 29 g *a.i.* $ha^{-1}$ was effective in reducing the larval population of DBM on cauliflower and thereby increasing the yield.

Liu *et al*. (2003) reported indoxacarb @ 0.05 to 0.07 kg *a.i.* $ha^{-1}$ to be effective against DBM by suppressing the larvae below economic threshold level. In addition, it was as effective as spinosad and significantly more effective than emamectin benzoate.

Syed *et al*. (2004) tested different insecticides under field condition on cabbage and cauliflower and found that avermectin was most effective when applied on cabbage in first and second sprays against diamond back moth.

Kanna *et al*. (2005) compared the efficacy of emamectin benzoate 5 SG with spinosad 2.5 SC, profenophos 50 EC and lambda cyhalothrin 5 EC against diamondback moth (*P. xylostella*). Among all the treatments emamectin benzoate 5 SG at 10.0 g *a.i.* $ha^{-1}$ and 8.75 g *a.i.* $ha^{-1}$ was more effective in reducing the larval population by 58.86 and 48.58 per cent, respectively in cabbage.

Gill *et al*. (2008) evaluated the efficacy of spinosad 2.5 SC@ 600 ml $ha^{-1}$, emamectin benzoate @ 170 g $ha^{-1}$, indoxacarb @ 333 ml $ha^{-1}$, endosulfan @ 1000 ml $ha^{-1}$ and cartap hydrochloride @ 500 g $ha^{-1}$ against *P. xylostella* in cauliflower and cabbage and found significant reduction in larval population ranging from 84.54 to 93.58 per cent in cauliflower and 89.24 to 91.94 per cent in cabbage crop over control in all the three treatments with spinosad recording significantly higher yield in cauliflower (193.03 q $ha^{-1}$) and cabbage (320.26 q $ha^{-1}$).

Deivendran *et al*. (2007) evaluated the efficacy of new insecticides against *P. xylostella* in cauliflower and revealed that indoxacarb at 90 g *a.i.* ha$^{-1}$ gave the highest mean larval mortality (67.0%) followed by spinosad at 75 g *a.i.* ha$^{-1}$ (62.0%), fipronil at 75 g *a.i.* ha$^{-1}$ (65.0%), thiodicarb at 750 g *a.i.* ha$^{-1}$ (57.0%), dichlorvos at 115 g *a.i.* ha$^{-1}$ (44.0%), endosulfan at 350 g *a.i.* ha$^{-1}$, nimbecidine at 75 g *a.i.* ha$^{-1}$ (37.0%) and *Bt* at 1000 g ha$^{-1}$ (14.0%) one day after the spray and all were significantly better than control. The overall order of efficacy recorded was indoxacarb >spinosad> fipronil >thiodicarb>*Bt*> dichlorvos >endosulfan>nimbecidine.

Emamectin benzoate when sprayed twice at 15 days interval in three test doses (7.5, 9.0 and 11.0 g *a.i.* ha$^{-1}$) was found effective in reducing the population of diamondback moth in all the three doses. The population of DBM ranged from 0.00 (11.0 g *a.i.* ha$^{-1}$) to 0.60 larvae/leaf (7.50 g *a.i.* ha$^{-1}$) showing the efficacy of the insecticide in managing the pest even at low doses (Shivalingaswamy *et al.*, 2008).

Kumar and Meena (2010) tested the efficacy and phytotoxicity of indoxacarb 14.5% SC at different doses (30, 40, 50, 75 and 100 g *a.i.* ha$^{-1}$) on cabbage and reported that indoxacarb 14.5% SC @ 75 g *a.i.* ha$^{-1}$ recorded the lowest population of *P. xylostella.* No phytotoxic symptoms were found on all the doses except for mild symptoms @ 100 g *a.i.* ha$^{-1}$ on the plants.

Sahoo (2012) evaluated different insecticides for their bio-efficacy against *L. erysimi* and found that the plots treated with dimethoate and oxydemeton-methyl recorded minimum aphid infestation and also recorded higher yield ranging from 1151.6 to 1310.3 kg seed ha$^{-1}$. Incremental cost benefit ratio indicated that most favourable return was obtained under dimethoate 30 EC (1:20.8 & 1:13.3) followed by oxydemeton-methyl 25 EC (1:16.8 & 1:9.1).

Mandal *et al.* (2012) studied the efficacy of different insecticides for the management of mustard aphid in rapeseed and found that chlorpyriphos 20 EC was most effective followed by chlorpyriphos+ cypermethrin 55 EC, thiamethoxam 25 WG and imidacloprid 17.8 SL for aphid management but highest yield was recorded from chlorpyriphos+cypermethrin followed by thiamethoxam, chlorpyriphos and imidacloprid treated plot.

Kikuchi *et al.* (2013) found that emamectin benzoate, cartap hydrochloride, tolfenpyrad, fipronil, pyridalyl, chlorfluazuron, teflubenzuron, *Bt*-kurstaki, *Bt*-aizawai, chlorantraniliprole and flubendiamide were 85.7 to 100 per cent lethal against the larval population of diamondback moth in cabbage.

Yadav and Malik (2014) reported that two sprays each of spinosad (0.009%) *Bt* (1%) and fipronil (0.01%) were effective with 71.0, 69.51 and 68.77 reduction of diamondback moth population over control in cauliflower.

Vaseem *et al.* (2014) revealed that plots treated with chlorantraniliprole were found to be effective against *P. xylostella* recording significantly higher cabbage yield (236.30 q $ha^{-1}$) followed by spinosad (220.74 q $ha^{-1}$) and indoxacarb (204.37 q $ha^{-1}$) over control (165.25 q $ha^{-1}$). Highest cost benefit ratio was realized in chlorantraniliprole (1:10.9) followed by indoxacarb (1:9.18).

Sakhrie *et al.* (2015) evaluated the efficacy of various bio pesticides and chemical pesticides on *P. xylostella* in cauliflower and reported that the highest per cent reduction in *P. xylostella* population was recorded in neem oil (63.71%) followed by imidacloprid, chlorpyrifos and citronella oil showing 57.85 per cent, 48.60 per cent and 47.97 per cent reduction, respectively over control.

Gupta *et al.* (2015) reported that among various insecticides and combination products, Action 505 (chlorpyriphos+cypermethrin) @ 1.6 l $ha^{-1}$ significantly reduced the diamondback moth (DBM) (60%) and aphid population (70%) in cabbage besides giving the highest yield (170% increase over control).

Chowdary *et al.* (2015) revealed that per cent head damage in cabbage was significantly low in plots treated with chlorantraniliprole at two different doses 30 g *a.i.* $ha^{-1}$ (2.53%) and 20 g *a.i.* $ha^{-1}$ (5.39%) followed by emamectin benzoate (10.67%), spinosad (13.89%), flubendiamide (14.38%) and indoxacarb (20.82%) and all the treatments were effective over control (73.36%).

Rabari *et al.* (2016) recorded highest yield of cabbage in plots treated with spinosad (339.26 q $ha^{-1}$) and it was on par with emamectin benzoate (334.58 q $ha^{-1}$) and indoxacarb (327.30 q $ha^{-1}$).

Djomaha *et al.* (2016) evaluated the efficacy of neem seed oil and imidacloprid on the populations of three cabbage pests, *B. brassicae*, *Lipaphis pseudobrassicae* (Davis) and *P. xylostella* and reported that the use of neem seed oil and imidacloprid reduced the loss by 6.06 and 9.92 per cent, respectively and suggested that neem extracts can be incorporated and used at a weekly basis in the integrated management of these pests.

Dutta *et al.* (2016) conducted bioefficacy studies of novel insecticides diafenthiuron 500 SC, buprofezin 40 SC, lufenuron 5 EC and indoxacarb 14.5 SC along with azadiractin 1 EC against mustard aphid *L. erysimi* and found that buprofezin (1.57 t $ha^{-1}$) recorded higher yield followed by diafenthiuron (1.52 t $ha^{-1}$).

Sunitha and Mohite (2016) tested newer insecticide molecules *viz.* emamectin benzoate, rynaxypyr, chlorfenapyr, fipronil for their toxicity against various larval instars of diamond back moth in cabbage, and revealed that rynaxypyr 1.67 SC was significantly most effective followed by emamectin benzoate 20 SC, chlorfenapyr 10 SC and fipronil 5 SC.

Dotasara *et al.* (2017a) reported that spinosad (45 SC @ 0.5ml $l^{-1}$) treatment showed highest per cent reduction of DBM over control (89.97%) with less number of larvae (0.58 larvae/ plant) in cauliflower. The larval count and per cent reduction over control in the different treated plots ranged from 0.58 to 3.94 and 89.97 to 41.37, respectively as against 8.79 numbers of larvae in untreated control. Flubendiamide (48 SC @ 0.3 ml $l^{-1}$) and chlorantriniliprole (18.5 SC @ 0.3 g $l^{-1}$) were next effective pesticides to reduce the pest incidence significantly.

Dotasara *et al.* (2017b) observed that imidacloprid 17.8 SL @ 0.2 g $l^{-1}$ showed highest reduction (87.53, 83.86 %) of mustard aphid, *L. erysimi* followed by fipronil 5 SC @ 1.0 ml $l^{-1}$ (83.56, 78.90 %) reduction after first and second sprays, respectively in cauliflower.

Patel *et al.* (2017) tested two neonicotinoid insecticides *viz.*, imidacloprid and thiamethoxam with some conventional insecticides against *L. erysimi* in mustard and reported that dimethoate 30 EC @ 1 ml $l^{-1}$ gave considerable control (0.33 aphids/plant) as compared to the other conventional insecticides while chlorpyriphos (3.5 aphids/plant) was moderately toxic to mustard aphid following the neonicotinoids.

Basnet *et al.* (2018) tested the efficacy of spinosad, margosan and *Beauveria bassiana* at three different doses against cabbage aphid (*B. brassicae* L.). Highest average reduction of cabbage aphid population was found in spinosad @ 0.725 ml $l^{-1}$ followed by *Beauveria* @ 3.0 ml $l^{-1}$.

Studies on efficacy of insecticides against diamondback moth in cauliflower revealed that among all the treatments significantly lower larval population and higher yield was obtained with chlorantraniliprole 18.5 SC (0.006%) which was at par with spinosad 45 SC (0.009%) followed by emamectin benzoate 5 WSG (0.002%) and flubendiamide 39.35 SC (0.096%). Maximum avoidable loss of 45.24% and higher yield (19.98 t $ha^{-1}$) was obtained with chlorantraniliprole followed by spinosad. Maximum cost benefit in terms of ICBR was observed with spinosad (1: 9.93) followed by emamectin benzoate (1: 8.64) (Patel and Patel, 2018).

Sawant and Patil (2018) reported that among the various insecticidal treatments against DBM in cabbage, significantly highest per cent larval reduction of *P. xylostella* over control was recorded in chlorantraniliprole treated plots (91.30 % with 1.02 larvae/plant) followed by spinosad (87.55 % with 1.46 larvae/plant). The highest yield and ICBR of 238.15 q $ha^{-1}$ and 1:16.40 was registered from chlorantraniliprole treated plots followed by spinosad (233.83 q $ha^{-1}$) and with ICBR of 1:12.22.

Bhede *et al.* (2019) reported that cyantraniliprole (10.16% OD), buprofezin (25% SC) and flonicamid (50% WG) were most effective insecticides against aphids while the application of cyantraniliprole (10.16% OD), emamectin benzoate (5% SG), chlorantraniliprole (18.5% SC) and flubendiamide (20% WG) were effective in managing diamondback moth in cauliflower.

Harika *et al.* (2019) tested newer insecticides for their efficacy on diamond back moth in cauliflower and it was found that spinosad 45 SC, indoxacarb 14.5 SC and emamectin benzoate 5 SG were most effective treatments and also gave good cost benefit (C:B) ratio of 30.13, 69.85 and 60.18, respectively.

Among different treatments, the per cent reduction of larval population of DBM over untreated check in cabbage was highest in chlorantraniliprole @ 10 g *a.i.* $ha^{-1}$ (81.02%), followed by spinosad @15 g *a.i.* $ha^{-1}$ (78.13%) and indoxacarb @ 40 g *a.i.* $ha^{-1}$ (78.02%). Chlorantraniliprole recorded highest marketable yield of 149.92 q $ha^{-1}$ and highest incremental cost benefit (1:18.44) followed by spinosad (1:16.33) and diafenthiuron (1:13.96) (Chowdary and Sharma, 2019).

Jakhar *et al.* (2019) assessed the per cent reduction of diamondback moth population after three insecticidal sprays in cauliflower and found that spinosad was effective in reducing the larval population of DBM (86.66-94.33%) and was found to be on par with indoxacarb (85.66-91.00%) followed by emamectin benzoate (68.66-70.33%) and chlorantraniliprole (67.66-68.66%).

Nayak *et al.* (2019) reported that chlorantraniliprole (0.44 larva/plant) was very effective in recording lowest larval population of *P. xylostella* (L.) in cabbage and was statistically on par with emamectin benzoate (0.53 larva/plant), flubendiamide (0.60 larva/ plant), spinosad (0.67 larva/plant), indoxacarb (0.73 larva/plant) when compared to the standard check dichlorvos (0.78 larva/plant).

Vishal *et al.* (2019) recorded minimum population (2.33 aphids/plant) in plots treated with acephate 75 SP @ 350 g *a.i.* $ha^{-1}$ followed by imidacloprid 17.8 SL @ 20g *a.i.* $ha^{-1}$ (4.67 aphids/plant) and dimethoate 30 EC @ 300g *a.i.* $ha^{-1}$ (7.00 aphids/plant) at 7 days after spray while 174.33 aphids/plant were recorded in control plot of mustard.

Sharma *et al.* (2020) reported that among nine insecticides tested against mustard aphid, *L. erysimi*, imidacloprid and thiamethoxam among newer insecticides and oxy demeton methyl and dimethoate among conventional insecticides were effective with imidacloprid recording highest incremental cost benefit ratio (1:13.28) followed by dimethoate (1:9.88) and oxydemeton-methyl (1:9.15).

Studies on bioefficacy of insecticides against major pests of cabbage by Mane *et al.* (2020) revealed that spraying of spinosad and indoxacarb were effective in managing cabbage butterfly, diamondback moth, tobacco caterpillar and cabbage head borer and recording higher yields of 639.26 q $ha^{-1}$ of cabbage in spinosad followed by 628.27 q $ha^{-1}$ in indoxacarb treatments while novaluron, flubendiamide, emamectin benzoate, profenophos were at par with each other.

Sambathkumar (2020) conducted bioassays to evaluate efficacy of newer generation insecticide molecules against DBM and leaf webber. Chlorantraniliprole 18.5 SC and flubendiamide 39.5 SC up on exposure to short period (24 hrs) led to feeding cessation and complete control followed by spinosad 2.5 SC @ 25 g *a.i.* $ha^{-1}$, emamectin benzoate 5 SG @ 15 g *a.i.* $ha^{-1}$ and fipronil 5 SC @ 750 g *a.i.* $ha^{-1}$ at 36 hrs after treatment. The insecticides brought rapid and complete larval mortality of leaf webber larvae compared to DBM larvae.

Yadav *et al.* (2021) concluded that dimethoate 30 EC @ 625 ml $ha^{-1}$ was most effective insecticide for control of *L. erysimi* recording lowest pooled mean aphid population of 4.36, 3.85 and 2.83 aphids/10 cm on main apical shoot during *rabi*, 2017-18, 2018-19 and 2019-20. The maximum seed yield of 16.80 q $ha^{-1}$ was also recorded in dimethoate treated plot in mustard.

## 2.3. Dissipation Pattern and Residue Dynamics of Insecticides in Vegetables and Soil

### 2.3.1. Chlorantraniliprole

Chlorantraniliprole 20 SC when sprayed at 60 ml per 4200 $m^2$ recorded initial deposits of 2.308 mg $kg^{-1}$ which dissipated to 0.10 mg $kg^{-1}$ at 15 days after spray with half-life of 3.30 days in tomato while the residues in soil 4.55 mg $kg^{-1}$ dissipated to 0.165 mg $kg^{-1}$ by $15^{th}$ day with half-life of 3.66 days (Malhat *et al*., 2012).

Kar *et al.* (2013) reported that three applications of chlorantraniliprole on cauliflower at recommended dose (9.25 g *a.i.* $ha^{-1}$) and double the recommended dose (18.50 g *a.i.* $ha^{-1}$) resulted in average initial deposits of chlorantraniliprole *i.e* 0.18 and 0.29 mg $kg^{-1}$, respectively. The residues dissipated below the limit of quantification of 0.10 mg $kg^{-1}$ after 3 and 5 days at recommended and double the recommended doses, respectively. The half-life value (T1/2) of chlorantraniliprole was worked out to be 1.36 days.

Chlorantraniliprole when applied thrice at 10 days intervals @ 60 g *a.i.* $ha^{-1}$ in capsicum dissipated to below determination level (BDL) in 7 and 15 days under open field and polyhouse conditions, respectively (Pathipati *et al.,* 2017).

Reddy *et al.* (2017a) studied dissipation pattern of chlorantraniliprole 20 SC @ 30 g *a.i.* $ha^{-1}$ in chilli and revealed that the initial deposit of 0.56 mg $kg^{-1}$ chlorantraniliprole recorded at 2 hours after last spray dissipated to 0.06 mg $kg^{-1}$ at 5 days after last spray and to BDL by $7^{th}$ day.

Chlorantraniliprole when sprayed at two doses (0.2 and 0.4 ml $l^{-1}$) showed initial deposits of 0.81 and 2.00 mg $kg^{-1}$ in single dose and double doses, respectively in cabbage heads on 0 day (2 hrs after last spray) which reached BDL by $3^{rd}$ day showing 100 per cent dissipation of chlorantraniliprole at both the doses. Soil samples collected after 15 days of last spray, did not show the presence of chlorantraniliprole residue (Kabadad and Gali, 2018).

Persistence studies of chlorantraniliprole on chilli at recommended (30 g *a.i.* $ha^{-1}$) and double (60 g *a.i.* $ha^{-1}$) the recommended doses revealed that the initial deposits of 3.16 and 4.18 mg $kg^{-1}$ reached below LOQ at $10^{th}$ and $20^{th}$ day after last treatment with half-lives of 1.18 and 2.05 days, respectively (Ahlawat *et al.*, 2019).

Subbireddy *et al.* (2019) determined the persistence and dissipation of two insecticide mixtures indoxacarb 14.5% + acetamiprid 7.7% and chlorantraniliprole 9.3%+ lambda-cyhalothrin 4.6% ZC applied at 111 and 35 g *a.i.* $ha^{-1}$, respectively at fruit setting stage and reported that an initial deposit of 1.04 μg $g^{-1}$ of indoxacarb dissipated to and reached below its determination limit of 0.01 μg $g^{-1}$ on the $10^{th}$ day while acetamiprid reached BDL within 24 hours. In case of chlorantraniliprole and lambda cyhalothrin, the initial deposit of 0.08 and 0.06 μg $g^{-1}$ reached below its determination limit on $10^{th}$ and $3^{rd}$ day with a half-life value of 3.85 and 0.83 days, respectively.

Preethi *et al.* (2019) reported that the mean initial deposits of chlorantraniliprole after the second spray was 0.24 and 0.41 μg $g^{-1}$ at 10 g *a.i.* $ha^{-1}$ and 20 g *a.i.* $ha^{-1}$ doses and reached BDL of 0.05 μg $g^{-1}$ on $7^{th}$ and $10^{th}$ day after application. Dissipation of chlorantraniliprole followed first order reaction kinetics and the calculated half-lives were 2.29 to 2.53 days.

The average initial deposits of chlorantraniliprole in okra at recommended dose (25 g *a.i.* $ha^{-1}$) was 0.21 mg $kg^{-1}$ while in double the recommended dose (50 g *a.i.* $ha^{-1}$) it was 0.46 mg $kg^{-1}$. The initial residues were found to be below the MRL (0.3 mg $kg^{-1}$) in okra fruits which dissipated to below LOQ (0.03 mg $kg^{-1}$) after 7 days with half-life of 2.27 days and waiting period of zero days. The residues dissipated to below LOQ in 10 days in double the recommended dose with half-life of 2.45 days and waiting period of 1 day (Akanksha *et al.*, 2020).

### 2.3.2 Spinosad

Sharma *et al.* (2007) evaluated the persistence of spinosad in soil, cabbage and cauliflower at two application rates (17.5 and 35.0 g *a.i.* $ha^{-1}$) by high performance liquid chromatography and found that the initial deposits of 0.82, 2.97 and 2.66 mg $kg^{-1}$ at 17.5 g *a.i.* $ha^{-1}$ persisted up to 7 days in soil, cabbage and cauliflower, respectively.

However, at 35.0 g *a.i.* $ha^{-1}$, spinosad residues persisted up to 7 days in soil and 10 days in cabbage and cauliflower.

Mandal *et al.* (2009) estimated the residues of spinosad in cauliflower after three applications of spinosad at 15 and 30 g *a.i.* $ha^{-1}$. The average initial deposits of spinosad of 0.57 and 1.34 mg $kg^{-1}$ dissipated to below the limit of quantification (LOQ) of 0.02 mg $kg^{-1}$ after 10 days at both the doses, respectively. The half-life values of spinosad were worked out to be 1.20 and 1.58 days, respectively, at recommended and double the recommended doses. Thus, a waiting period of 6 days was suggested for the safe consumption of spinosad treated cauliflower.

The average initial deposits of spinosad of 0.33 at single (15 g *a.i.* $ha^{-1}$) and 0.56 mg $kg^{-1}$ at double doses (30 g *a.i.* $ha^{-1}$) dissipated below its limit of quantification of 0.01 mg $kg^{-1}$ after 5 and 7 days with half-lives of 1.4 and 1.5 at single and double doses, respectively (Singh and Battu, 2012).

Pathipati *et al.* (2018) reported that spinosad 45 SC when sprayed @ 125 ml $ha^{-1}$ thrice in poly house, the initial deposits of 1.61 mg $kg^{-1}$ dissipated to BDL in 20 days.

Akbar *et al.* (2020) studied the biological degradation of spinosad when sprayed at 35.5 g *a.i.* $ha^{-1}$ on cauliflower. The samples collected at 0,1,3 and 7 days showed initial deposits of 3.222 mg $kg^{-1}$ in leaves and 2.540 mg $kg^{-1}$ in cauliflower curd. Half-life value was 3.87 days both in the leaves and cauliflower curd.

### 2.3.3 Emamectin benzoate

Liu *et al.* (2012) observed the recoveries of emamectin benzoate on cabbage and soil from 71 per cent to 102 per cent at fortification levels of 0.01, 0.1 and 1.0 mg $kg^{-1}$. The reported limit of quantification (LOQ) was 0.01 mg $kg^{-1}$. The dissipation experiments showed the half-lives (T1/2) of emamectin benzoate as 1 day with pre-harvest intervals (PHI) of 7 and 12 days, in cabbage and soil, respectively.

The dissipation of emamectin benzoate was studied by Wang *et al.* (2012) who reported half-lives of 1.34-1.72, 2.75-3.09 and 1.89-4.89 days in cabbage, apple and soil, respectively. The final residues were 0.001 to 0.052 mg $kg^{-1}$ in cabbages, 0.003 to 0.090 mg $kg^{-1}$ in apples and 0.001 to 0.089 mg $kg^{-1}$ in soils.

Emamectin benzoate 5% SG when applied at the recommended dose (3 g *a.i.* ha$^{-1}$) in tomato dissipated to below MRL 10 days after treatment with a half live of approximately 2.5 days (Malhat *et al.,* 2013).

Singh *et al.* (2013) reported that emamectin benzoate 5% SG when applied at 8.5 and 17 g *a.i.* ha$^{-1}$ during the head initiation stage in cabbage showed initial deposits of 0.11 and 0.21 mg kg$^{-1}$ which dissipated to below the determination limit of 0.05 mg kg$^{-1}$ in 3 and 5 days, respectively.

Chahil *et al.* (2014) reported average initial deposits of 0.22 and 0.30 mg kg$^{-1}$ after taking up four sprays of emamectin benzoate @ 8.5 and 17 g *a.i.* ha$^{-1}$ at 10 days interval in cauliflower which dissipated to below LOQ of 0.05 mg kg$^{-1}$ in 5 and 7 days with half lives of 1.72 and 2.26 days, respectively.

Vijayasree *et al.* (2014) studied the dissipation kinetics of emamectin benzoate in cowpea fruits at single and double doses of 11.0 and 22 g *a.i.* ha$^{-1}$, respectively. The initial deposit of 0.073 and 0.153 mg kg$^{-1}$ of emamectin benzoate dissipated below quantitation level on the fifth and seventh day with half-life of 1.13 and 1.49 days and safe waiting period of 2.99 and 6.12 days at single and double dose, respectively.

Jyot *et al.* (2014) studied the dissipation pattern of emamectin benzoate in okra when applied at 68.1 and 136.2 g *a.i.* ha$^{-1}$. The average initial deposits of emamectin benzoate observed were 0.22 and 0.42 mg kg$^{-1}$, respectively which dissipated to below the limit of quantification (LOQ) of 0.05 mg kg$^{-1}$ after 5 days at both the doses.

Dong *et al.* (2015) evaluated the dissipation rate of emamectin benzoate and lufenuron in cabbage and soil at different pre-harvest intervals (PHI). The half-lives of emamectin benzoate and lufenuron were 1.08-2.70 and 1.74-5.04 days in cabbage, and 1.42-4.01 and 0.94-6.18 days in soil, respectively. The residues were below MRL on the 3$^{rd}$ day for emamectin benzoate (0.1 mg kg$^{-1}$) and 5$^{th}$ day for lufenuron (0.5 mg kg$^{-1}$) suggesting 5 days PHI for the commercial formulation of emamectin benzoate and lufenuron application in the chinese cabbage.

Emamectin benzoate when sprayed at 10 g *a.i* ha$^{-1}$ and 20 g *a.i* ha$^{-1}$ twice in brinjal recorded mean initial deposit of 0.359 and 0.550 µg g$^{-1}$, which dissipated to below detectable limit (BDL $< 0.05$ µg g$^{-1}$) on 5 and 7 days after treatment with half-life of 1.53 and 1.57 days, respectively. More than 80 per cent of emamectin benzoate residues got dissipated 3 days after treatment (Vinothkumar *et al.,* 2018).

### 2.3.4 Indoxacarb

Persistence of indoxacarb residues in tomato and of thiamethoxam residues in okra were studied following foliar application of indoxacarb and thiamethoxam. The residues of indoxacarb (0.5 and 1.0 ml $l^{-1}$) and thiamethoxam (0.2 and 0.4 g $l^{-1}$) dissipated to below detectable limits within 7-10 days after their last application in tomato. The half-lives were 1.1 to 1.5 days and pre harvest intervals of 1 day was calculated on the basis of respective MRL values (Sharma and Mahapatra, 2005).

Gupta *et al.* (2009) conducted studies on persistence and efficacy of bifenthrin (25 and 50 g *a.i.* $ha^{-1}$), fipronil (50 and 100 g *a.i.* $ha^{-1}$) and indoxacarb (70 and 140 g *a.i.* $ha^{-1}$) in okra fruits and reported that the residues persisted up to 10 days with half-lives of 1.32-1.58, 0.65-1.12 and 0.58-1.02 days, respectively. Based on ADI, one day for bifenthrin and indoxacarb, and 3 days for fipronil were suggested as waiting period. Sinha *et al.* (2010) reported initial deposits of indoxacarb residues of 0.11 and 0.21 mg $kg^{-1}$ in brinjal following the application @ 70 and 140 g *a.i.* $ha^{-1}$.

Indoxacarb 14.5 SC was applied at recommended (52.2 g *a.i.* $ha^{-1}$) and double the recommended dose (104.4 g. *a.i.* $ha^{-1}$) thrice at 10 days interval during curd initiation stage in cauliflower. It was found that the average initial deposits of 0.23 and 0.45 mg $kg^{-1}$ dissipated to below its LOQ of 0.01 mg $kg^{-1}$ after 7 days with half-lives of 1.12 and 1.31 days, respectively, at single and double the doses (Takkar *et al.,* 2011).

Indoxacarb when applied at two doses (52.2 and 104.4 g *a.i.* $ha^{-1}$) showed an average initial deposit of 0.18 and 0.39 mg $kg^{-1}$ which dissipated to less than its LOQ of 0.01 mg $kg^{-1}$ after 7 and 10 days with 2.88 and 1.92 days half-lives, respectively in cabbage (Urvashi *et al*., 2012).

Saimandir and Gopal (2012) reported that the mean initial deposits of indoxacarb on brinjal fruits were 2.60 to 3.64 mg $kg^{-1}$ and 2.63 to 3.68 mg $kg^{-1}$ when applied at two doses *i.e.* 75 and 150 g *a.i.* $ha^{-1}$ during first and second year studies, respectively. The residues declined with time and reached non-detectable level (<0.02 mg $kg^{-1}$) after 15-20 days with half-life of 3.0-3.8 days from both first and second year sprays. There was no significant difference in dissipation pattern between the two rates of applications suggesting that the dissipation of indoxacarb was independent of the dose of insecticide.

The biological half-life and final residue levels of indoxacarb and pyridalyl were determined in cauliflower over a 10-day cultivation period following applications of a standard dose (100 g *a.i.* $ha^{-1}$ and 200 g *a.i.* $ha^{-1}$, respectively) and double dose (200 g *a.i.* $ha^{-1}$ and 400 g *a.i.* $ha^{-1}$, respectively). The biological half-lives of indoxacarb and pyridalyl were 6.33 and 7.74 days for the standard dose, and 6.26 and 7.44 days for the double dose, respectively (Yoon *et al.*, 2013).

Sharma *et al.* (2018) carried out persistence studies of imidacloprid (0.018%), indoxacarb (0.015%) and lambda-cyhalothrin (0.004%) after single spray on tomato under protected conditions. The initial deposits of imidacloprid, indoxacarb and lambda-cyhalothrin dissipated to below detectable limits on $10^{th}$ day of application with half-life values of 2.91, 5.26 and 3.06 days, respectively.

Anita *et al.* (2019) conducted persistence studies of indoxacarb at two doses *i.e.* 37.13 and 74.26 g *a.i.* $ha^{-1}$ on tomato and revealed that the residues of indoxacarb reached below MRL value of 0.05 mg $kg^{-1}$ on $10^{th}$ and $15^{th}$ day at both the doses with half-lives of 2.37 and 2.48 in single and double doses, respectively.

**2.3.5 Diafenthiuron**

Keum *et al.* (2002) reported that the initial concentrations of diafenthiuron in whole Chinese cabbage leaves after application were 4.61 and 27.03 mg $kg^{-1}$ in plots A (1 g *a.i.* per 1000 $m^2$) and B (10 g *a.i.* per 1000 $m^2$), respectively and they decreased rapidly at a similar rate.

Stanley *et al.* (2014) reported initial deposits of 3.82 and 4.10 µg $g^{-1}$ of diafenthiuron when applied at 400 g *a.i.* $ha^{-1}$ in first and second field trials on green cardamom capsules while higher deposits of 6.61 and 7.32 µg $g^{-1}$ were found at double dose (800 g *a.i.* $ha^{-1}$). The residues dissipated to BDL by $10^{th}$ day with half-life of 2-2.8 days and a waiting period of 5.5-6.7 days in green capsules of cardamom was suggested.

The half-lives of diafenthiuron in packhoi and soil were 1.27 and 5.94 day, respectively. The final residue levels of diafenthiuron could not be detected in soil, while only trace amount of diafenthiuron residues were detected in pakchoi. The limit of quantification (LOQ) of method was 0.02 mg $kg^{-1}$ for packhoi and soil (Wang *et al*., 2011).

Dissipation studies on diafenthiuron when applied at 1 g $l^{-1}$ (225 g *a.i.* $ha^{-1}$) and 2 g $l^{-1}$ (450 g *a.i.* $ha^{-1}$) on chilli revealed that initial deposits of diafenthiuron in chilli fruits from the two treatments were 0.684 and 1.168 mg $kg^{-1}$, respectively which dissipated to below the detectable level on the seventh day in both the doses. The half-life calculated was 1.35 and 2.40 days at recommended and double the recommended dose, respectively with a waiting period of 9.76 and 11.31 days being suggested for diafenthiuron on chilli from consumer safety point of view (Anusha *et al.*, 2018).

### 2.3.6 Chlorpyriphos

Raina and Raina (2008) studied the dissipation pattern of chlorpyriphos in cauliflower at recommended (500 g *a.i.* $ha^{-1}$) and double dose (1000 g *a.i.* ha $^{-1}$) and reported that the average initial deposits varied from 0.56-0.86 and 1.29-1.43 mg $kg^{-1}$, respectively. The residual half-life of chlorpyriphos ranged from 1.4-1.5 and 1.5-1.6 days for lower and higher dose, respectively. The residues reached below the MRL of 0.05 mg $kg^{-1}$ in 5.0-6.3 and 7.1-7.3 days at normal and double dose, respectively.

Lu *et al.* (2014) studied the residue behavior of chlorpyriphos in six vegetable crops under greenhouse conditions at vegetative stage after foliar spray with chlorpyriphos 40 EC @ 0.97 kg *a.i.* $ha^{-1}$. The initial deposits of chlorpyrifos showed differences among the six selected vegetable plants, ranging from 16.5±0.9 mg $kg^{-1}$ (*Brassica chinensis*) to 74.0±5.9 mg $kg^{-1}$ (pepper plant). At pre-harvest interval of 21 days, the chlorpyrifos residues in edible parts of the crops were $<0.01$ (eggplant fruit), $<0.01$ (pepper fruit), 0.56 (lettuce), 0.97 (*Brassica chinensis*), 1.47 (asparagus lettuce), and 3.50 mg $kg^{-1}$ (celery). The half-lives of chlorpyrifos were found to be 7.79 (soil), 2.64 (pepper plants), 3.90 (asparagus lettuce), 3.92 (lettuce), 5.81 (*Brassica chinensis*), 3.00 (eggplant plant), and 5.45 days (celery). The dissipation of chlorpyriphos in soil and the six selected plants was different, indicating that the persistence of chlorpyrifos residues strongly depended upon leaf characteristics of the selected vegetables.

Gupta *et al.* (2015) studied the persistence behavior of insecticides chlorpyriphos, profenofos, triazophos, cypermethrin, and deltamethrin in cabbage at the recommended and double doses and found that the residues of different insecticides persisted for 5–8 days at low dose and 8–12 days at high dose. The residues dissipated with time and 87–100 per cent dissipation was recorded on the 8$^{th}$ day. The half-life values varied from 0.4 to 1.6 days.

Antonious *et al.* (2017) investigated the persistence of chlorpyrifos and its metabolites when sprayed at 946.4 ml per acre in kale and collard leaves. The initial deposits of chlorpyrifos were higher on collard (14.5 µg $g^{-1}$) than kale (8.2 µg $g^{-1}$) with half-lives of 7.4 and 2.2 days, respectively.

Katna *et al.* (2018) investigated the persistence of chlorpyrifos and a combination fungicide fluopyram + tebuconazole (Luna experience, 400 SC) in French beans after three foliar applications at 600 and 125 + 125 a.i. $ha^{-1}$ (standard dose) and 1200 and 250 + 250 g a.i. $ha^{-1}$ (double dose) at an interval of 10 days. The initial deposits of chlorpyriphos on bean pods were 3.083 and 6.017 mg $kg^{-1}$ with a half-life of 1.86 and 2.29 days, at respective doses. In case of fluopyram, the initial deposits of 3.396 and 5.772 mg $kg^{-1}$ were recorded while for tebuconazole the initial residues were 3.613 and 5.887 mg $kg^{-1}$ in green pods at standard and double dose with almost same half-lives of 3.4 and 3.8–3.9 days. Residues declined below the limit of quantitation (LOQ) of 0.05 mg $kg^{-1}$ in green beans after 15 and 25 days after the application of double dose of chlorpyrifos and Luna experience, respectively.

Chillies when sprayed with chlorpyriphos 20 EC @ 200 g *a.i.* $ha^{-1}$ and 400 g *a.i.* $ha^{-1}$ twice at 15 days interval showed an initial deposits of 3.47 and 5.12 µg $g^{-1}$ which dissipated to 97.34 and 95.99 per cent, respectively after 7 days of second application. The half-lives and safe waiting periods were 1.41 and 6.17 days at recommended dose and 1.65 and 8.23 days at double the recommended dose (Vinothkumar *et al.*, 2019).

### 2.3.7. Dimethoate

Pandey *et al.* (2004) conducted dissipation studies of dimethoate 35 EC on cabbage at two doses (1.5 and 2.5 ml $l^{-1}$). The samples collected at regular intervals after second spray showed that the initial deposits of 2.46 in normal dose (1.5 ml $l^{-1}$) dissipated to 0.01 mg $kg^{-1}$ by 30 days with half-life of 4.59 days while the initial deposits of 4.89 mg $kg^{-1}$ in higher doses dissipated to 0.04 mg $kg^{-1}$ by 30 days with half live of 4.50 days.

Dissipation of three insecticides *viz*,. dimethoate 30 EC (300 g *a.i.* $ha^{-1}$), ethion 50 EC (375 g *a.i.* $ha^{-1}$) and oxydemeton-methyl 25 EC (500 g *a.i.* $ha^{-1}$) were estimated on chilli. The studies revealed that all the three insecticides persisted up to fifteen days and reached BDL by 20$^{th}$ day with half-lives of 1.94, 3.43 and 4 days and waiting periods of 13.63, 28 and 7 days for dimethoate, ethion and oxydemeton methyl, respectively on chilli (Thania *et al*., 2011).

Sharma and Parihar (2013) reported that the initial deposit of dimethoate on chillies sprayed at 300 and 600 g *a.i.* $ha^{-1}$ was 3.12 and 5.16 mg $kg^{-1}$ with half-lives of 1.74 and 1.51 days and waiting periods of 3.29 and 4.50 days, respectively. In case of ethion sprayed at 500 and 1000 g *a.i.* $ha^{-1}$, initial deposits were 2.40 and 4.84 mg $kg^{-1}$ respectively with half-lives of 1.81 and 2.32 days and waiting periods 2.65 and 5.63 days, respectively. Red chilli powder did not carry residues of dimethoate and ethion.

The dissipation pattern of dimethoate 30 EC @ 300 g *a.i* $ha^{-1}$ was studied on chilli by Reddy *et al*. (2017b). Three sprays were taken up and samples collected after last spray revealed that dimethoate dissipated to below determination level (BDL) by 15$^{th}$ day after last spray.

Gopalakrishnan *et al.* (2018) reported that dimethoate when sprayed at 200 and 400 g *a.i* $ha^{-1}$ at 10 days interval, the mean initial deposit (1 hr after spraying) of 7.25 μg $g^{-1}$ and 19.51 μg $g^{-1}$ for foxtail amaranthus and 18.37 μg $g^{-1}$ and 29.46 μg $g^{-1}$ for spinach, respectively reached below detectable level of $< 0.05$ μg $g^{-1}$ at 10 days after treatment in foxtail amaranthus and 15 and 20 DAT in spinach for both doses. Half-life of dimethoate residues were 0.85 and 0.86 days in foxtail amaranthus; 2.22 and 1.12 days in spinach at 200 and 400 g *a.i* $ha^{-1}$, respectively.

## 2.4. Decontamination of Insecticide Residues in Vegetables

Yuan *et al.* (2009) reported that washing was the most effective means of removing pesticide residues and minimizing dietary intakes from cabbage. Satpathy *et al.* (2012) evaluated the effect of household processing like washing with water and other solutions like NaCl (0.9%), $NaHCO_3$ (0.1%), acetic acid (0.1%), $KMnO_4$ (0.001%), ascorbic acid (0.1%) malic acid (0.1%) and oxalic acid (0.1%) and boiling on removal of organophosphate residues (malathion, fenitrothion, formothion, parathion, methyl parathion and chlorpyriphos) in tomato, bean, okra, eggplant, cauliflower and capsicum. It was observed that washing with different house hold chemicals reduced the residues by 20-89 per cent and boiling reduced the residues by 52-100 per cent. Boiling of vegetables was found to be more effective than washing in dislodging the residues.

Sheikh *et al.* (2012) revealed that imidacloprid residues were reduced by 73 per cent by detergent washing and the residues of emamectin benzoate residues which were high in unwashed okra (0.51 ppm) were reduced to below MRL (0.2 ppm) by detergent washing and subsequent processing by frying, thermal dehydration or sun-drying.

Panhwar and Sheikh (2013) reported that plain water washing reduced fat soluble residues of bifenthrin, endosulphan and profenofos in cauliflower by 25, 28.1 and 14.32 per cent, respectively. Degree of reduction in plain water washing on water soluble pesticides namely diafenthiuron, imidacloprid in cauliflower were 40.69, 39.07 and 21.17 per cent, respectively.

Liang *et al.* (2012) evaluated the effect of NaCl at different concentrations (2% and 5%) at different time period of treatment in the removal of pesticide residues of trichlorfon, dimethoate, dichlorvos, fenitrothion and chlorpyrifos in raw cucumber and results indicated that washing of cucumber with NaCl solution (5%) for 20 min proved to be effective, showing 65.8, 65.2, 77.4, 51.1 and 69 per cent reduction in the above pesticides, respectively.

Kar *et al.* (2012) evaluated the effect of decontamination methods for removal of the residues of chlorantraniliprole on cabbage and cauliflower and reported that washing of cabbage and cauliflower with tap water removed about 17-40 per cent of chlorantraniliprole residues while boiling removed 100 per cent of chlorantraniliprole residues on both cabbage and cauliflower in both the cases. The effects of household processing on pesticide residues in cauliflower revealed that washing; boiling and cooking process minimized the residues of nine pesticides in the range of 3.32- 70.0, 21.08-70.67 and 31.63-85.30 per cent respectively (Thanki *et al*., 2012).

Zhang *et al*. (2013) reported that dipping chinese cabbage in 5 per cent soda salt solution for 10 min followed by tap water wash for 1 min reduced the residues of dimethoate and dicofol to an extent of 32.20 and 26.90 per cent, respectively. Yu-shan *et al.* (2013) found that soda salts had good removal effect on mixed pesticide residues of dimethoate, dicofol and cyhalothrin with 32.5, 26.9 and 44.4 per cent removal of the above pesticides, respectively.

Vemuri *et al.* (2014) evaluated traditional processing methods for removal of pesticide residues in tomato. In the process of washing under running tap water, dimethoate residues were reduced up to 48 per cent while direct cooking reduced up to 56.41 per cent and washing with salt water (2%) up to 78 per cent. By processing with salt water (2%) plus cooking the entire residues from the tomato sample were removed up to 99 per cent.

Rao *et al.* (2014) reported that washing under running tap water reduced the residues of chlorpyriphos and dimethoate by 35.30 and 30.7 per cent whereas direct cooking led to reduction of 64 per cent of dimethoate and 45.9 per cent of chlorpyriphos residues. Washing with salt water solution (2%) lead to reduction of 45.30 and 43 per cent residues of dimethoate and chlorpyriphos in brinjal.

Vijayasree *et al.* (2014) conducted decontamination for reduction of emamectin benzoate and spinosad residues and found that slaked lime 2%, tamarind 2% and scrubbing treatments lead to complete removal of emamectin benzoate residues while 87.46, 83.5 and 84.49 per cent of spinosad residues were removed by the above treatments, respectively.

Chandra *et al.* (2015) investigated the effects of household processing on removal of organophosphate (chlorpyrifos and monocrotophos) and pyrethroid (cypermethrin) residues in brinjal and okra which included washing separately with water, NaCl (2.0 %), $NaHCO_3$ (1.0 %), acetic acid (0.5 %) and boiling in water. In the household processing of brinjal, residues of chlorpyrifos, cypermethrin and monocrotophos reduced by 29.5-99.2, 30.2-92.1 and 65.6-99.7 per cent, respectively. Whereas in okra, residues of chlorpyrifos, cypermethrin and monocrotophos were reduced by 24.5-98.9, 27.2-92.2 and 62.4-99.5 per cent, respectively. Maximum residues were reduced by boiling (99.7%). Washing under running tap water reduced residues of dimethoate up to 48% whereas direct cooking reduced up to 56.41 per cent while washing with 2 per cent salt water reduced to an extent of 78 per cent. By processing with 2 per cent salt water plus cooking lead to a reduction of 99 per cent of dimethoate residues in brinjal (Vemuri *et al.,* 2015).

Nowowi *et al.* (2016) investigated the effectiveness of several cleaning solutions in removing pesticide residues of chlorpyriphos in cauliflower. Tamarind juice solution showed highest removal rate of 93.04 per cent followed by filtered flour solution

(17.03%) and vinegar solution (11.42%). Begum *et al.* (2016) reported that dipping in salt water solution (2 %) for 15 minutes followed by washing under tap water plus cooking was found to be more effective in reducing all pesticides tested (diazinon, malathion, fenitrothion, quinalphos and chloropyrifos) when compared with other treatments as it resulted in reduction of chlorpyriphos residues up to 72 per cent in brinjal and 32 per cent in chilli.

Banshtu and Patyal (2018) evaluated the efficacy of various decontamination processes on reduction of chlorpyriphos and cypermethrin residues in cauliflower. Washing reduced 37.41 and 40.10 per cent of chlorpyriphos and cypermethrin residues in zero-day samples while cooking resulted in reduction of chlorpyriphos residues up to 36.58-58.95 per cent and cypermethrin residues by 45.45-66.31 per cent. Washing with various chemical solutions (2% NaOH and 0.05% HCl) lead to reduction of 58.53 to 69.03 of both the residues while highest reduction was obtained in washing plus cooking wherein 70 per cent residues were efficiently removed.

Brar *et al.* (2018) reported that washing with tap water, NaCl (2%) and lukewarm water were effective in removal of chlorpyrifos and ethion up to 36.17, 45.74 and 48.63 per cent in brinjal. However, open pan and microwave cooking were found most effective (up to 70.06%) in removing insecticide residues. The residues of indoxacarb were found to be reduced by 87 to 89 per cent by peeling while other household processing methods like washing and washing plus boiling reduced the residues up to 53.96-54.87 and 71.42-73.17 per cent, 0 days after spraying in tomato (Anita *et al.*, 2018).

Athulya *et al.* (2019) reported that washing reduced the residues up to 80.76-85 per cent in brinjal while 66.66-74.8 per cent in cabbage. Boiling and removal of outer leaves in cabbage reduced the residues up to 100 per cent. Washing with sodium chloride (5%) was found most effective showing maximum reduction (62.02 and 67.94 %) followed by washing with hot water (59.40-58.54 %) and simple tap water wash (53.79-50.80 %) in zero-day samples of chilli treated with chlorantraniliprole at recommended (30 g *a.i.* $ha^{-1}$) and double (60 g *a.i.* $ha^{-1}$) the recommended doses as reported by Ahlawat *et al.* (2019).

# Chapter III

# MATERIAL AND METHODS

The present investigation on **"Seasonal incidence of insect pests, bioefficacy and dissipation pattern of selected insecticides in cauliflower"** was carried out during ***rabi*, 2018-19 and 2019-20.** The field trials were laid out at College farm, College of Agriculture, Rajendranagar, Hyderabad, Telangana. The experimental site is situated at an altitude of 542.3 m above mean sea level with $17°19^1$ N latitude and 78° $25^1$ E longitude and it falls under semi-arid tropical climate. The residue analysis for dissipation and decontamination studies were carried out at Pesticide Residues Laboratory, AINP on Pesticide Residues, PJTSAU, Rajendranagar, Hyderabad.

The material used and methods followed in pursuit of the present study are presented hereunder in detail.

## 3.1 Raising of Cauliflower Nursery

For all the experiments planned, cauliflower seedlings of var. Dhaval 043 $F_1$ were raised in a nursery at the Horticultural Garden, College of Agriculture, Rajendranagar. Raised nursery beds were prepared by adding 30 kg Farm Yard Manure (FYM), 5 kg neem cake and 5 kg SSP to the soil, mixed thoroughly and the beds levelled. The seed was sown in shallow furrows made across the bed and covered with a layer of vermicompost, watered and mulched with mulberry leaves (Plate 3.1). Based on the requirement, the bed was watered once in two days. The sowings were done on 17.09.2018 and 20.09.2019 for the years 2018-19 and 2019-20, respectively. Germination was observed within 5 days of sowing.

## 3.2 Seasonal Incidence of Insect Pests in Cauliflower and Correlation with Weather Factors

### 3.2.1 Preparatory Cultivation in Main Field

The soil in the experimental block was red soil. The field was ploughed three times using a tractor drawn cultivator, and then it was levelled thoroughly after removal of stubbles, trash and weeds. During the last ploughing, FYM was applied @ 8 t $ha^{-1}$. Furrows were formed at a spacing of 45 cm with irrigation channels at every 5 m across the furrows. About 5 t $ha^{-1}$ of vermicompost was applied after removal of stubbles and before formation of ridges and furrows.

**a. Preparation of raised nursery beds**

**b. Sowing of seed**

**c. Germination of seeds**

**d. Seedlings ready for transplantation**

**Plate 3.1. Raising of cauliflower nursery**

### 3.2.2 Transplanting

The cauliflower seedlings were transplanted on 20.10.2018 and 30.10.2019 at a spacing of 60 cm x 45 cm as bulk in an area of 20 m x 10 m. Pesticides were not applied to this experimental plot (Plate 3.2).

### 3.2.3 Irrigation

The plot was adequately irrigated before and after transplanting and at 7-10 days interval throughout the crop period.

### 3.2.4 Intercultivation

Recommended fertilizer doses of nitrogen @ 80 kg $ha^{-1}$, phosphorous @ 150 kg $ha^{-1}$ and potassium @ 100 kg $ha^{-1}$were applied in the form of urea, single super phosphate (SSP) and murate of potash (MOP), respectively. Urea was applied in three equal splits, one as basal and as pocket application at seedling and curd initiation stages of the crop. MOP was applied in two splits as basal and at curd initiation stage along with nitrogen while phosphorous was applied at the time of transplanting as basal as per the Good Agricultural Practices (PJTSAU, 2018). The crop was kept free from weeds by hand weeding during the critical growth stages and was well managed throughout the period of experiment.

### 3.2.5 Observations Recorded on Insect Pests

The plot was divided into 5 quadrants of 40 sq. m. representing five replicates. Ten plants from each quadrant were randomly selected. Observations on incidence of insect pests and their natural enemies were recorded at weekly intervals starting from 14 days after transplanting following the standard procedure (Plate 3.3 and 3.4).

**Aphids**: Number of aphids per 3 leaves per plant.

**Painted bug:** Number of bugs per plant

**Leaf webber, diamondback moth and tobacco caterpillar:** Number of larvae per plant

**Head borer:** Total number of infested curds per 50 curds

**Lady bird beetle:** Number of grubs and adults per plant

**Syrphids:** Number of syrphid maggots per plant

**a. Field preparation**

**b. Transplanting**

**c. Transplanted crop**

**Plate 3.2. Main field preparation and transplanting**


**Leaf webber – *Crocidolomia binotalis* and its damage on leaves**


**Diamondback moth – *Plutella xylostella*** **Tobacco caterpillar – *Spodoptera litura***


**Head borer (*Hellula undalis*) damage in cauliflower curds**

**Plate 3.3. Incidence of lepidopteran insect pests in cauliflower**

**Aphids-*Lipaphis erysimi***

**Painted bug-*Bagrada cruciferarum***

**Coccinellids**

**Syrphids**

**Plate 3.4. Sucking pests (aphids and bugs) and natural enemies (coccinellids and syrphids) incidence in cauliflower**

### 3.2.6 Correlation of Incidence of Insect Pests with Abiotic Factors

The data on weather parameters *viz.*, maximum and minimum temperature ($^0$C), maximum and minimum relative humidity (%), rainfall (mm) and sunshine (hrs) collected from the Agro Climatic Research Centre, PJTSAU, Rajendranagar and the data obtained on the seasonal incidence of insect pests of cauliflower and their natural enemy complex were subjected to correlation and multiple regression by using the following formula

$$\text{Correlation 'r'} = \frac{\sum xy - \frac{\sum x . \sum y}{n}}{\sqrt{\left\{\sum x^2 - \frac{(\sum x)^2}{n}\right\}\left\{\sum y^2 - \frac{(\sum y)^2}{n}\right\}}}$$

Where,

r = Simple correlation coefficient

x = Independent variable *i.e.* abiotic component

y = Dependent variable *i.e.* mean number of insect pests

n = Number of observations

Test of significance of correlation coefficient

$$t = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{n-2}$$

Where,

The value of 't' is based on (n-2) degrees of freedom.

n = the number of sets of observations

r = correlation coefficient

Besides, correlation, multiple linear regression equation was also fitted for the insect pests and natural enemies using the following formula as given here under.

$$\mathbf{Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9}$$

Where,

a = Constant

Y = Dependent variable

$X_1$, $X_2$, $X_3$, $X_4$ $X_5$, $X_6$, $X_7$, $X_8$ and $X_9$ = Independent variables

$b_1$, $b_2$, $b_3$, $b_4$, $b_5$, $b_6$, $b_7$, $b_8$ and $b_9$= Partial regression co-efficient

The correlation and multiple regression was done using the software from Indostat Services, Hyderabad at University Computer Centre, PJTSAU. Principal component analysis for major insect pests was carried out using R software (IBM SPSS, 2017; R core team, 2017).

## 3.3 Bioefficacy of Selected Insecticides against Insect Pest Complex in Cauliflower

For conducting bioefficacy studies, the seedlings were transplanted at 60 cm x 45 cm spacing in 5m x 4m plots on ridges and furrows. The experimental design was randomized complete block design (RCBD) consisting of eight treatments in three replications (Figure 3.1 and Plate 3.5). All the recommended agronomic practices as discussed in 3.2. were followed.

### 3.3.1 Test Insecticides

Insecticides belonging to different groups were selected for determining their bioefficacy against insect pests in cauliflower. The details of the insecticides used in the study along with their concentration and source of supply are presented in Table 3.1.

### 3.3.2. Insecticidal Application

Test insecticides were applied using a high-volume knapsack compression sprayer @ 500 l $ha^{-1}$. Sprayings were undertaken at curd initiation stage during morning to prevent the drift of spray fluid reaching the adjacent plots. In all the treatments, two sprayings were given during the course of investigation. First spraying was done at curd initiation stage when pest incidence was above ETL and second spraying was taken up 15 days after the first spray. The sprayer and the container used for preparing spray fluid were thoroughly washed before taking the next treatment.

### 3.3.3 Population Count

The observations on insect pests as followed for seasonal incidence studies were recorded one day before spraying as pre-treatment counts. Post treatment counts were recorded at 3, 5 and 7 days after each spraying. For the second spraying, data at 14 days after first spray was taken as pre count.

The per cent reduction of insect pests in different treatments over control at seven days after first and second spray was calculated by modified Abbot’s formula (Fleming and Retnakaran, 1985) as given below.

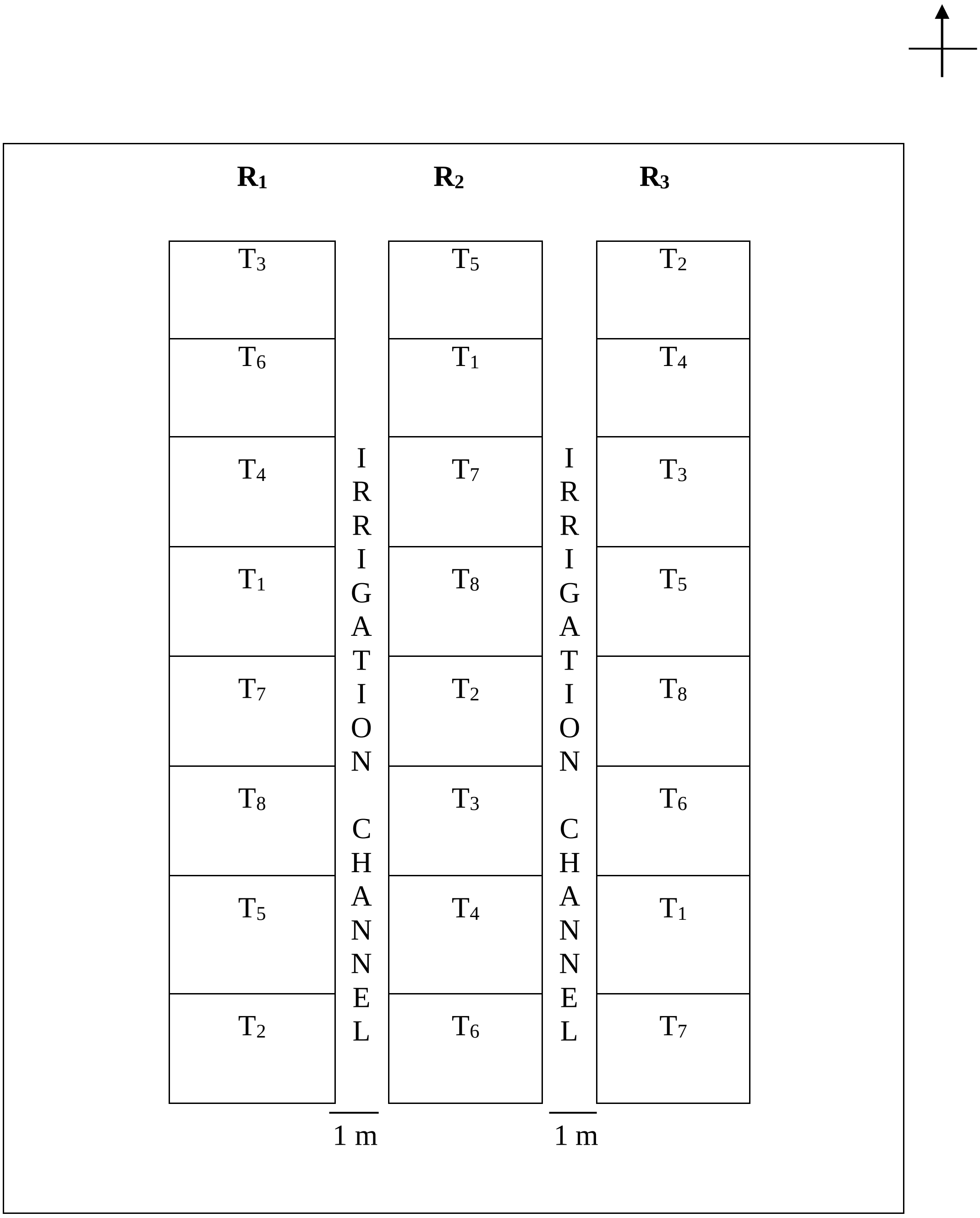



**Fig. 3.1. Layout of the experimental field for bioefficacy studies**

$T_1$: Chlorantraniliprole 18.5% SC
$T_2$: Spinosad 2.5% SC
$T_3$: Emamectin benzoate 5% SG
$T_4$: Indoxacarb 14.5% SC
$T_5$: Diafenthiuron 50% WP
$T_6$: Chlorpyriphos 50% EC
$T_7$: Dimethoate 30% EC
$T_8$: Control

**Table 3.1. Details of insecticides used in the present study**

| S. No | Technical name | Trade name | Formulation | Dose (g *a.i.* / ha.) | Dose (ml or g / l) | Group (IRAC) and mode of action | Firm Name |
|---|---|---|---|---|---|---|---|
| 1 | Chlorantraniliprole | Coragen | 18.5% SC | 10 | 0.1 | 28<br>Ryanodine receptor modulators | M/s FMC India Pvt Ltd |
| 2 | Spinosad | Success | 2.5% SC | 17.5 | 1.4 | 5<br>Nicotinic acetylcholine receptor (nAChR) allosteric modulators | M/s Dow Agro Sciences |
| 3 | Emamectin benzoate | Proclaim | 5% SG | 10 | 0.4 | 6<br>Glutamate-gated chloride channel (GluCl) allosteric modulators | M/s Syngenta India Ltd |
| 4 | Indoxacarb | King doxa | 14.5% SC | 40 | 0.55 | 22A<br>Voltage-dependent sodium channel blockers | M/s Gharda Chemicals |
| 5 | Diafenthiuron | Pegasus | 50% WP | 300 | 1.2 | 12<br>Inhibitors of mitochondrial ATP synthase | M/s Syngenta India Ltd |
| 6 | Chlorpyriphos | Lethal | 50% EC | 500 | 2 | 1 B<br>(Organophosphates) | M/s Insecticides India |
| 7 | Dimethoate | Tafgor | 30% EC | 200 | 1.3 | 1 B<br>(Organophosphates) | M/s Rallis India Ltd |


**a. Field view during *rabi*, 2018-19**


**b. Field view during *rabi*, 2019-20**

**Plate 3.5. Field view of the experimental plots**

Population reduction (%) =

$$[1-\left\{\frac{\text{Post}-\text{treatment population in treatment}}{\text{Pre}-\text{treatment population in treatment}}\right\} X \left\{\frac{\text{Pre}-\text{treatment population in control}}{\text{Post}-\text{treatment population in control}}\right\}] X100$$

The data on insect damage was taken at the time of harvest through counting of number of damaged heads to the total number of heads per plot and converted to per cent insect damage.

### 3.3.4 Yield

The yield on net plot basis was recorded separately for each plot and converted to hectare yield as follows:

$$\text{Yield (kg ha}^{-1}\text{)} = \frac{\text{Yield per plot}}{\text{Net area of plot}} \text{ X } 10{,}000$$

### 3.3.5 Statistical Analysis

The data from various experimental plots were analyzed following appropriate statistical methods (RBD) as suggested by Gomez and Gomez (1984). Data were transformed using square root transformation or angular transformation as required before statistical analysis.

## 3.4 Dissipation Pattern of Selected Insecticides in Cauliflower

Pesticide residue studies were conducted during 2019-20 to establish dissipation pattern of chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, diafenthiuron, chlorpyriphos and dimethoate in cauliflower. 1 kg curds were collected at regular intervals (0, 1, 3, 5, 7, 10, 15 and 20 days) after last spray from the bio-efficacy treatments and subjected to residue analysis on LC-MS/MS at Pesticide Residues Laboratory, PJTSAU, Rajendranagar, Hyderabad.

### 3.4.1 Chemicals and Reagents

Certified Reference Materials of insecticides (CRMs) (Dr. Ehrenstorfer and Sigma Aldrich, Germany) of purity levels {chlorantraniliprole-97.8 %, spinosad-93.6%, emamectin benzoate-96.5%, indoxacarb-98.4%, diafenthiuron-98.3%, chlorpyriphos-99.8% and dimethoate-99.3%} and all the analytical grade solvents and reagents *viz*., Acetonitrile (HPLC grade), n- Hexane (HPLC grade), sodium chloride (NaCl), anhydrous sodium sulphate ($Na_2SO_4$) and anhydrous magnesium sulphate ($MgSO_4$) (Merck India Pvt Ltd.,) primary secondary amine (59.6 µm particle size)

(PSA-Ethylene diamine N- propyl bonding with silica gel base) (Agilent Technologies) and LC-MS/MS grade Methanol, Acetonitrile and Water (JT Baker) were used for extraction, clean up and detection of pesticide residues.

### 3.4.2 Method Validation

The method adopted for analysis on LC-MS/MS was evaluated through linearity, LOD, LOQ, fortification, recovery studies, repeatability and reproducibility studies as per SANTE, 2017. Primary (500 µg $ml^{-1}$ or 500 ppm), intermediate (20 µg $ml^{-1}$ or 20 ppm) and working standard (1 µg $ml^{-1}$ or 1 ppm) were prepared for each of the selected insecticides from the Certified Reference Materials (CRMs) using methanol as solvent in 25 ml calibrated graduated volumetric flasks. All the standards were stored in deep freezer maintained at -20°C.

**3.4.2.1 Linearity Studies:** From the working standard (1 µg $ml^{-1}$), series of standards of concentrations 10, 20, 50, 100, 200 and 500 µg $l^{-1}$ (ppb) levels were prepared by diluting with methanol in calibrated volumetric flasks. Each concentration level was injected (1 µl) three times in LC-MS/MS.

**3.4.2.2 Determination of LOD (Limit of Detection) and LOQ (Limit of Quantification)**

LOD was calculated from the linearity calibration graph using the formula:

LOD= 3 x (Standard Deviation/Slope)

LOQ was calculated from the linearity calibration graph using the formula:

LOQ= 10 x (Standard Deviation/Slope)

**3.4.2.3 Fortification and Recovery Studies:** Prior to pesticide application and field sample analysis, the residue analysis method was validated following the SANTE document (11813/2017). For recovery studies, the control cauliflower samples from control plots were fortified at three fortification levels *viz*., LOQ level (0.05 µg $ml^{-1}$), 5 x LOQ (0.25 µg $ml^{-1}$) and 10 x LOQ (0.1 µg $ml^{-1}$) to know the suitability of the method to detect and quantify pesticides in cauliflower below Maximum Residue Limits (MRLs) of Codex Alimentarius Commission (CAC). For repeatability and reproducibility studies, spiking was done at 5 x LOQ (0.25 µg $ml^{-1}$) level on the same day for repeatability and next day for reproducibility and the accuracy of the analytical methods was determined based on relative standard deviation (Appendix C).

**Sample Preparation:** Control cauliflower sample (15 g) homogenized with robot coupe blixer was weighed in 50 ml centrifuge tube and calculated amount of the standard (1 µg $ml^{-1}$) was added to attain the required fortification levels of 0.05 µg $ml^{-1}$, 0.25µg $ml^{-1}$ and 0.1 µg $ml^{-1}$. Each fortification was replicated 3 times and the spiked samples were equilibrated for 30 minutes.

**Extraction**: To the 15 g fortified sample, 30±0.1 ml acetonitrile was added and the samples were homogenized at 14000-15000 rpm for 2-3 min using Heidolph silent crusher. 3±0.1 g sodium chloride was added and mixed by shaking gently followed by centrifugation for 3 min at 3000 rpm to separate the organic layer.

**Clean Up:** After centrifugation, the supernatant organic layer of about 16 ml was taken into the 50 ml centrifuge tube containing 9±0.1 g anhydrous sodium sulphate to remove the moisture content. 8 ml of extract was taken into 15 ml tube containing 0.4±0.01 g PSA sorbent (for dispersive solid phase d-SPE cleanup) and 1.2±0.01 g anhydrous magnesium sulphate. The sample tube was vortexed for 30 sec followed by centrifugation for 5 min at 5000 rpm. The extract of 1 ml acetonitrile was transferred into 2 ml vial by filtering through 0.22 µm PTFE syringe filter for residue analysis of respective insecticides on LC-MS/MS under standard operational conditions.

For matrix match standard preparation, the control cauliflower samples were reconstituted with known volumes of working standard solutions after cleanup process to obtain desired concentrations of 0.05 µg $ml^{-1}$, 0.25µg $ml^{-1}$ and 0.1 µg $ml^{-1}$.

### 3.4.2.4 Estimation of Insecticides by LC-MS/MS Analysis

The instrumentation used was Shimadzu LC-MS/MS-8040 mass spectrometer for quantification of insecticides. The method parameters adopted are given in the Tables 3.2 & 3.3.

**Table 3.2 Details of general operating parameters of LC-MS/MS for the analysis of selected insecticides**

| | |
|---|---|
| LC-MS/MS | SHIMADZU LC-MS/MS 8040. |
| Detector | Mass Spectrophotomultiplier |
| Column | KINETEX, C18, 2.6 µm particle size, 100 mm length, 3 mm ID |
| Column Oven temperature | 40°C |
| Nebulizing gas | Nitrogen |
| Nebulizing gas flow | 2.0 lit/min |
| Capillary Voltage | 6kV |
| Pump Mode/ flow | Gradient |
| Flow rate | 0.4mL/min |
| Injection Volume | 1 µL |
| DL temperature | 250°C |
| Heat Block temperature | 300°C |
| Software used | Shimadzu Lab Solutions Version 5.80 |

### 3.4.2.5 Calculation of Standard Peak Areas and Per cent Recovery

1 µl of matrix match standard and fortified sample were injected into LC-MS/MS. The residues of pesticides recovered from fortified samples were calculated using the following formula.

$$\text{Residues (mg kg}^{-1}\text{)} = \frac{\text{Peak area of sample (fortified) x Conc. of matrix match Std (ppm) x µl of matrix match Std. injected x Final volume of the fortified sample injected}}{\text{Standard Peak area x Weight of fortified sample analysed x µl of fortified sample injected}}$$

$$\text{Weight of the fortified sample analysed} = \frac{\text{Sample weight (15 g) x Aliquot taken}}{\text{Volume of Solvent (Acetonitrile-30 ml)}}$$

The area under the peak was integrated by Gaussian curve method using Shimadzu Lab Solutions Version 5.80 Software.

The per cent recovery and recovery factors were calculated using the following formulae:

$$\text{Per cent Recovery} = \frac{\text{Concentration of fortified sample}}{\text{Fortified Level}} \text{ X 100}$$

$$\text{Recovery Factor} = \frac{100}{\text{Per cent recovery}}$$

**Table 3.3. Details of specific parameters of LC-MS/MS for the analysis of selected insecticides**

| Pesticide | Mobile Phase | Total time programme | | MRM Transitions | | | Retention time (min) |
|---|---|---|---|---|---|---|---|
| | | Time (min) | % B | Precursor ion | Quantifier ion | Qualifier ion | |
| Chlorantraniliprole | A: 5mM Ammonium Formate in 80:20 $H_2O$: Methanol<br>B: 5mM Ammonium Formate in 90:10 Methanol: $H_2O$ | 0.01 | 60 | 481.90 | 283.80 | 450.85 | 2.342 min |
| | | 2.00 | 70 | | | | |
| | | 5.00 | 60 | | | | |
| | | 5.01 | Stop | | | | |
| Spinosad | A: 5mM Ammonium Formate in 80:20 $H_2O$: Methanol<br>B: 5mM Ammonium Formate in 90:10 Methanol: $H_2O$ | 0.01 | 95 | 746.4 | 142.15 | 98.15 | 3.93 min A<br>4.706 min D |
| | | 3.00 | 85 | | | | |
| | | 5.00 | 95 | | | | |
| | | 6.01 | Stop | | | | |
| Emamectin benzoate | A: 5 Mm Ammonium Formate in 80:20 Water: Methanol +0.1% Formic acid<br>B: 5 Mm Ammonium Formate in 90:10 Water: Methanol +0.1% Formic acid | 0.01 | 80 | 886.65 | 158 | 125.95<br>302.15 | 4.49 min |
| | | 2.00 | 95 | | | | |
| | | 4.00 | 95 | | | | |
| | | 6.00 | 80 | | | | |
| | | 8.00 | Stop | | | | |
| Indoxacarb | A: 5mM Ammonium Formate in 80:20 $H_2O$: Methanol<br>B: 5mM Ammonium Formate in 90:10 Methanol: $H_2O$ | 0.01 | 95 | 527.90 | 203 | 293 | 2.281 min |
| | | 3.00 | 85 | | | | |
| | | 5.00 | 95 | | | | |
| | | 5.01 | Stop | | | | |
| Diafenthiuron | A: 80:20 Acetonitrile: Water+0.5% Formic acid<br>B: 95:5 Acetonitrile: Water+0.5% Formic acid | 0.01 | 50 | 385.10 | 329.20 | 278.15<br>236.15 | 2. 267 min |
| | | 1.00 | 60 | | | | |
| | | 2.00 | 60 | | | | |
| | | 4.00 | 50 | | | | |
| | | 4.10 | Stop | | | | |
| Chlorpyriphos | A: 5mM Ammonium Formate in 80:20 $H_2O$: Methanol<br>B: 5mM Ammonium Formate in 90:10 Methanol: $H_2O$ | 0.01 | 35 | 351.9 | 96.8 | 199.8 | 10.739 min |
| | | 3.00 | 60 | | | | |
| | | 4.00 | 95 | | | | |
| | | 5.00 | 85 | | | | |
| | | 9.00 | 70 | | | | |
| | | 10.00 | 35 | | | | |
| | | 12.50 | 35 | | | | |
| | | 12.51 | Stop | | | | |
| Dimethoate | A: 5mM Ammonium Formate in 80:20 $H_2O$: Methanol<br>B: 5mM Ammonium Formate in 90:10 Methanol: $H_2O$ | 0.01 | 35 | 230 | 198.85 | 124.9 | 1.473 min |
| | | 2.00 | 35 | | | | |
| | | 3.00 | 60 | | | | |
| | | 4.00 | 60 | | | | |
| | | 4.50 | 35 | | | | |
| | | 5.00 | Stop | | | | |

### 3.4.3 Dissipation Pattern

Cauliflower curds (1 kg) were collected from individual treatments in all replications after two sprays, in labelled polybags. Care was taken to wear hand gloves to avoid contamination. Samples were collected at regular intervals *i.e.* 0 (2 hrs after last spray), 1, 3, 5, 7, 10, 15 and 20 days after last spray. The collected samples were then taken to the laboratory, processed immediately and stored at -4°C for further analysis.

**Sample Preparation:** The cauliflower curd samples collected at regular intervals from various treatments were homogenized with robot coupe blixer and subjected to the following process (Plate 3.6).

**Extraction:** The cauliflower samples were analyzed using AOAC official method, 2016 (QuEChERS method) and its modification described by Anastassiades *et al.* (2003) and Lehotay *et al.* (2005) for extraction and clean up after validation as per SANTE/11813/2017 guidelines.

Each sample (15±0.1 g) was taken in 50 ml centrifuge tube and 30±0.1 ml acetonitrile was added and the samples were homogenized at 14000-15000 rpm for 2-3 min using Heidolph silent crusher. To the samples, 3±0.1 g sodium chloride was added and mixed by shaking gently followed by centrifugation for 3 min at 3000 rpm to separate the organic layer (Plate 3.6).

After centrifugation, the supernatant organic layer of about 16 ml was taken into the 50 ml centrifuge tube and 9±0.1 g anhydrous sodium sulphate was added to remove the moisture content. 8 ml of extract was taken into 15 ml tube containing 0.4±0.01 g PSA sorbent (for dispersive solid phase d-SPE cleanup) and 1.2±0.01 g anhydrous magnesium sulphate. The sample tube was vortexed for 30 sec followed by centrifugation for 5 min at 5000 rpm. The extract of 1 ml acetonitrile was transferred into 2 ml vial by filtering through 0.22 µm PTFE syringe filter for residue analysis of respective insecticides on LC-MS/MS under standard operational conditions.

### 3.4.4 Calculation of Residues, Dissipation Per cent, PHI and Half-life:

The standard peak areas obtained from the chromatograms of the samples collected at (2 hrs) 0, 1, 3, 5, 7, 10, 15, 20 and 25 days after final spray were analyzed for residues following the validated methods. Residues in mg $kg^{-1}$ were calculated using the formula given

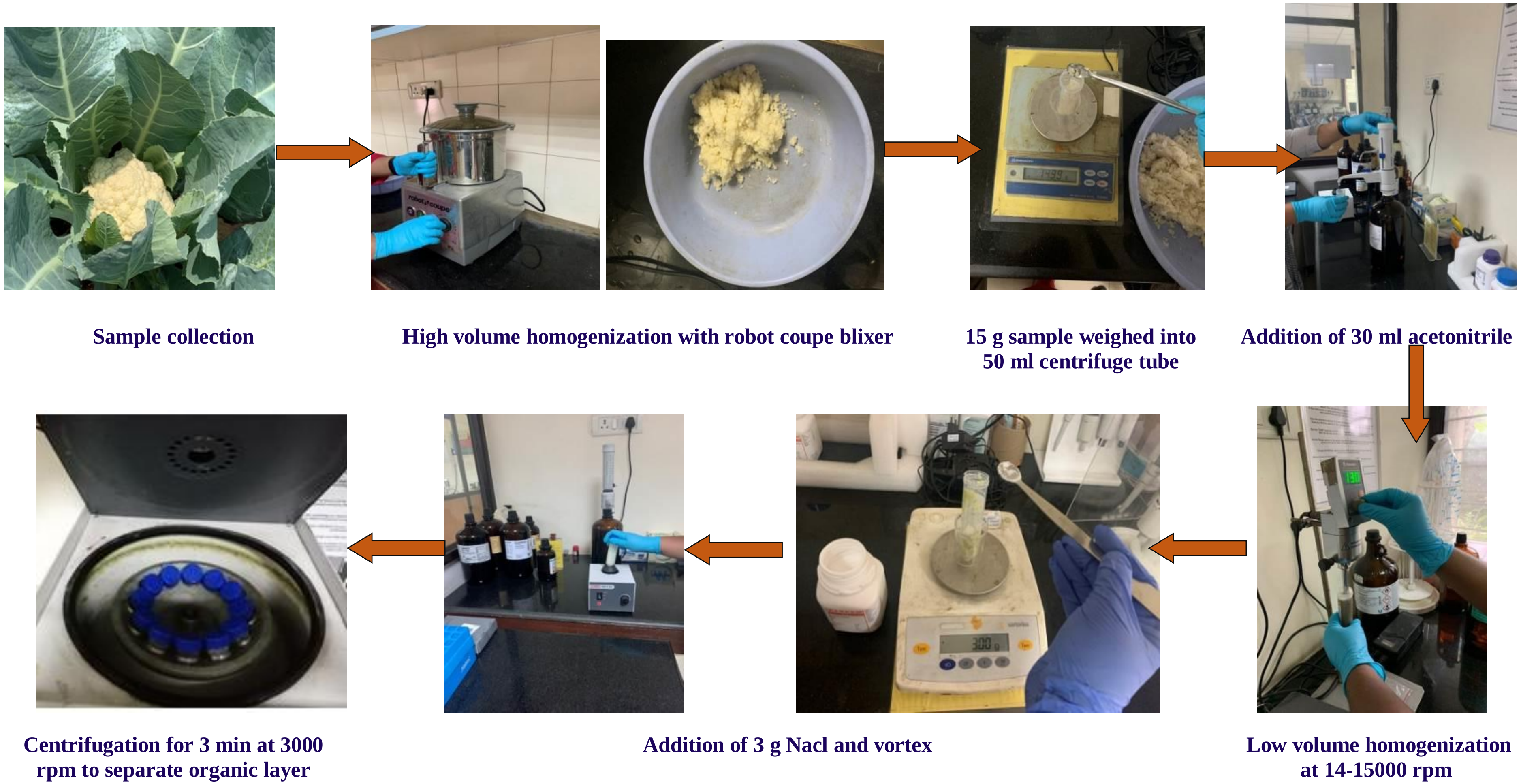
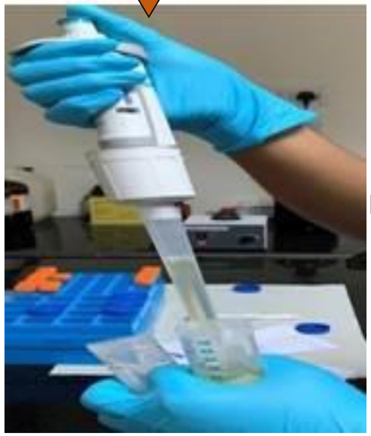



**Plate 3.6. Schematic representation of QuEChERS method**

**(Cont..)**



**16 ml supernatant is taken into centrifuge tube containing 9 g $Na_2SO_4$**


**Centrifugation for 5 min at 5000 rpm**

**8 ml extract taken into 15 ml tube with 0.4 g PSA and 1.2 g anhydrous $Mg_2SO_4$**

**1 ml extract filtered into 2 ml vials by using PTFE filter**

**1 ml filtrate extract injected into LC-MS/ MS for analysis**

**Plate 3.6. Schematic representation of QuEChERS method**

**a) Residues:**

$$\text{Residues (mg kg}^{-1}\text{) in sample} = \frac{\text{Sample peak area x Conc. of matrix match Std } (\mu g\ ml^{-1}) \text{ x } \mu l \text{ of matrix match Std. injected x Final volume of the sample}}{\text{Matrix match Standard Peak area x Weight of sample analysed x } \mu l \text{ of sample injected}} \text{ X Recovery factor}$$

**b) Dissipation percentage:**

$$\text{Per cent dissipation} = \frac{\text{Initial deposit - Residues at given time}}{\text{Initial deposit}} \text{ X 100}$$

**c) Safe Waiting Period/ Pre-harvest Period:** Waiting period ($T_{tol}$) is defined as the minimum number of days to lapse before the insecticide reaches the tolerance limit.

The waiting periods were calculated wherever MRLs are available as per CAC/FSSAI, by the following formula (Gunther and Blinn, 1955; Regupathy and Dhamu, 2001)

$$T_{tol} = \frac{[a - \text{Log tol}]}{b}$$

Where

$T_{tol}$ = Minimum time (in days) required for the pesticide residue to reach below the Tolerance limit.

a = Log of apparent initial deposits obtained in the regression equation ($Y = a+bX$)

tol = Tolerance limit of the insecticide (MRL)

b = Slope of the regression line

**d) Half-Life ($RL_{50}$):** The time in days required to reduce the pesticide residues to half of its initial deposits. Mathematically, it is

$$RL_{50} \text{ (or) } t_{1/2} = \frac{\text{Log (2)}}{b}$$

Where,

b = Slope of regression line (Hoskins, 1961).

## 3.5 Decontamination of Selected Insecticide Residues in Cauliflower

For conducting decontamination studies, the seedlings were transplanted at 60 cm X 45 cm spacing in 9 m X 5 m bulk plot on ridges and furrows. All the recommended agronomic practices were followed. Two sprayings of the test insecticide (1 insecticide/ 2 rows) were given at curd initiation stage at 15 days interval. Plastic sheets were used to avoid cross contamination of test insecticide from the adjacent rows. About 8 kgs of the zero-day samples (2 hrs after 2$^{nd}$ application) were collected from each treatment separately to undertake various decontamination methods separately. Subsequently, the residues were calculated to know the efficiency of the various decontamination methods in the removal of pesticide residues from the cauliflower samples. The following decontamination / risk mitigation methods were used for evaluating the efficiency in removal of pesticide residues from cauliflower (Preethi *et al.*, 2019; Nowowi *et al.*, 2016) (Plate 3.7).

**$T_1$ (Tap water wash):**

Four litres of tap water was taken in a plastic tub of 7 litres capacity and 1 kg of cauliflower curds were dipped in it for 10 min, followed by the tap water wash for 30 sec. Further, the curds were removed, air dried and homogenized.

**$T_2$ (Soaking in 2% salt solution for 10 min followed):**

Four litres of 2 % salt solution was prepared by mixing 80 g of table salt in 4 litres of water in a plastic tub (7 l) and 1 kg cauliflower curds were dipped for 10 min. Later they were removed, dried and homogenized for analysis.

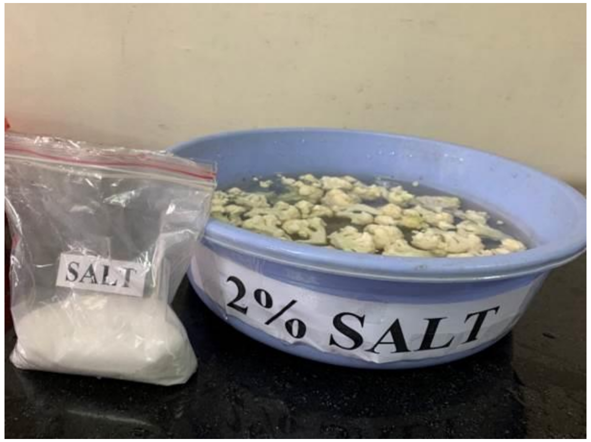
**$T_3$ (Dipping in 0.1% sodium bicarbonate solution for 10 min):**

Four litres of 0.1 % of $NaHCO_3$ solution was prepared by mixing 4 g of $NaHCO_3$ in 4 litres of water in a plastic tub of (7 l). After 1 min 1 kg cauliflower curds were dipped in it for 10 min followed by air drying and homogenization for residue analysis.

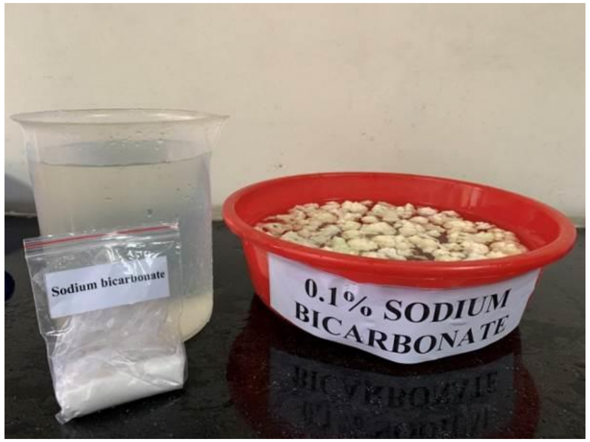
**$T_4$ (Dipping in 4 % acetic acid solution):**

Four litres of tap water was taken in a plastic tub (7 l) and 160 ml of acetic acid was added. 1 kg cauliflower curds were dipped in the tub for 10 min, followed by drying and homogenization for residue analysis.

Tap water wash




2 % Salt solution




0.1 % Sodium bicarbonate


0.1 % Sodium bicarbonate

Cooking in open vessel

Cooking in pressure cooker

**Plate 3.7. Various decontamination methods tested for selected insecticides used in cauliflower**

**$T_5$ (Cooking in open vessel for 10 min):**

Four litres of tap water was taken into a vessel and 1 kg cauliflower curds were added and boiled for 10 min followed by drying and homogenization for residue analysis.

**$T_6$ (Cooking in pressure cooker for 10 min):**

Cauliflower curds (1 kg) were boiled in 4 l of water taken in a pressure cooker for 10 min. Later, the boiled material was removed and kept for air drying followed by analysis.

**$T_7$ (Control):**

Untreated cauliflower curds (1 kg) were processed for residues.

**Per cent removal of pesticide:**

$$\text{Per cent removal} = \frac{\text{Initial deposit - Residues after treatment}}{\text{Initial deposit}} \times 100$$

# Chapter IV

# RESULTS AND DISCUSSION

The results obtained from the present investigation on “Seasonal incidence of insect pests, bio-efficacy and dissipation pattern of selected insecticides in cauliflower” are presented under the following headings:

4.1 Seasonal incidence of insect pests in cauliflower and their correlation with weather factors.
4.2 Bio-efficacy of selected insecticides against insect pest complex in cauliflower.
4.3 Dissipation pattern and residue dynamics of selected insecticides in cauliflower.
4.4 Decontamination of selected insecticide residues in cauliflower.

## 4.1 Seasonal Incidence of Insect Pests in Cauliflower and their Correlation with Weather Factors

### 4.1.1 Seasonal Incidence of Insect Pests and Natural Enemies

In 2018-19, the insect pests recorded in cauliflower during the crop growth were sucking pests (aphids and bugs), defoliators (leaf webber and tobacco caterpillar and diamondback moth along with head borer damage. The natural enemies like coccinellid beetles and syrphids were also observed.

Aphids first appeared during 47$^{th}$ SMW (2018) (2.60/3leaves/plant) and attained its peak during the 1$^{st}$ SMW (2019) (115.0/3leaves/plant). Thereafter, it declined but the incidence persisted up to the harvest of the crop (Table 4.1). The seasonal mean population was recorded as 61.01/3leaves/plant (Fig 4.1).

The leaf webber population was noticed during 48$^{th}$ SMW and gradually increased reaching its peak during 52$^{nd}$ SMW (4.80 larvae/plant) and thereafter decreased at harvest. The seasonal mean population was 1.66 larvae/plant (Fig 4.2).

The incidence of other pests *viz.*, bugs, tobacco caterpillar and DBM was low. The seasonal mean population of painted bugs was 0.26 per plant, tobacco caterpillar was 0.23 larvae per plant with a peak of 0.94 larvae per plant during 52$^{nd}$ SMW while the seasonal mean population of diamond back moth was 0.26 larvae per plant reaching

**Table. 4.1. Seasonal incidence of insect pests and natural enemies in cauliflower during *rabi*, 2018-19**

| Standard Meteorological Week (SMW) | Month | *Mean insect population | | | | | Head borer (% damage) | Natural enemies | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aphids (no./3 leaves/ plant) | Leaf webber (no./plant) | Painted bug (no./ plant) | Tobacco caterpillar (no./plant) | DBM (no./plant) | | Coccinellids (no./plant) | Syrphids (no./plant) |
| 46 | 12-18 Nov | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 47 | 19-25 Nov | 2.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 26 Nov-02 Dec | 10.60 | 0.08 | 0.10 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| 49 | 03-09 Dec | 49.72 | 0.66 | 0.32 | 0.14 | 0.00 | 0.00 | 0.00 | 0.06 |
| 50 | 10-16 Dec | 51.80 | 1.20 | 0.50 | 0.20 | 0.14 | 0.00 | 0.02 | 0.20 |
| 51 | 17-23 Dec | 68.00 | 2.60 | 0.24 | 0.70 | 0.24 | 0.00 | 0.14 | 0.78 |
| 52 | 24-31 Dec | 89.80 | 4.80 | 0.56 | 0.94 | 0.60 | 0.00 | 0.48 | 1.60 |
| 1 | 01-07 Jan | 115.00 | 4.20 | 0.40 | 0.48 | 0.80 | 0.00 | 0.74 | 2.00 |
| 2 | 08-14 Jan | 109.20 | 3.40 | 0.60 | 0.32 | 1.16 | 2.00 | 1.20 | 2.40 |
| 3 | 15-21 Jan | 102.60 | 3.20 | 0.52 | 0.14 | 0.40 | 4.00 | 0.92 | 1.30 |
| 4 | 22-28 Jan | 98.40 | 0.96 | 0.20 | 0.02 | 0.10 | 10.00 | 0.68 | 0.64 |
| 5 | 29 Jan-4 Feb | 56.60 | 0.40 | 0.00 | 0.00 | 0.00 | 20.00 | 0.30 | 0.22 |
| 6 | 5-11 Feb | 38.80 | 0.06 | 0.00 | 0.00 | 0.00 | 30.00 | 0.10 | 0.18 |
| **Mean** | | **61.01** | **1.66** | **0.26** | **0.23** | **0.26** | **5.08** | **0.35** | **0.72** |

*Mean of 50 plants

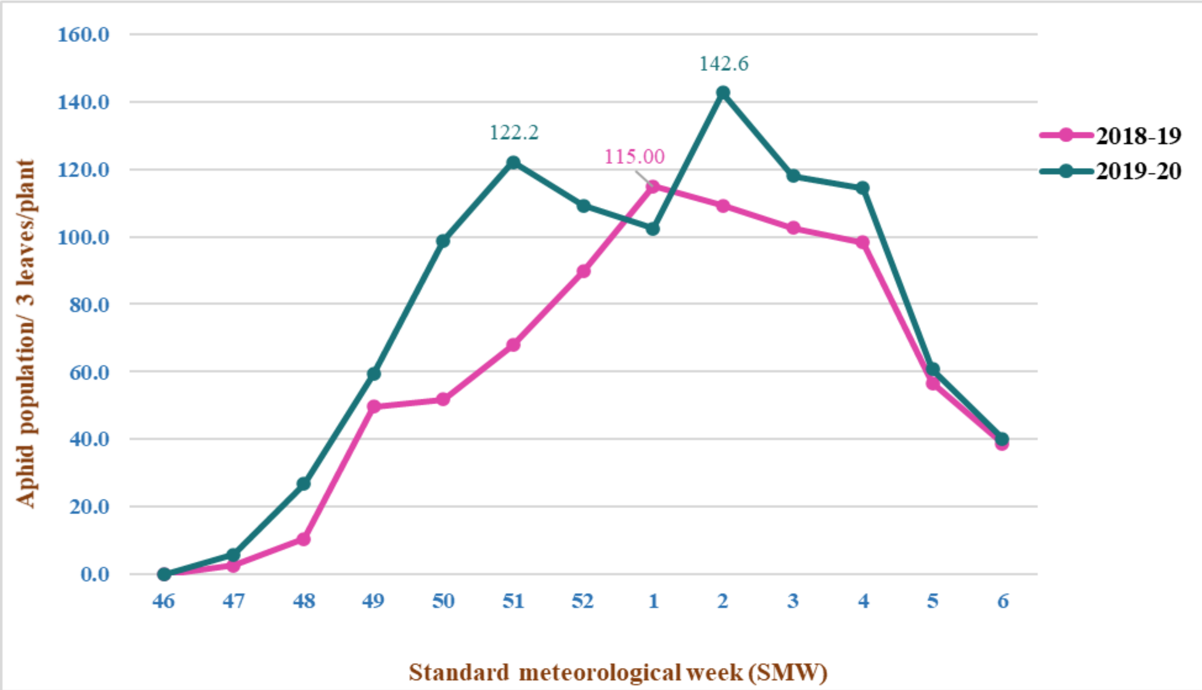



**Fig. 4.1. Seasonal incidence of aphids during *rabi*, 2018-19 and 2019-20 in cauliflower**

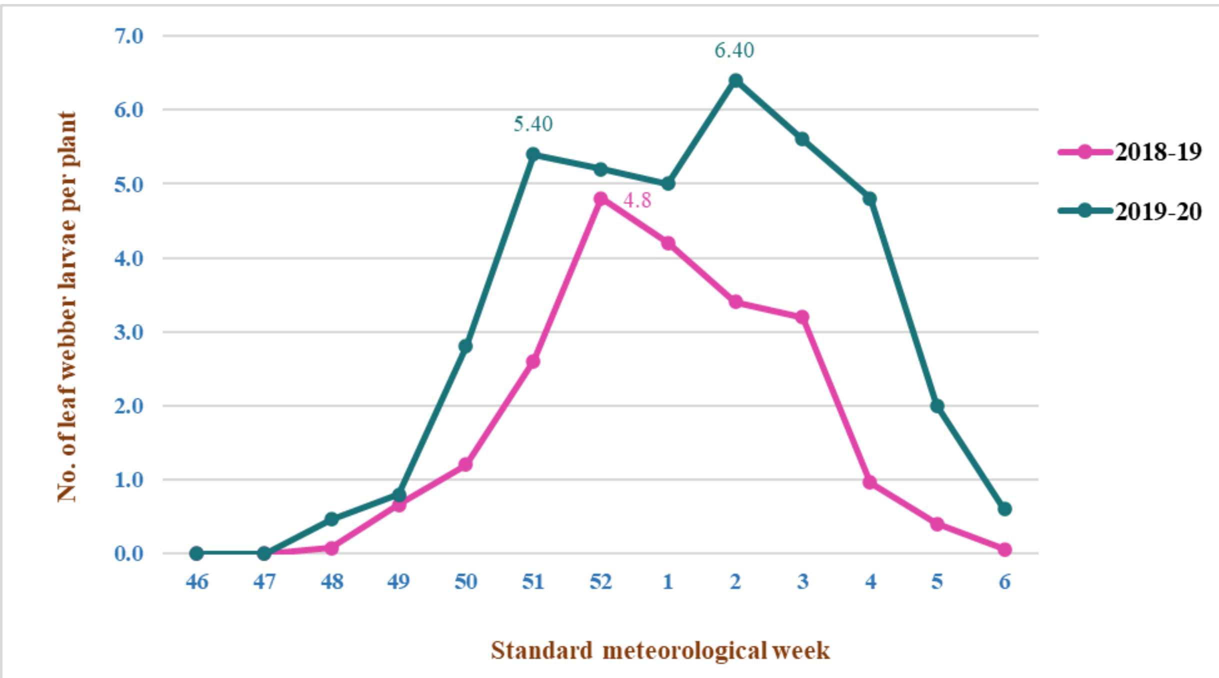



**Fig. 4.2. Seasonal incidence of leaf webber during *rabi*, 2018-19 and 2019-20 in cauliflower**

its peak during 2$^{nd}$ SMW (1.16 larvae per plant). The head borer damage started during 2$^{nd}$ SMW (2.0%) and reached its peak by 6$^{th}$ SMW (30.0%).

The occurrence of natural enemies *viz.*, coccinellid beetles was first recorded during 50$^{th}$ SMW (0.02/plant). It was found to gradually increase reaching its peak during the 2$^{nd}$ SMW (1.20/plant) and subsequently the population decreased to 0.10 per plant during 6$^{th}$ SMW (harvest) (Fig 4.3). The seasonal mean recorded was 0.35 per plant. Syrphid incidence was first observed during 49$^{th}$ SMW (0.06/plant) which increased steadily and attained a peak of 2.40 per plant during 2$^{nd}$ SMW and then declined but the incidence persisted till harvest.

In 2019-20, aphids first appeared during 47$^{th}$ SMW (2019) (5.90/3leaves/plant), attained its first peak during 51$^{st}$ SMW (2019) (122.2/3leaves/plant) and the second peak during 2$^{nd}$ SMW (2020) (142.6/3leaves/plant). Thereafter, it declined but the incidence persisted up till the harvest of cauliflower (Table 4.2). The seasonal mean population was recorded as 76.98/3leaves/plant.

The leaf webber population was noticed during 48$^{th}$ SMW (0.46 larvae/plant) and gradually increased reaching its first peak during 51$^{st}$ SMW (5.40 larvae/plant), subsequent peak during 2$^{nd}$ SMW (6.40 larvae/plant) and there after decreased at harvest. The seasonal mean population was 3.05 larvae/plant.

The incidence of other pests *viz.*, bugs, tobacco caterpillar and diamondback moth was low. The seasonal mean population of painted bugs was 0.05 per plant, tobacco caterpillar was 0.28 larvae per plant with a peak of 1.1 larvae per plant during 1$^{st}$ SMW while the seasonal mean population of diamondback moth was 0.23 larvae per plant reaching its peak during 1$^{st}$ SMW (1.0 larvae per plant). The head borer damage started during 2$^{nd}$ SMW (4.00%) and reached its peak by 6$^{th}$ SMW (38.0%).

The occurrence of natural enemies *viz.*, coccinellid beetles was first recorded during 49$^{th}$ SMW (0.04/plant). It was found to gradually increase reaching its peak during the 1$^{st}$ SMW (1.40/plant) and subsequently the population decreased to 0.26 per plant during 6$^{th}$ SMW (harvest). The seasonal mean recorded was 0.52 per plant. Syrphid incidence was first observed during 49$^{th}$ SMW (0.06/plant) which increased steadily and attained a peak of 2.90 per plant during 2$^{nd}$ SMW and then declined but the incidence persisted till harvest (Fig 4.4).

**Table. 4.2. Seasonal incidence of insect pests and natural enemies in cauliflower during *rabi*, 2019-20**

| Standard Meteorological Week (SMW) | Month | Mean* insect population | | | | | Head borer (% damage) | Natural enemies | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aphids (no./3 leaves/ plant) | Leaf webber (no./plant) | Painted bug (no./ plant) | Tobacco caterpillar (no./plant) | DBM (no./plant) | | Coccinellids (no./plant) | Syrphids (no./plant) |
| 46 | 12-18 Nov | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 47 | 19-25 Nov | 5.9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 26 Nov-02 Dec | 26.8 | 0.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 49 | 03-09 Dec | 59.4 | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.06 |
| 50 | 10-16 Dec | 98.8 | 2.80 | 0.00 | 0.10 | 0.08 | 0.00 | 0.16 | 0.20 |
| 51 | 17-23 Dec | 122.2 | 5.40 | 0.10 | 0.20 | 0.32 | 0.00 | 0.40 | 0.50 |
| 52 | 24-31 Dec | 109.2 | 5.20 | 0.20 | 0.50 | 0.56 | 0.00 | 1.10 | 1.20 |
| 1 | 01-07 Jan | 102.4 | 5.00 | 0.20 | 1.10 | 1.00 | 0.00 | 1.40 | 2.40 |
| 2 | 08-14 Jan | 142.6 | 6.40 | 0.20 | 1.00 | 0.60 | 4.00 | 1.20 | 2.90 |
| 3 | 15-21 Jan | 118.0 | 5.60 | 0.02 | 0.30 | 0.24 | 12.00 | 1.08 | 2.60 |
| 4 | 22-28 Jan | 114.4 | 4.80 | 0.00 | 0.40 | 0.12 | 18.00 | 0.80 | 2.05 |
| 5 | 29 Jan-4 Feb | 60.8 | 2.00 | 0.00 | 0.00 | 0.04 | 26.00 | 0.30 | 1.50 |
| 6 | 5-11 Feb | 40.2 | 0.60 | 0.00 | 0.00 | 0.00 | 38.00 | 0.26 | 0.40 |
| **Mean** | | **76.98** | **3.05** | **0.05** | **0.28** | **0.23** | **7.54** | **0.52** | **1.06** |

*Mean of 50 plants

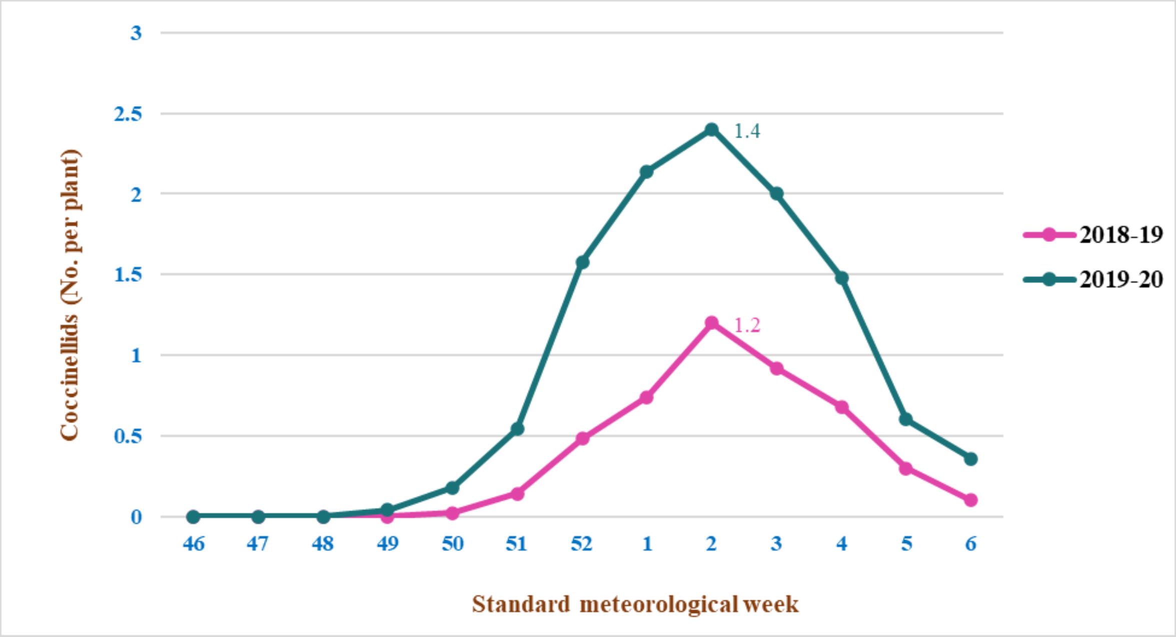



**Fig. 4.3. Seasonal incidence of coccinellids during *rabi*, 2018-19 and 2019-20 in cauliflower**

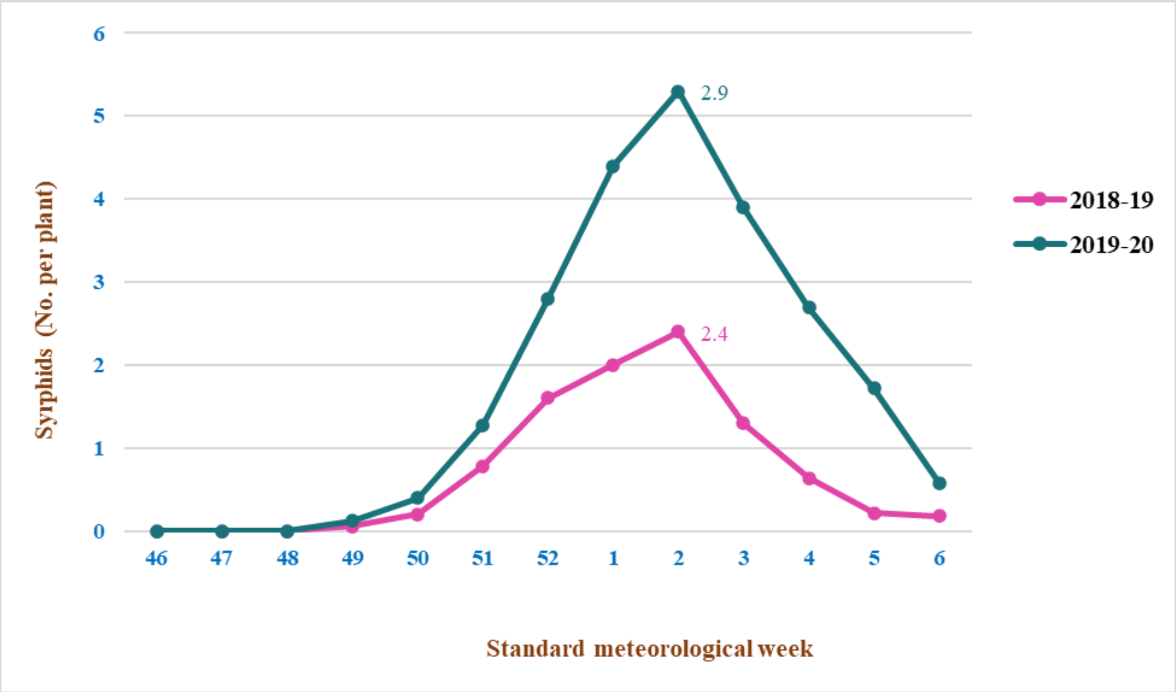



**Fig. 4.4. Seasonal incidence of syrphids during *rabi*, 2018-19 and 2019-20 in cauliflower**

### 4.1.2 Correlation and Multiple Linear Regression of Insect Pests with Abiotic (Weather) Factors and Natural Enemies with Abiotic and Biotic Factors

As the insect pests *i.e.*. aphids and leaf webber and the natural enemies *i.e*. coccinellids and syrphids were predominant during both the years, hence correlation and multiple regression analysis was carried out for these insects with abiotic and/biotic factors (Table 4.3.).

Aphids showed non-significant correlation with all the abiotic factors. Negative correlation was observed with maximum temperature (r=-0.353), minimum temperature (r=-0.227), mean temperature (r=-0.338), wind speed (r=-0.354) and evaporation (r=-0.217) and positive correlation with morning RH (r=0.269), evening RH (r=0.033), rainfall (r=0.103), rainy days (r=0.064) and sunshine (r=0.039).

Leaf webber showed significant negative correlation with wind speed (r=-0.448) while exhibiting non-significant negative correlation with maximum temperature (r=-0.276), minimum temperature (r=-0.114), mean temperature (r=-0.210), evening RH (r=-0.046), rainfall (r=-0.129), rainy days (r=-0.158) and evaporation (r=-0.258). It exhibited a non-significant positive correlation with morning RH (r=0.170) and sunshine (r=0.086).

Coccinellids showed significant positive correlation with aphids (r=0.816) while the weather factors showed non-significant correlation. Negative non-significant correlation was observed with maximum temperature (r=-0.140), minimum temperature (r=-0.159), wind speed (r=-0.366) and evaporation (r=-0.045) while exhibiting positive non-significant correlation with mean temperature (r=0.199), morning RH (r=0.055) evening RH (r=0.014), rainfall (r=0.099), rainy days (r=0.077) and sunshine (r=0.119).

Syrphids exhibited positive significant correlation with aphid population (r=0.785). Non-significant negative correlation was observed with maximum temperature (r=-0.074), minimum temperature (r=-0.186), mean temperature (r=-0.198), evening RH (r=-0.129), rainfall (r=-0.058), rainy days (r=-0.08) and wind speed (r=-0.266) while non-significant positive correlation was observed with morning RH (r=0.003) sunshine (r=0.186) and evaporation (r=0.013).

A multivariate analysis was performed using principal component analysis (PCA) to reduce the dimensions of data. The variables were transformed to principal components to explain the extent and nature of the relationships among different

**Table 4.3. Correlation of insect pests in cauliflower with abiotic parameters and natural enemies with abiotic and biotic parameters**

| | **Abiotic/biotic parameters** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum temperature (ºC) | Minimum temperature (ºC) | Mean temperature (ºC) | Morning relative humidity (RH I%) | Evening relative humidity (RH II%) | Rainfall (mm) | Rainy days (R.D.) | Sunshine (hrs) | Wind speed (Km/hr) | Evaporation (E.pan) (mm) | Aphids |
| **Aphids** | -0.353 | -0.227 | -0.338 | 0.269 | 0.033 | 0.103 | 0.064 | 0.039 | -0.354 | -0.217 | - |
| **Leaf webber** | -0.276 | -0.114 | -0.210 | 0.170 | -0.046 | -0.129 | -0.158 | 0.086 | -0.448* | -0.258 | - |
| **Coccinellids** | -0.140 | -0.159 | 0.199 | 0.055 | 0.014 | 0.099 | 0.077 | 0.119 | -0.366 | -0.045 | 0.816*** |
| **Syrphids** | -0.074 | -0.186 | -0.198 | 0.003 | -0.129 | -0.058 | -0.080 | 0.186 | -0.266 | 0.013 | 0.785*** |

* Significant at 5% level
** Significant at 1% level
*** Significant at 0.5% level

variables. These new variables are uncorrelated and most of the information within the initial variables is compressed into the first components (Dim1 and Dim2). The positively correlated variables are positioned on the same side of the axis while the negatively correlated ones are positioned on the opposite quadrants. The distance between each vector component explains the significance of each variable *i.e.* lesser the distance more significant is the relation. The length of the vector explains the variance due to that vector *i.e.* longer the vector length more is the variation caused by the vector.

The relationship between aphids and abiotic factors is plotted in Fig.4.5. The components, Dim1 and Dim2 captured 34.6 and 25.3 per cent of the variability in data, respectively. The distance between aphids and morning relative humidity (RH I) was very less indicating a closer relation among them. Similarly, the Dim1 and Dim2 components (Fig 4.5) clearly demonstrated that the weather parameters *viz.,* sunshine hours, evaporation, temperature (maximum, minimum and mean), evening relative humidity (RH II) were the important factors contributing to maximum variability in aphid population (Fig 4.5).

The relationship between leaf webber and abiotic factors is plotted in Fig.4.6. The components, Dim1 and Dim2 captured 34.5 and 25 per cent of the variability in data, respectively. The distance between leaf webber and morning relative humidity (RH I) was very less indicating a significant relation among them. Similarly, the Dim1 and Dim2 components (Fig 4.6) clearly demonstrated that the weather parameters *viz.,* sunshine hours, evaporation, temperature (maximum, minimum and mean), evening relative humidity (RH II) are the important factors contributing to maximum variability in leaf webber population in cauliflower.

The relationship between natural enemies with biotic (aphids) and abiotic factors is plotted in Fig.4.7. The components, Dim1 and Dim2 captured 29.4 and 26.2 per cent of the variability in data, respectively. The distance between aphids and natural enemies was very less indicating a significant relation among them. Similarly, the Dim1 and Dim2 components (Fig 4.7) clearly demonstrated that the weather parameters *viz.,* sunshine hours, evaporation, temperature (maximum, minimum and mean), relative humidity also contributed to maximum variability in population of natural enemies.

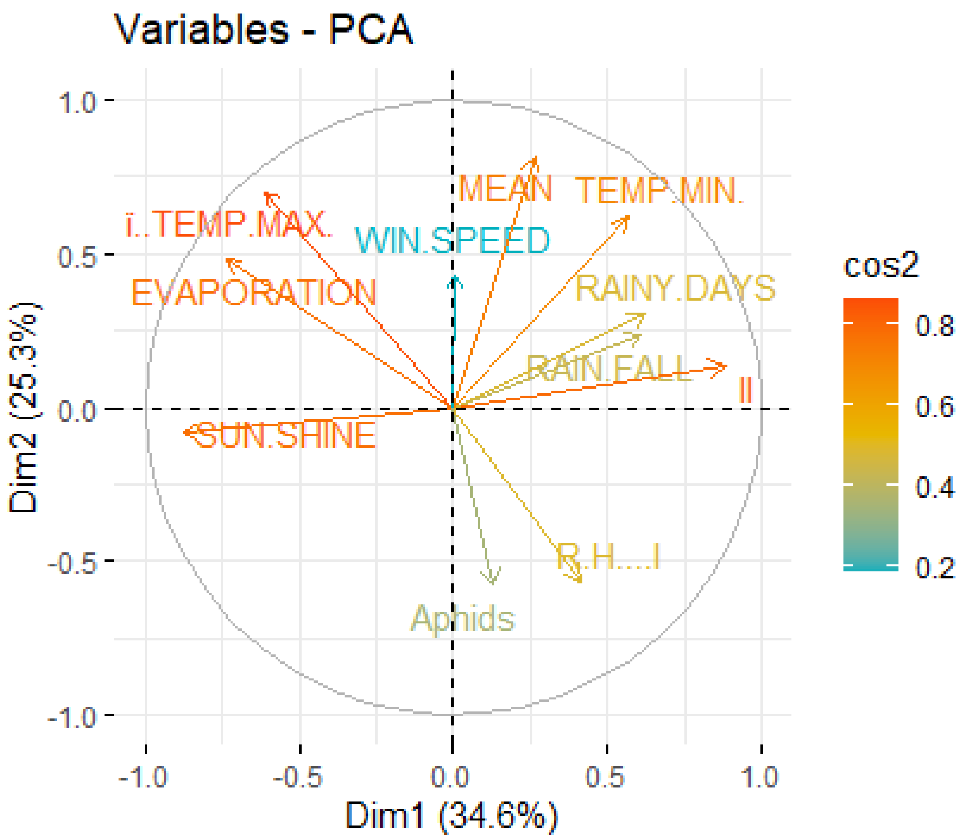



**Fig. 4.5. Principal component analysis (PCA) for aphids with weather parameters**

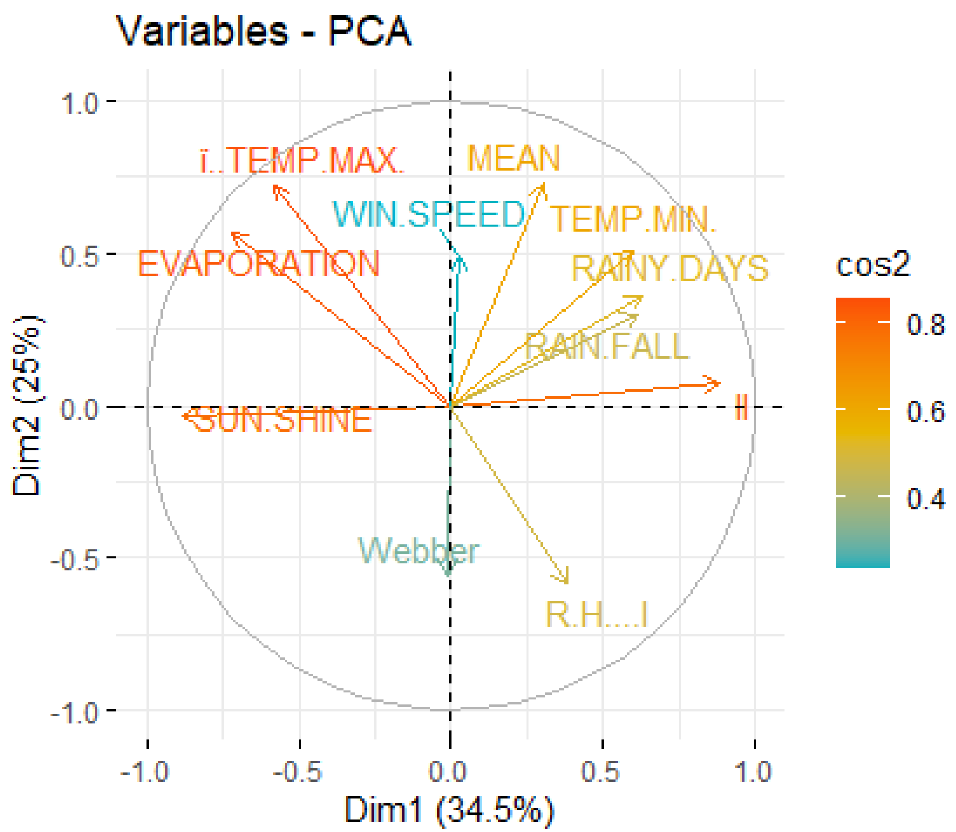



**Fig. 4.6. Principal component analysis (PCA) for leaf webber with weather parameters**

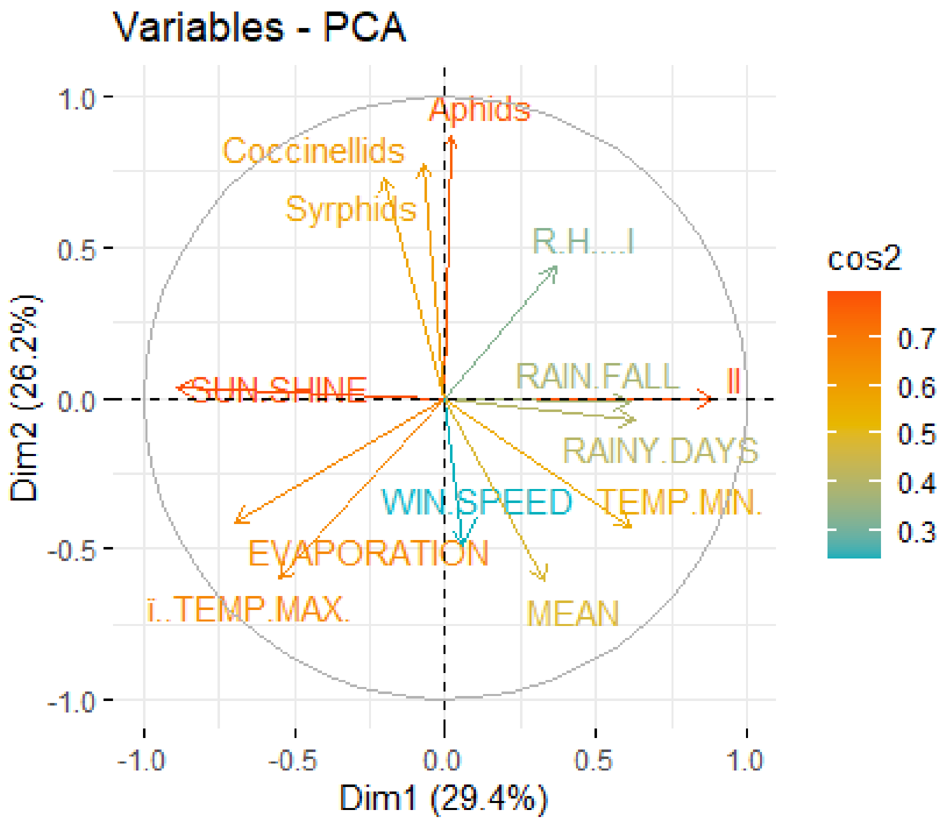



**Fig. 4.7. Principal component analysis (PCA) for natural enemies with aphids and weather parameters**

Multiple linear regression equation was developed for aphids and leaf webber (Table 4.4). The abiotic factors contributed for 29.77 and 27.27 per cent of total variation in the population of aphids and leaf webber in cauliflower. Similarly, multiple linear regression equation was developed for coccinellids and syrphids with abiotic and biotic factors (aphids). The abiotic factors and biotic factors (aphids) contributed to 79.47 and 80.30 per cent of total variation in the population of coccinellids and syrphids on cauliflower.

**Table 4.4. Multiple linear regression of insect pests with abiotic and natural enemies with abiotic and biotic parameters**

| Insects | Regression equation | $R^2$ value |
|---|---|---|
| Aphids | $Y=128.76 + (-4.32) X_1 + 2.72 X_2 + (-9.37) X_3 + 2.17 X_4 + (-0.11) X_5 + 1.12 X_6 + 2.34 X_7 + (-0.81) X_8 + (-10.47) X_9 +17.91 X_{10}$ | 0.297 |
| Leaf webber | $Y=21.97 + 0.75 X_1 + 1.56 X_2 + (-2.86) X_3 + 0.03 X_4 + (-0.10) X_5 + 0.007 X_6 + (-0.183) X_7 + (-0.05) X_8 + (-0.48) X_9 + 0.46 X_{10}$ | 0.272 |
| Coccinellids | $Y=-1.61 + 2.08 X_1 + 1.93 X_2 + (-3.94) X_3 + (-0.01) X_4 + 0.01 X_5 + (-0.04) X_6 + 0.44 X_7 + (-0.04) X_8 + (-0.02) X_9 + (-0.01) X_{10} + 0.008 X_{11*}$ | 0.794 |
| Syrphids | $Y=2.82 + 6.26 X_1 + 6.28 X_2 +(-12.49) X_3 + (-0.03) X_4 + (-0.02) X_5 + (-0.07) X_6 + 0.60 X_7 + (-0.1) X_8 + 0.10 X_9 + 0.068 X_{10} +0.02 X_{11*}$ | 0.803 |

Y=Dependent variable, $X_1$= Max. Temp.(ºC), $X_2$= Min. Temp.(ºC), $X_3$= Mean Temp.(ºC), $X_4$= Morning RH (%), $X_5$= Evening RH (%), $X_6$= Rainfall(mm), $X_7$= Rainy days, $X_8$= Sunshine (hours), $X_9$= Wind speed (Kmph) , $X_{10}$= Evaporation(mm) and $X_{11*}$ = Aphids

Thus, from the period under study (2018-19 and 2019-20) on the seasonal incidence of insect pests, it is evident that aphid and leaf webber were the major biotic constraints in cauliflower. Although the incidence of diamondback moth, painted bug and tobacco caterpillar were noticed, it was very low.

The incidence of aphids was noticed during 47$^{th}$ SMW during both the years. In the first year, there was a gradual increase in aphid population peaking during 1$^{st}$ SMW (115/3leaves/plant) while in the second year, there was a sudden increase in population peaking early *i.e.* by 51$^{st}$ SMW (122.2/3leaves/plant) with a slight decline before reaching the second peak (142.6/3leaves/plant) during 2$^{nd}$ SMW. Similar to our findings, Bhede *et al.* (2018) reported that the incidence of aphid *B. brassicae* initiated from 48th SMW and reached its peak in 52nd SMW (114.35/leaf) during 2015-16 while in 2016-17, the aphid was first noticed during 50th SMW and reached its first peak (84.70/leaf) during 1st SMW and second peak (126.10/leaf) during 6th SMW. Earlier, Malik *et al.* (2000) reported that *B. brassicae* fluctuated from 51st meteorological week to 4th meteorological week. Gaikwad *et al.* (2018a) reported peak incidence of aphids (120.00/leaf) during 51st SMW while Patel and Patel (2018) observed the appearance of aphids from 49th SWM reaching peak level (37.44 aphids per leaf) at 3rd SMW. Our results corroborate with the findings of Siddiqui *et al.* (2009), Bana *et al.* (2012), Singh *et al.* (2012), Badjena and Mandal (2005) and Singh *et al.* (2010).

A perusal of weather parameters (Appendix A & B) revealed that lowest minimum temperature (5.5ºC) was recorded during 1st SMW with maximum temperature being 28.7ºC during 2018-19 while in 2019-20, lowest minimum temperature of 14.1 and 14.7ºC was recorded in 51st and 2nd SMW with maximum temperature being 28 and 27.9ºC, respectively. Bhede *et al.* (2018) reported that the prevailing maximum and minimum temperatures were 30.3ºC and 8.5ºC during first season and 29.2ºC and 8.5ºC in second season when the peak incidence of aphids was observed. Dewanda and Khan (2016) reported that the severity of aphid incidence was found to be higher in winter season as compared to monsoon season.

In the present study, aphids showed negative correlation with temperature (maximum, minimum and mean), wind speed and evaporation. Earlier, Chaudhari *et al.* (2001) reported that population of aphid was negatively correlated with temperature. Also, Bhagat *et al.* (2018) reported that maximum, minimum and average temperature showed negative non-significant correlation with aphids in cabbage. However, significant negative correlation of aphids with minimum temperature were reported by Gaikwad *et al.* (2018a), Bhede *et al.* (2018), Sakhrie *et al.* (2016), Bana *et al.* (2012) and Malik *et al.* (2000) while Patel and Patel (2018) reported significant negative correlation with maximum and non-significant negative correlation with minimum temperature, average temperature and sunshine. On the contrary, Saranya *et al.* (2017) reported that aphid population exhibited a significant positive correlation with mean atmospheric temperature and wind velocity. Relative humidity (morning and evening), rainfall, rainy days and sunshine showed positive correlation in the current investigation. Earlier, Singh *et al.* (2012) reported non-significant positive correlation of aphids with rainfall while Bana *et al.* (2012) also reported non-significant positive correlation of aphids with morning RH and sunshine. The weather parameters contributed to 29.77 per cent of total variation in the population of aphids in the present study.

Leaf webber incidence was noticed in the 48th SMW during both the years. However, in 2018-19 single peak occurred during 52nd SMW while in 2019-20, two peaks were noticed, the first during 51st SMW and the second during 2nd SMW. The incidence of leaf webber showed similar trend as in aphids. A perusal of weather parameters (Appendix A & B) revealed that the minimum and maximum temperatures that favoured aphids were equally suitable for leaf webber. Aiswarya *et al.* (2018) reported that leaf webber larvae appeared in the last week of November (47th SMW) and reached peak of 7 larvae per plant in 48th SMW although the temperatures were relatively slightly higher (31.5°C and 10.1°C) than observed in our study. Also, Bhede (2017) reported that the leaf webber peak incidence was observed during 2nd SMW (4.10/plant) when the prevailing maximum and minimum temperatures were 31.6°C and 11.7°C, respectively. Patait *et al.* (2008) reported that the population of *C. binotalis* on cabbage varied from 3.8 to 44.0 and 1.0 to 6.2 larvae/quadrat during rainy and winter seasons. Gaikwad *et al.* (2018a) reported that leaf webber attained peak during 2nd SMW (3.00/plant) while Badjena and Mandal (2005) noticed the peak during third week of January.

The leaf webber was found to be significant and negatively correlated with wind speed but with all other weather parameters it was non-significant and negative except morning RH and sunshine which were positively correlated. Bhede (2017) also reported non-significant negative correlation of minimum temperature with leaf webber. However, Gaikwad *et al.* (2018a) reported that leaf webber exhibited significant negative correlation with minimum temperature while it showed non-significant positive correlation with morning RH and sunshine. Patait *et al.* (2008) reported that the population of *C. binotalis* on cabbage was negatively correlated to morning RH and minimum temperature. Contrary to the present findings, Chaudhari *et al.* (2001) reported that cabbage leaf webber population showed positive correlation with average temperature and rainfall. The weather parameters contributed to 27.27 per cent of total variation in the population of leaf webber in the present investigation.

The head borer damage was noticed during 2nd SMW during both the years. The peak damage was attained by the end of 6th SMW recording 30 per cent damage during 2018-19 and 38 per cent damage during 2019-20. Although Aishwarya *et al.* (2018)

observed head borer incidence from 47th SMW, it reached peak during 3rd SMW. The maximum and minimum temperatures during the peak period of incidence were 28.9°C and 11.5°C, respectively. Gaikwad *et al.* (2018a) reported that the incidence of head borer in cauliflower initiated from 50th SMW and attained its peak at the end of crop season during 8th SMW.

Along with the insect pests, the natural enemies that were majorly recorded were coccinellids and syrphids on aphids. The incidence of spiders and mummified aphids were negligible.

The incidence of coccinellids initiated during 50th SMW, which increased gradually and attained peak in the 2nd SMW (1.20/plant) during 2018-19 and during 1st SMW (1.40/plant) in 2019-20. They were found to be negatively correlated with temperature (minimum and maximum), wind speed and evaporation, and significantly positively correlated with the aphid population. Bhede *et al.* (2017) reported peak coccinellid population in the 1st SMW (1.60 and 1.45/plant) during both the seasons. Bana *et al.* (2012) reported that the coccinellid predator *C. septempunctata* was found predating on aphid, *L. erysimi* and the coccinellid population was maximum at 3rd week (35.25/10 plants) and 2nd week of January (40.00/10 plants) during first and second years of study wherein the aphid incidence was also maximum. Patra *et al.* (2013) reported that both maximum and minimum temperatures had major role in building up the population of coccinellids. Yadav and Agarwal (2018) reported three coccinellid species in cabbage ecosystem. The population of *C. septempunctata* started during 50th SMW and increased gradually and reached peak in the 11th SMW (16.7/ 10 plants) while that of *C. transversalis* (2.67/ 10 plants) and *M. sexmaculata* (1.3/ 10 plants) during 4th and 9th SMW, respectively. The population of coccinellid beetles increased gradually with the increase of aphid population and decreased gradually with the decrease in aphid population. The weather parameters and aphid contributed for 79.47 of total variation in the population of coccinellids on cauliflower. Mandal and Patnaik (2006) also reported a positive correlation of coccinellids with aphid population. Dwivedi *et al.* (2018) reported that the population of coccinellid predators on *L. erysimi* in mustard exhibited positive correlation with aphid population.

The incidence of syrphids initiated during 49th SMW and increased gradually reaching peak of 2.40 and 2.90 per plant during 2nd SMW in first and second seasons, respectively. Syrphids were found to be negatively correlated to all weather parameters except morning RH and evaporation. However, they showed significant positive correlation with aphid population. Gaikwad *et al.* (2018a) observed that the syrphid maggots appeared during 48th SMW, reached peak ()4.52/plant during 52nd SMW and were significantly negatively correlated with minimum temperature. Dwivedi *et al.* (2018) reported that the syrphids appeared during second and first week of January reaching a peak of 5.90 and 4.80 larvae per ten twigs during fourth week of February during both the seasons. Positive correlation was observed with aphids during both the seasons. Bhede (2017) recorded peak population of syrphids in the 1st SMW (5.75/plant) and 52nd SMW (3.55/plant) during 2015-16 and 2016-17, respectively. A significant negative correlation of syrphids with minimum temperature during first season and significant positive correlation with aphids was observed during both the seasons. The weather parameters and aphid contributed for 97.4 per cent during 2015-16 and 79.7 per cent during 2016-17 of total variation in the population of syrphid fly maggot in cauliflower. Mishra and Singh (2010) reported that the predators were seasonal and their abundance coincided with the insect pests in cabbage. Badjena and Mandal (2005) noticed incidence of syrphids in cauliflower from the first week of December to the second week of February and peak population (18.3 larvae/10 plants) in the 2nd week of January. A significantly positive correlation was found with the aphid population. Earlier, Wagle *et al*. (2005) reported that aphidophagous predator like *Syrphus spp.* appeared more or less with aphid population (4th SMW) and remained active up to March (13th SMW) and as the pest populations decreased, the population of natural enemies also declined. In the present study, the weather parameters and aphid contributed to 80.30 of total variation in the population of syrphids in cauliflower.

Thus, it can be summarized that aphids and leaf webber occurred early in late October transplanted cauliflower while other lepidopteran pests (diamondback moth and tobacco caterpillar) and bugs during mid growth stage while head borer damage occurred at later stages *i.e.* curd formation stage. Aphids and leaf webber showed a negative correlation with temperature, windspeed and evaporation and positive correlation with morning RH and sunshine. The predators *viz.*, coccinellids and syrphids exhibited a negative correlation with maximum and minimum temperatures and windspeed while showing positive correlation with morning RH and evaporation. The predators were found to be dependent on the density of aphids and showed positive correlation with aphid population.

## 4.2 Bio-efficacy of Selected Insecticides against Insect Pest Complex in Cauliflower

The insecticides *viz.*, chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, diafenthiuron, chlorpyriphos and dimethoate belonging to different groups and possessing different modes of action were selected for evaluating the bioefficacy against insect pests in cauliflower. The rationale for selecting the novel insecticides was to target the lepidopteran pest complex. However, during the crop growth stage, the incidence of only leaf webber was above ETL besides sucking pest (aphids) while the incidence of other lepidopteran and sucking pests were very low. Hence, the efficacy of the selected insecticides was evaluated against these two insect pests.

The selected insecticides were sprayed twice, first during curd initiation stage when the leaf webber infestation crossed ETL and the second at 15 days interval. Lack of intervention at this stage may cause complete damage of the curd. Hence, sprayings were scheduled at this stage and also to know the dissipation pattern in the curd.

### 4.2.1. Efficacy of Insecticides against Leaf Webber During *Rabi*, 2018-19

The population of *C. binotalis* in various treatments a day before first spraying ranged from 3.67 to 4.07 larvae/plant (Table 4.5). There was no significant difference in population among the various treatments.

The mean larval population of leaf webber at 3 DAS indicated that all the insecticidal treatments were significantly superior over control (4.13 larvae/plant). The population was significantly lowest (0.73 larvae/plant) in plots sprayed with chlorantraniliprole and was on par with spinosad (0.80 larvae/plant), emamectin benzoate (0.80 larvae/plant) and indoxacarb (0.93 larvae/plant). The next best treatments in managing leaf webber were chlorpyriphos (2.07 larvae/plant), diafenthiuron (2.73 larvae/plant) and dimethoate (3.00 larvae/plant) which were found to be on par with each other.

At 5 days after first spray, chlorantraniliprole treatment continued to be effective by recording significantly lowest webber population of 0.60 larvae/plant. It was found to be on par with spinosad (0.67 larvae/plant), emamectin benzoate (0.73 larvae/plant) and indoxacarb (0.87 larvae/plant) followed by chlorpyriphos, diafenthiuron and dimethoate with 2.0, 2.67 and 2.93 larvae per plant, respectively which were found to be

**Table 4.5. Bio-efficacy of insecticides against leaf webber in cauliflower during *rabi*, 2018-19**

| Treatments | Dose (g a.i. ha$^{-1}$) | Number of leaf webber larvae/plant* | | | | Per cent reduction over control after I spray | Number of leaf webber larvae/plant* | | | | Per cent reduction over control after II spray |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Spray | 3 DAS I | 5 DAS I | 7 DAS I | | Pre spray | 3 DAS II | 5 DAS II | 7 DAS II | |
| Chlorantraniliprole 18.5 SC | 10 | 3.87 (2.20) | 0.73 a (1.31) | 0.60 a (1.26) | 0.53 a (1.23) | 86.90 | 1.53 a (1.59) | 0.33a (1.15) | 0.27 a (1.13) | 0.20a (1.10) | 87.74 |
| Spinosad 2.5 SC | 17.5 | 3.80 (2.19) | 0.80 a (1.34) | 0.67 a (1.28) | 0.60 a (1.26) | 85.00 | 1.73 a (1.65) | 0.47a (1.21) | 0.40 a (1.18) | 0.33a (1.15) | 81.92 |
| Emamectin Benzoate 5 SG | 10 | 3.67 (2.16) | 0.80a (1.34) | 0.73a (1.32) | 0.73 a (1.31) | 81.00 | 1.93 a (1.71) | 0.40 a (1.18) | 0.33 a (1.15) | 0.33a (1.15) | 83.79 |
| Indoxacarb 14.5 SC | 40 | 3.73 (2.18) | 0.93 a (1.39) | 0.87 a (1.36) | 0.80 a (1.34) | 79.64 | 1.87 a (1.69) | 0.60 a (1.26) | 0.53 a (1.23) | 0.47a (1.21) | 76.50 |
| Diafenthiuron 50 WP | 300 | 4.07 (2.24) | 2.73 b (1.92) | 2.67b (1.90) | 2.47bc (1.86) | 42.38 | 2.73 b (1.93) | 2.13 bc (1.77) | 1.87 bc (1.69) | 1.53b (1.59) | 47.25 |
| Chlorpyriphos 50 EC | 500 | 3.73 (2.17) | 2.07b (1.75) | 2.00b (1.73) | 1.87b (1.69) | 52.50 | 2.40 b (1.84) | 1.60b (1.61) | 1.40 b (1.55) | 1.07b (1.44) | 58.09 |
| Dimethoate 30 EC | 200 | 3.67 (2.16) | 3.00b (1.99) | 2.93b (1.98) | 2.80 c (1.95) | 27.45 | 3.13 b (2.03) | 2.53c (1.87) | 2.33 c (1.82) | 2.20c (1.79) | 34.00 |
| Control | - | 4.07 (2.24) | 4.13c (2.27) | 4.20c (2.26) | 4.27 d (2.29) | 0.00 | 4.47 c (2.34) | 4.87 d (2.42) | 4.80 d (2.41) | 4.73 d (2.39) | 0.00 |
| C.D. ($P \leq 0.05$) | - | N/S | 0.25 | 0.24 | 0.19 | - | 0.24 | 0.18 | 0.19 | 0.18 | - |
| SE(m) (±) | - | 0.09 | 0.082 | 0.08 | 0.06 | - | 0.08 | 0.06 | 0.06 | 0.06 | - |
| SE(d) (±) | - | 0.13 | 0.12 | 0.11 | 0.09 | - | 0.11 | 0.08 | 0.07 | 0.08 | - |
| C.V. (%) | - | 7.15 | 8.56 | 8.35 | 6.49 | - | 7.32 | 6.13 | 6.90 | 6.97 | - |

*Mean of 5 plants

Figures in parentheses are square root transformed values; Treatments denoted with same alphabets within a column are not significant at 5% level

DAS – Days after Spraying; I – First spray; II – Second spray;

on par with each other in managing the leaf webber larvae. The population in control plot was 4.20 larvae/plant.

At 7 days after first spray, chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb with 0.53, 0.60, 0.73 and 0.80 larvae per plant were found to be significantly superior over control (4.27 larvae/plant) but were on par with each other. They were followed by chlorpyriphos (1.87 larvae/plant) and diafenthiuron (2.47 larvae/plant). Dimethoate treatment was least effective but had significantly lower population than control (4.27 larvae/plant).

The per cent reduction of leaf webber in different treatments over control in decreasing order of efficacy was chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate with 86.90, 85.0, 81.0, 79.64, 52.50, 42.38 and 27.45 per cent reduction, respectively.

The population of leaf webber ranged from 1.53 to 4.47 larvae/plant at 14 days after first spray necessitating second spray. At 3 days after second spray, chlorantraniliprole continued its supremacy over other treatments by recording significantly lowest leaf webber population of 0.33 larvae/plant but was on par with emamectin benzoate (0.40 larvae/plant), spinosad (0.47 larvae/plant) and indoxacarb (0.60 larvae/plant). Chlorpyriphos was found to be next in order of effectiveness with 1.60 larvae/plant and was on par with diafenthiuron (2.13 larvae/plant) while dimethoate (2.53 larvae/plant) was on par with diafenthiuron but significantly different from chlorpyriphos. The population of leaf webber in control plots was 4.87 larvae per plant.

At 5 DAS, chlorantraniliprole (0.27 larvae/plant), emamectin benzoate (0.33 larvae/plant), spinosad (0.40 larvae/plant) and indoxacarb (0.53 larvae/plant) were on par while rest of the treatments were significantly less effective in managing leaf webber. After 7 DAS, similar trend was followed wherein chlorantraniliprole (0.20 larvae/plant), spinosad (0.33 larvae/plant), emamectin benzoate (0.33 larvae/plant) and indoxacarb (0.47 larvae/plant) were on par and significantly different from other treatments and control (4.73 larvae/plant) (Table 4.5).

The per cent reduction in larval population over control at seven days after first spray was 87.74, 83.79, 81.92, 76.50, 58.09, 47.25 and 34.0 in chlorantraniliprole, emamectin benzoate, spinosad, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate over control, respectively.

### 4.2.2. Efficacy of Insecticides against Leaf Webber During *Rabi*, 2019-20

The population of leaf webber in various treatments a day before first spraying ranged from 5.87 to 6.27 larvae per plant. There was no significant difference in population among the various treatments (Table 4.6).

At 3 DAS, the lowest leaf webber larval population of 1.53 larvae per plant was observed in plots sprayed with chlorantraniliprole which was found to be on par with spinosad and emamectin benzoate (1.60 larvae/plant each) and indoxacarb (1.87 larvae/plant). Other treatments *viz*., chlorpyriphos (3.87 larvae/plant), diafenthiuron (4.47 larvae/plant) and dimethoate (4.80 larvae/plant) recorded significantly higher population of leaf webber but all the insecticidal treatments were significantly superior over control.

At 5 DAS, chlorantraniliprole treatment continued its efficacy by recording significantly lowest webber population of 1.33 larvae per plant and was found to be on par with plots treated with spinosad (1.40 larvae/plant), emamectin benzoate (1.47 larvae/plant) and indoxacarb (1.73 larvae/plant). They were followed by chlorpyriphos with 3.33 larvae/plant which was on par with diafenthiuron (4.33 larvae/plant). Difenthiuron was found to be on par with dimethoate (4.60 larvae/plant) with the latter being least effective in managing the leaf webber larvae.

At 7 days after first spray, chlorantraniliprole recorded significantly lowest larval population per plant (1.07) and was on par with spinosad (1.33) followed by emamectin benzoate (1.47) which was on par with spinosad and indoxacarb (1.67). The other treatments like chlorpyriphos (3.13 larvae/plant), diafenthiuron (4.07 larvae/plant) and dimethoate (4.53 larvae/plant) recorded significantly lower population than control (6.20 larvae/plant).

The per cent reduction of leaf webber in different treatments over control in decreasing order of efficacy was chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate with 82.77, 77.98, 77.06, 73.37, 51.00, 32.07 and 26.77, respectively.

**Table 4.6. Bio-efficacy of insecticides against leaf webber in cauliflower during *rabi*, 2019-20**

| Treatments | Dose (g a.i. ha$^{-1}$) | Number of leaf webber larvae/plant* | | | | Per cent reduction over control after I spray | Number of leaf webber larvae/plant* | | | | Per cent reduction over control after II spray |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-spray | 3 DAS I | 5 DAS I | 7 DAS I | | Pre-spray | 3 DAS II | 5 DAS II | 7 DAS II | |
| Chlorantraniliprole 18.5 SC | 10 | 6.07<br>(2.66) | 1.53$^{a}$<br>(1.59) | 1.33$^{a}$<br>(1.52) | 1.07$^{a}$<br>(1.44) | 82.77 | 1.87$^{a}$<br>(1.69) | 0.47$^{a}$<br>(1.21) | 0.40$^{a}$<br>(1.18) | 0.33$^{a}$<br>(1.15) | 80.36 |
| Spinosad 2.5 SC | 17.5 | 5.93<br>(2.63) | 1.60$^{a}$<br>(1.61) | 1.40$^{a}$<br>(1.55) | 1.33$^{ab}$<br>(1.53) | 77.98 | 1.93$^{a}$<br>(1.71) | 0.60$^{a}$<br>(1.26) | 0.53$^{a}$<br>(1.23) | 0.47$^{a}$<br>(1.21) | 73.45 |
| Emamectin Benzoate 5 SG | 10 | 6.27<br>(2.70) | 1.60$^{a}$<br>(1.61) | 1.47$^{a}$<br>(1.57) | 1.47$^{ab}$<br>(1.57) | 77.06 | 2.07$^{a}$<br>(1.75) | 0.53$^{a}$<br>(1.23) | 0.47$^{a}$<br>(1.21) | 0.47$^{a}$<br>(1.21) | 75.16 |
| Indoxacarb 14.5 SC | 40 | 6.13<br>(2.67) | 1.87$^{a}$<br>(1.69) | 1.73$^{a}$<br>(1.65) | 1.67$^{b}$<br>(1.63) | 73.37 | 2.13$^{a}$<br>(1.77) | 0.80$^{a}$<br>(1.34) | 0.73$^{a}$<br>(1.31) | 0.67$^{a}$<br>(1.29) | 65.63 |
| Diafenthiuron 50 WP | 300 | 5.87<br>(2.62) | 4.47$^{b}$<br>(2.34) | 4.33$^{bc}$<br>(2.31) | 4.07$^{d}$<br>(2.25) | 32.07 | 4.73$^{bc}$<br>(2.39) | 2.87$^{c}$<br>(1.96) | 2.60$^{c}$<br>(1.90) | 2.40$^{c}$<br>(1.84) | 44.23 |
| Chlorpyriphos 50 EC | 500 | 6.27<br>(2.69) | 3.87$^{b}$<br>(2.21) | 3.33$^{b}$<br>(2.08) | 3.13$^{c}$<br>(2.03) | 51.00 | 3.60$^{b}$<br>(2.14) | 1.93$^{b}$<br>(1.71) | 1.80$^{b}$<br>(1.67) | 1.67$^{b}$<br>(1.63) | 49.07 |
| Dimethoate 30 EC | 200 | 6.07<br>(2.66) | 4.80$^{b}$<br>(2.41) | 4.60$^{c}$<br>(2.37) | 4.53$^{d}$<br>(2.35) | 26.77 | 4.93$^{c}$<br>(2.44) | 3.27$^{c}$<br>(2.06) | 3.07$^{c}$<br>(2.01) | 2.87$^{c}$<br>(1.97) | 36.08 |
| Control | - | 6.20<br>(2.68) | 6.33$^{c}$<br>(2.71) | 6.27$^{d}$<br>(2.70) | 6.20$^{e}$<br>(2.71) | 0.0 | 6.40$^{d}$<br>(2.72) | 6.33$^{d}$<br>(2.71) | 5.93$^{d}$<br>(2.63) | 5.80$^{d}$<br>(2.61) | 0.0 |
| C.D. ($P \leq 0.05$) | - | N/S | 0.21 | 0.21 | 0.14 | - | 0.22 | 0.20 | 0.20 | 0.16 | - |
| SE(m) (±) | - | 0.08 | 0.07 | 0.07 | 0.05 | - | 0.07 | 0.06 | 0.07 | 0.05 | - |
| SE(d) (±) | - | 0.11 | 0.10 | 0.10 | 0.06 | - | 0.10 | 0.09 | 0.09 | 0.07 | - |
| C.V. (%) | - | 5.01 | 5.82 | 6.16 | 4.07 | - | 6.09 | 6.56 | 7.02 | 5.49 | - |

*Mean of 5 plants

Figures in parentheses are square root transformed values; Treatments denoted with same alphabets within a column are not significant at 5% level

DAS – Days after Spraying; I – First spray; II – Second spray;

The population of leaf webber ranged from 1.87 to 6.40 larvae per plant 14 days after first spray and it was taken as pre-spray count for second spraying. At 3 DAS chlorantraniliprole continued its efficacy over other treatments by recording significantly lowest leaf webber population of 0.47 larvae per plant and was on par with emamectin benzoate (0.53 larvae/plant), spinosad (0.60 larvae/plant) and indoxacarb (0.80larvae/plant). Chlorpyriphos (1.93 larvae/plant) was next best followed by diafenthiuron (2.87 larvae/plant) and dimethoate (3.27 larvae/plant) which were on par with each other but significantly superior over control (6.33 larvae/plant).

At 5 DAS, chlorantraniliprole (0.40 larvae/plant), emamectin benzoate (0.47 larvae/plant), spinosad (0.53 larvae/plant) and indoxacarb (0.73 larvae/plant) were on par while rest of the treatments were less effective in managing leaf webber. After 7 DAS, similar trend was observed wherein chlorantraniliprole (0.33 larvae/plant), spinosad and emamectin benzoate (0.47 larvae/plant each) and indoxacarb (0.67 larvae/plant) were on par and significantly superior over chlorpyriphos (1.67 larvae/plant each), diafenthiuron (2.40 larvae/plant), dimethoate (2.87 larvae/plant) and control (5.80 larvae/plant).

The per cent reduction in larval population in various treatments over control in decreasing order of efficacy was chlorantraniliprole (80.36 %), emamectin benzoate (75.16 %), spinosad (73.45 %), indoxacarb (65.63 %), chlorpyriphos (49.07 %), diafenthiuron (44.23 %) and dimethoate (36.08 %).

### 4.2.3 Pooled Mean Efficacy of Insecticides against Leaf Webber

The pooled mean efficacy of the insecticides over two-year period *i.e. rabi*, 2018-19 and 2019-20 was calculated and the results are furnished in table 4.7.

The pre spray mean population of leaf webber ranged from 4.87-5.13 larvae/plant. Chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb were found to be on par with each other (3$^{rd}$ day) and significantly different from the remaining three insecticides *i.e.* chlorpyriphos, diafenthiuron and dimethoate. The mean number of larvae per plant in different treatments were 1.13, 1.20, 1.20, 1.40, 2.97, 3.60 and 3.90, respectively while in control it was 5.23 larvae per plant. Similar trend was noticed on 5$^{th}$ day with chlorantraniliprole recording lowest mean number of larvae per plant (0.97) followed by spinosad (1.03), emamectin benzoate (1.10) and indoxacarb

**Table 4.7. Bio-efficacy of insecticides against leaf webber in cauliflower (Pooled) during *rabi*, 2018-19 and 2019-20**

| Treatments | No. of leaf webber larvae/plant* | | | | Per cent reduction over control after I spray | No. of leaf webber larvae/plant* | | | | Per cent reduction over control after II spray | Overall mean per cent reduction |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-Spray | 3 DAS I | 5 DAS I | 7 DAS I | | Pre-spray | 3 DAS II | 5 DAS II | 7 DAS II | | |
| Chlorantraniliprole 18.5 SC | 4.97 (2.43) | 1.13[a] (1.46) | 0.97[a] (1.40) | 0.80[a] (1.34) | 84.41 | 1.70 [a] (1.64) | 0.40 [a] (1.18) | 0.33 [a] (1.15) | 0.27 [a] (1.13) | 83.64 | 84.03 |
| Spinosad 2.5 SC | 4.87 (2.42) | 1.20[a] (1.48) | 1.03[a] (1.43) | 0.97 [ab] (1.40) | 80.71 | 1.83 [a] (1.68) | 0.53 [ab] (1.24) | 0.47 [ab] (1.21) | 0.40 [ab] (1.18) | 77.48 | 79.10 |
| Emamectin Benzoate 5 SG | 4.97 (2.44) | 1.20 [a] (1.48) | 1.10 [a] (1.45) | 1.10 [ab] (1.45) | 78.57 | 2.00[a] (1.73) | 0.47 [ab] (1.21) | 0.40 [ab] (1.18) | 0.40 [ab] (1.18) | 79.40 | 78.99 |
| Indoxacarb 14.5 SC | 4.93 (2.43) | 1.40 [a] (1.55) | 1.30 [a] (1.52) | 1.23 [b] (1.49) | 75.84 | 2.00 [a] (1.73) | 0.70 [b] (1.30) | 0.63 [b] (1.28) | 0.57 [b] (1.25) | 70.64 | 73.25 |
| Diafenthiuron 50 WP | 4.97 (2.44) | 3.60 [bc] (2.14) | 3.50 [c] (2.12) | 3.27 [d] (2.07) | 36.31 | 3.73 [bc] (2.17) | 2.50 [c] (1.87) | 2.23 [d] (1.80) | 1.97[d] (1.72) | 45.60 | 40.96 |
| Chlorpyriphos 50 EC | 5.0 (2.42) | 2.97 [b] (1.99) | 2.67 [b] (1.94) | 2.50 [c] (1.87) | 51.60 | 3.00 [b] (1.99) | 1.77[d] (1.66) | 1.60 [c] (1.61) | 1.33 [c] (1.53) | 54.33 | 52.97 |
| Dimethoate 30 EC | 4.87 (2.42) | 3.90 [c] (2.21) | 3.77 [c] (2.18) | 3.67 [d] (2.16) | 27.05 | 4.03 [c] (2.24) | 2.90 [c] (1.97) | 2.70 [d] (1.92) | 2.53 [d] (1.88) | 35.33 | 31.19 |
| Control | 5.13 (2.47) | 5.23 [d] (2.50) | 5.23 [d] (2.49) | 5.30 [e] (2.51) | - | 5.43 [d] (2.54) | 5.60 [d] (2.57) | 5.37 [e] (2.52) | 5.27 [d] (2.50) | - | - |
| C.D. (P≤0.05) | N/S | 0.21 | 0.17 | 0.12 | - | 0.17 | 0.11 | 0.10 | 0.12 | - | - |
| SE(m) (±) | 0.071 | 0.07 | 0.06 | 0.04 | - | 0.06 | 0.04 | 0.03 | 0.04 | - | - |
| SE(d) (±) | 0.10 | 0.10 | 0.08 | 0.05 | - | 0.08 | 0.05 | 0.04 | 0.06 | - | - |
| C.V. (%) | 5.01 | 6.31 | 5.37 | 3.70 | - | 4.81 | 3.97 | 3.42 | 4.48 | - | - |

*Mean of 5 plants

Figures in parentheses are square root transformed values; Treatments denoted with same alphabets within a column are not significant at 5% level

DAS – Days after Spraying; I – First spray; II – Second spray;

(1.30) which were found to be on par with each other. Chlorpyriphos, diafenthiuron and dimethoate recorded 2.67, 3.50 and 3.77 mean no. larvae per plant as compared to 5.23 in control. The mean larval population of leaf webber per plant in chlorantraniliprole (0.80), spinosad (0.97) and emamectin benzoate (1.10) were on par but chlorantraniliprole differed significantly from indoxacarb (1.23) on 7th day. Chlorpyriphos with mean number of 2.50 larvae per plant differed significantly from diafenthiuron (3.27) and dimethoate (3.67). All insecticides were superior over control (5.30). The mean per cent reduction of leaf webber in different treatments over control in decreasing order of efficacy was chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate with 84.41, 80.71, 78.57, 75.84, 51.60, 36.31 and 27.05, respectively.

The mean population of leaf webber ranged from 1.70-5.43 larvae per plant a day before second spray. Chlorantraniliprole (0.40), emamectin benzoate (0.47) and spinosad (0.53) were found to be on par while chlorantraniliprole was found to be significantly different from indoxacarb (0.70) and from the remaining three insecticides *i.e* chlorpyriphos (1.77), diafenthiuron (2.50) and dimethoate (2.90) while in control 5.60 mean larvae per plant were observed on 3rd day. Similar trend was noticed with chlorantraniliprole recording lowest mean number of larvae per plant (0.33) on 5th day followed by emamectin benzoate (0.40) and spinosad (0.47) which were found to be on par but chlorantraniliprole differed significantly from indoxacarb (0.63). Chlorpyriphos, diafenthiuron and dimethoate recorded 1.60, 2.23 and 2.70 mean larvae per plant as compared to 5.37 in control. On 7th day, the mean larval population of leaf webber in chlorantraniliprole (0.27), spinosad (0.40) and emamectin benzoate (0.40) were on par but chlorantraniliprole differed significantly from indoxacarb (0.57). Chlorpyriphos with 1.33 mean number larvae per plant differed significantly from diafenthiuron (1.97) and dimethoate (2.53). All insecticides were superior over control (5.27). The mean per cent reduction in larval population in various treatments over control in decreasing order of efficacy was chlorantraniliprole (83.64 %), emamectin benzoate (79.40 %), spinosad (77.48 %), indoxacarb (70.64 %), chlorpyriphos (54.33 %), diafenthiuron (45.60 %) and dimethoate (35.33 %).

A perusal of table 4.7 showed that the population of leaf webber declined from 3 days to 7 days after I and II sprays respectively and increased at 14 days indicating that the effectiveness of the insecticides was only upto 7 days. The overall mean per cent reduction revealed that chlorantraniliprole was the most effective insecticide against leaf webber with 84.03 per cent reduction in population followed by spinosad (79.10%), emamectin benzoate (78.99%) and indoxacarb (73.25%). Chlorpyriphos, diafenthiuron and dimethoate were less effective with 52.97, 40.96 and 31.19 per cent reduction over control, respectively (Fig 4.8).

Thus, from the present studies it is clearly evident that chlorantraniliprole was the best treatment in managing leaf webber in cauliflower followed by spinosad, emamectin benzoate and indoxacarb. All these four insecticides have a novel mode of action targeting insect ryanodine receptors, nicotinic acetyl choline receptors, GABA receptors and blocking sodium channels, respectively.

Chlorantraniliprole belonging to the anthranilic diamide chemical class has a novel mode of action. It acts as an activator of insect ryanodine receptors, causing rapid muscle dysfunction and paralysis. It is a broad spectrum foliar insecticide with contact and systemic action, widely used on vegetables in India for the management of lepidopteran insects both in field and poly houses. Bhede (2017) reported that cyantraniliprole, emamectin benzoate, chlorantraniliprole, flubendiamide and novaluron were found effective against leaf webber larvae in cauliflower providing 98.44, 95.40, 91.76, 90.11 and 85.22 per cent reduction in larval population followed by thiodicarb, chlorfenapyr, fipronil and diafenthiuron. Similarly in mustard, Kalasariya and Parmar (2020) found that schedule 3 consisting of thiamethoxam 25 WG @ 0.006% at seedling stage, emamectin benzoate 5 WG @ 0.0025% at pre-flowering stage, *Nomuraea rileyi* @ 2.5 kg ha$^{-1}$ at 50% flowering stage and chlorpyriphos 16% + alphamethrin 1% EC @ 0.055% ($S_3$) at 50% pod formation stage were found superior in managing leaf webber.

The literature on bioefficacy of newer insecticides on leaf webber in cauliflower is scanty. However, greater efficacy of novel insecticides on other lepidopteran pests like diamondback moth and tobacco caterpillar have been confirmed by several authors. Chowdary and Sharma (2019) reported that the per cent reduction of diamondback moth, *Plutella xylostella* (L.) larval population over untreated check was highest in chlorantraniliprole @ 10 g *a.i.* ha$^{-1}$ (81.02%), followed by spinosad @ 15 g *a.i.* ha$^{-1}$ (78.13%) and indoxacarb @ 40 g *a.i.* ha$^{-1}$ (78.02%). Also, Harika *et al.* (2019) revealed that spinosad 45 SC, indoxacarb 14.5 SC and emamectin benzoate 5 SG proved to be highly effective in reducing diamondback moth larval population in cauliflower with 84.85, 77.40 and 69.17 per cent reduction in population over untreated control at 3 and

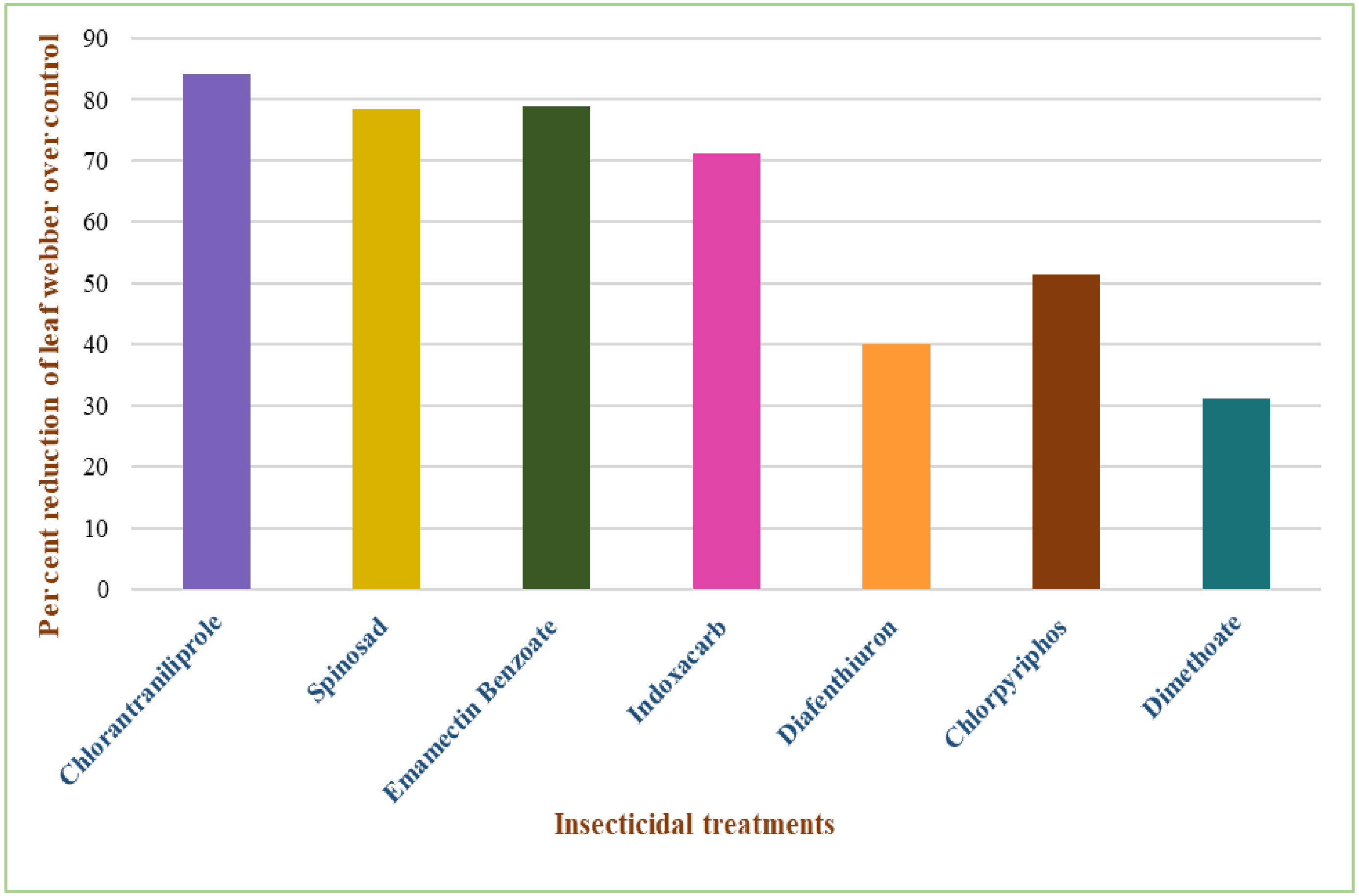



**Fig. 4.8. Efficacy of selected insecticides against leaf webber in cauliflower**

7 days after spray. Similarly, Nayak *et al.* (2019) reported that chlorantraniliprole (0.44 larva/plant) was very effective in recording lowest larval population of *P. xylostella* (L.) and was statistically on par with emamectin benzoate (0.53 larva/plant), flubendiamide (0.60 larva/ plant), spinosad (0.67 larva/plant), indoxacarb (0.73 larva/plant) when compared to the standard check dichlorvos (0.78 larva/plant).

Earlier, Babu *et al*. (2002b) also stated that indoxacarb @ 29 g *a.i.* $ha^{-1}$ was effective in reducing the larval population of DBM on cauliflower and thereby increasing the yield. Liu *et al*. (2003) reported indoxacarb @ 0.05 to 0.07 kg g *a.i.* $ha^{-1}$ was effective against DBM by suppressing the larvae below ETL. In addition, indoxacarb was as effective as spinosad and significantly more effective than emamectin benzoate. Stanikzi and Thakur (2016) revealed that the maximum percentage reduction of diamondback moth on cabbage was recorded in spinosad 45 SC (49.4%) which was significantly superior over control followed by indoxacarb 14.5 SC (45.3%), cypermethrin 5 EC (44.2%), emamectin benzoate 5 SG (42.7%), profenophos 50 EC (40.9%), NSKE (39.1%), Neem oil (39.7%) was least effective among all the treatments.

Laboratory studies conducted by Vijayaraghavan *et al.* (2006) and Kannan *et al.* (2011) on leaf webber in cauliflower by leaf disc method revealed that the novel insecticides tested *viz*., emamectin benzoate, spinosad and indoxacarb were superior in toxicity compared to azadirachtin and quinalphos. Similar studies by Sambathkumar (2020) revealed that chlorantraniliprole 18.5% SC and flubendiamide 39.5% SC exposure for short period (24 hrs) led to feeding cessation and complete control of DBM and leaf webber.

These novel group of insecticides were followed by chlorpyriphos, diafenthiuron and dimethoate which caused 35.55 to 54.27% reduction in population of leaf webber over control.

#### 4.2.3. Efficacy of insecticides against aphids during *rabi*, 2018-19

The population of aphids in various treatments a day before first spraying ranged from 95.07 to 99.67 aphids/3 leaves/plant (Table 4.8). There was no significant difference in population among the various treatments.

The aphid population at 3 days after first spray was significantly lowest *i.e.* 30.07 aphids/3 leaves/plant in plots sprayed with dimethoate followed by chlorpyriphos

**Table 4.8. Bio-efficacy of insecticides against aphids in cauliflower during *rabi*, 2018-19**

| Treatments | Dose (g a.i. ha$^{-1}$) | No. of aphids/3 leaves/plant* | | | | Per cent reduction over control after I spray | No. of aphids/3 leaves/plant* | | | | Per cent reduction over control after II spray |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-spray | 3 DAS I | 5 DAS I | 7 DAS I | | Pre-spray | 3 DAS II | 5 DAS II | 7 DAS II | |
| Chlorantraniliprole 18.5 SC | 10 | 95.07 (9.80) | 92.40 $^{e}$ (9.66) | 90.53 $^{e}$ (9.57) | 88.47 $^{e}$ (9.46) | 14.59 | 98.53 $^{d}$ (9.98) | 88.80$^{e}$ (9.48) | 84.33 $^{e}$ (9.24) | 82.80$^{e}$ (9.15) | 16.62 |
| Spinosad 2.5 SC | 17.5 | 96.13 (9.85) | 93.33 $^{e}$ (9.71) | 92.33 $^{e}$ (9.66) | 92.13 $^{e}$ (9.65) | 12.04 | 106.00 $^{e}$ (10.34) | 96.07 $^{e}$ (9.85) | 93.13$^{e}$ (9.70) | 92.33$^{f}$ (9.66) | 13.57 |
| Emamectin Benzoate 5 SG | 10 | 96.73 (9.89) | 75.33 $^{d}$ (8.74) | 71.73$^{d}$ (8.53) | 71.60 $^{d}$ (8.52) | 32.07 | 93.60 $^{d}$ (9.73) | 72.33 $^{d}$ (8.56) | 68.47 $^{d}$ (8.33) | 69.73 $^{d}$ (8.41) | 26.08 |
| Indoxacarb 14.5 SC | 40 | 96.20 (9.86) | 94.60 $^{e}$ (9.78) | 92.80 $^{e}$ (9.69) | 94.27 $^{e}$ (9.76) | 10.06 | 100.13 $^{d}$ (10.06) | 95.07$^{e}$ (9.80) | 92.93$^{e}$ (9.69) | 90.20$^{ef}$ (9.55) | 10.62 |
| Diafenthiuron 50 WP | 300 | 96.73 (9.89) | 66.40 $^{c}$ (8.21) | 59.53 $^{c}$ (7.78) | 57.33 $^{c}$ (7.64) | 45.61 | 85.80 $^{c}$ (9.31) | 62.07 $^{c}$ (7.94) | 57.13 $^{c}$ (7.62) | 53.47 $^{c}$ (7.38) | 38.17 |
| Chlorpyriphos 50 EC | 500 | 99.67 (10.03) | 50.00 $^{b}$ (7.06) | 40.07 $^{b}$ (6.40) | 35.00 $^{b}$ (5.99) | 67.77 | 73.27 $^{b}$ (8.61) | 40.60 $^{b}$ (6.42) | 32.80 $^{b}$ (5.81) | 31.33 $^{b}$ (5.68) | 57.57 |
| Dimethoate 30 EC | 200 | 95.80 (9.84) | 30.07 $^{a}$(5.57) | 24.60 $^{a}$ (5.06) | 19.40$^{a}$ (4.50) | 81.41 | 65.20 $^{a}$ (8.13) | 15.47 $^{a}$ (4.04) | 13.07 $^{a}$ (3.74) | 12.93 $^{a}$ (3.72) | 80.32 |
| Control | - | 99.67 (10.03) | 104.20$^{e}$ (10.26) | 108.00 $^{f}$ (10.44) | 108.60 $^{f}$ (10.47) | 0 | 118.67 $^{f}$ (10.94) | 115.13$^{f}$ (10.77) | 118.47$^{f}$ (10.92) | 119.60$^{g}$ (10.98) | 0 |
| C.D. ($P \leq 0.05$) | - | N/S | 0.93 | 0.32 | 0.49 | - | 0.42 | 0.72 | 0.58 | 0.47 | - |
| SE(m) (±) | - | 0.12 | 0.30 | 0.10 | 0.16 | - | 0.14 | 0.24 | 0.18 | 0.15 | - |
| SE(d) (±) | - | 0.18 | 0.43 | 0.15 | 0.23 | - | 0.19 | 0.33 | 0.26 | 0.22 | - |
| C.V. (%) | - | 2.16 | 6.09 | 2.15 | 3.36 | - | 2.45 | 4.79 | 3.88 | 3.26 | - |

*Mean of 5 plants
Figures in parentheses are square root transformed values; Treatments denoted with same alphabets within a column are not significant at 5% level
DAS – Days after Spraying; I – First spray; II – Second spray;

(50.00) and diafenthiuron (66.40) while the remaining treatments *i.e.* chlorantraniliprole, spinosad and indoxacarb were least effective and were on par with control (Table 4.8).

At 5 days after first spray, highest reduction in aphid population was observed in dimethoate (24.60 aphids/3 leaves/plant) followed by chlorpyriphos (40.07 aphids/3 leaves/plant) and diafenthiuron (59.53 aphids/3 leaves/plant). The remaining treatments *viz.* chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb recorded significantly higher population of 90.53, 92.33, 71.73 and 92.80 aphids/3 leaves/plant.

At 7 days after first spray, dimethoate was found to be significantly superior recording 19.40 aphids/3 leaves/plant followed by chlorpyriphos and diafenthiuron recording 35.00 and 57.33 aphids/3 leaves/plant, respectively. The treatments *viz.* chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb recorded significantly higher aphid population. The per cent reduction of aphids in different treatments over control at seven days after first spray in decreasing order of efficacy was dimethoate, chlorpyriphos, diafenthiuron, emamectin benzoate, chlorantraniliprole, spinosad and indoxacarb with 81.41, 67.77, 45.61, 32.07, 14.59, 12.04 and 10.06, respectively.

The population of aphid ranged from 65.20 to 118.67 aphids/3 leaves/plant at 14 days after first spray necessitating second spraying. The mean aphid population at 3 days after second spray indicated that significantly lowest population of 15.47 aphids/3 leaves/plant was observed in plots sprayed with dimethoate followed by chlorpyriphos (40.60 aphids/3 leaves/plant). The remaining treatments *i.e.* chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb and diafenthiuron recorded significantly higher population of 88.80, 96.07, 72.33, 95.07 and 62.07 aphids/3 leaves/plant, respectively (Table 4.8).

At 5 days after second spray, gradual reduction in aphid population was observed in the treatments with dimethoate recording significantly lowest aphid population (13.07 aphids/3 leaves/plant). The next best treatment in managing aphids were chlorpyriphos (32.80 aphids/3 leaves/plant) and diafenthiuron (57.13 aphids/3 leaves/plant) which were significantly different from each other and from other treatments. The remaining treatments continued to record significantly higher aphid population including control.

At 7 days after second spray the aphid population ranged from 12.93 to 119.60 aphids/3 leaves/plant with dimethoate recording lowest aphid population and control recording highest population. Chlorpyriphos and diafenthiuron recorded a population of 31.33 and 53.47 aphids/3 leaves/plant, respectively. Other treatments *viz.*, chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb recorded significantly higher populations of 82.80, 92.33, 69.73 and 90.20 aphids/3 leaves/plant. The per cent reduction in aphid population in decreasing order of efficacy after second spray was dimethoate (80.32 %), chlorpyriphos (57.57 %), diafenthiuron (38.17 %), emamectin benzoate (26.08 %), chlorantraniliprole (16.62 %), spinosad (13.57 %) and indoxacarb (10.62 %) over control.

#### 4.2.3. Efficacy of Insecticides against Aphids During *Rabi*, 2019-20

The second season recorded higher population of aphids ranging from 122.53 to 125.00 aphids/3 leaves/plant a day before first spray showing that there was no significant difference in population among the various treatments (Table 4.9). At 3 days after first spray, dimethoate recorded significantly lower population of 36.87 aphids/3 leaves/plant followed by chlorpyriphos (55.13 aphids/3 leaves/plant). The remaining treatments *i.e.* chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb and diafenthiuron had higher population of aphids while highest population (125.93 aphids/3 leaves/plant) was recorded in control.

At 5 days after first spray, gradual reduction in aphid population was observed in the treatments with dimethoate recording significantly lowest aphid population (34.73 aphids/3 leaves/plant). The next best treatment in managing aphids were chlorpyriphos (46.07 aphids/3 leaves/plant) and diafenthiuron (74.73 aphids/3 leaves/plant) which differed significantly with each other. The remaining treatments recorded significantly higher pest population.

At 7 days after first spray, dimethoate continued to be superior over control by recording 30.00 aphids/3 leaves/plant followed by chlorpyriphos (42.8 aphids/3 leaves/plant). Other treatments recorded significantly higher aphid population. The population of aphids gradually decreased up to 7 days after first spray. The per cent reduction of aphids in different treatments over control in decreasing order of efficacy was dimethoate, chlorpyriphos, diafenthiuron, emamectin benzoate, chlorantraniliprole,

**Table 4.9. Bio-efficacy of insecticides against aphids in cauliflower during *rabi*, 2019-20**

| Treatments | Dose (g a.i. ha$^{-1}$) | No. of aphids/3 leaves/plant* | | | | Per cent reduction over control after I spray | No. of aphids/3 leaves/plant* | | | | Per cent reduction over control after II spray |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-spray | 3 DAS I | 5 DAS I | 7 DAS I | | Pre-spray | 3 DAS II | 5 DAS II | 7 DAS II | |
| Chlorantraniliprole 18.5 SC | 10 | 125.00<br>(11.22) | 119.20$^{e}$<br>(10.96) | 112.47$^{e}$<br>(10.65) | 110.80$^{e}$<br>(10.57) | 12.87 | 121.13$^{e}$<br>(11.05) | 113.33$^{e}$<br>(10.69) | 110.33$^{e}$<br>(10.55) | 102.33$^{e}$<br>(10.16) | 12.10 |
| Spinosad 2.5 SC | 17.5 | 124.13<br>(11.19) | 121.40$^{e}$<br>(11.06) | 120.40$^{ef}$<br>(11.02) | 121.27$^{f}$<br>(11.06) | 3.97 | 126.13$^{ef}$<br>(11.28) | 120.67$^{e}$<br>(11.03) | 120.07$^{ef}$<br>(11.00) | 113.07$^{ef}$<br>(10.67) | 6.73 |
| Emamectin Benzoate 5 SG | 10 | 122.53<br>(11.11) | 92.33$^{d}$<br>(9.66) | 85.47$^{d}$<br>(9.30) | 87.33$^{d}$<br>(9.40) | 29.94 | 100.20$^{d}$<br>(10.06) | 80.40$^{d}$<br>(9.02) | 75.40$^{d}$<br>(8.74) | 79.87$^{d}$<br>(8.99) | 17.06 |
| Indoxacarb 14.5 SC | 40 | 123.93<br>(11.18) | 120.67$^{e}$<br>(11.03) | 120.20$^{ef}$<br>(11.01) | 120.80$^{f}$<br>(11.04) | 4.19 | 129.2$^{ef}$<br>(11.41) | 120.07$^{e}$<br>(11.00) | 121.73$^{ef}$<br>(11.08) | 111.33$^{ef}$<br>(10.60) | 10.34 |
| Diafenthiuron 50 WP | 300 | 123.40<br>(11.15) | 80.87$^{c}$<br>(9.05) | 74.73$^{c}$<br>(8.70) | 69.47$^{c}$<br>(8.39) | 44.66 | 84.73$^{c}$<br>(9.26) | 57.40$^{c}$<br>(7.64) | 49.40$^{c}$<br>(7.10) | 44.40$^{c}$<br>(6.74) | 45.48 |
| Chlorpyriphos 50 EC | 500 | 124.20<br>(11.19) | 55.13$^{b}$<br>(7.47) | 46.07$^{b}$<br>(6.85) | 42.80$^{b}$<br>(6.60) | 66.13 | 63.20$^{b}$<br>(8.01) | 36.13$^{b}$<br>(6.09) | 35.20$^{b}$<br>(6.00) | 31.20$^{b}$<br>(5.64) | 48.63 |
| Dimethoate 30 EC | 200 | 124.87<br>(11.22) | 36.87$^{a}$<br>(6.15) | 34.73$^{a}$<br>(5.98) | 30.00$^{a}$<br>(5.56) | 76.38 | 48.20$^{a}$<br>(7.01) | 18.60$^{a}$<br>(4.42) | 14.60$^{a}$<br>(3.93) | 13.00$^{a}$<br>(3.73) | 71.94 |
| Control | - | 123.53<br>(11.16) | 125.93$^{e}$<br>(11.27) | 127.27$^{f}$<br>(11.32) | 125.67$^{f}$<br>(11.25) | 0 | 133.67$^{f}$<br>(11.60) | 133.20$^{f}$<br>(11.58) | 131.93$^{f}$<br>(11.53) | 128.47$^{f}$<br>(11.37) | 0 |
| C.D. ($P \leq 0.05$) | - | N/S | 0.50 | 0.45 | 0.44 | - | 0.47 | 0.45 | 0.54 | 0.82 | - |
| SE(m) (±) | - | 0.15 | 0.16 | 0.15 | 0.14 | - | 0.16 | 0.15 | 0.18 | 0.27 | - |
| SE(d) (±) | - | 0.21 | 0.23 | 0.21 | 0.20 | - | 0.22 | 0.21 | 0.25 | 0.38 | - |
| C.V. (%) | - | 2.26 | 2.93 | 2.73 | 2.70 | - | 2.69 | 2.87 | 3.52 | 5.45 | - |

*Mean of 5 plants

Figures in parentheses are square root transformed values; Treatments denoted with same alphabets within a column are not significant at 5% level

DAS – Days after Spraying; I – First spray; II – Second spray;

indoxacarb and spinosad with 76.38, 66.13, 44.66, 29.94, 12.87, 4.19 and 3.97 per cent reduction, respectively.

The aphid population one day before second spray ranged from 48.20 to 133.67 aphids/ 3 leaves/plant. The aphid population at 3 DAS indicated that significantly lowest population of 18.67 aphids/3 leaves/plant was observed in plots sprayed with dimethoate followed by chlorpyriphos with 36.13 aphids/3 leaves/plant. Diafenthiuron with 57.40 aphids/3 leaves/plant was found to be significantly different from other treatments. The remaining treatments *i.e.* chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb and diafenthiuron recorded significantly higher population of *i.e.* 110.33, 120.07, 80.40 and 120.07 respectively (Table 4.9).

At 5 days after second spray, gradual reduction in aphid population was observed in the treatments with dimethoate recording the lowest aphid population (14.60 aphids/3 leaves/plant). Chlorpyriphos was the next best treatment in managing aphids by recording 35.20 aphids/3 leaves/plant while diafenthiuron recorded 49.40 aphids/3 leaves/plant.

At 7 days after second spray the aphid population ranged from 13.00 to 128.47 aphids/3 leaves/plant with dimethoate recording lowest aphid population and control recording highest population. Chlorpyriphos and diafenthiuron recorded a population of 31.20 and 44.40 aphids/3 leaves/plant, respectively. Other treatments *viz.,* chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb recorded significantly higher populations of 80-114 aphids/3 leaves/plant. The per cent reduction of aphid population in different treatments over control in decreasing order of efficacy was dimethoate (71.94%), chlorpyriphos (48.63%), diafenthiuron (45.48%), emamectin benzoate (17.06%), chlorantraniliprole (12.10%), indoxacarb (10.34%) and spinosad (6.73%).

#### 4.2.3 Pooled Mean Efficacy of Insecticides against Aphids in Cauliflower

The pooled mean efficacy of the insecticides over two-year period *i.e rabi*, 2018-19 and 2019-20 was calculated and the results are furnished in table 4.10.

The pre spray mean population of aphids ranged from 109.63 to 111.93 aphids/3 leaves/plant. Dimethoate was found to be significantly different followed by chlorpyriphos and diafenthiuron on 3$^{rd}$ day. The other treatments like emamectin benzoate, chlorantraniliprole, spinosad and indoxacarb recorded significantly higher

**Table 4.10. Bio-efficacy of insecticides against aphids in cauliflower (Pooled) during *rabi*, 2018-19 and 2019-20**

| Treatments | No. of aphids/3 leaves/plant* | | | | Per cent reduction over control at 7 DAS I | No. of aphids/3 leaves/plant* | | | | Per cent reduction over control at 7 DAS II | Overall mean per cent reduction over control |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre spray | 3 DAS I | 5 DAS I | 7 DAS I | | Pre spray | 3 DAS II | 5DAS II | 7 DAS II | | |
| Chlorantraniliprole 18.5 SC | 110.03 (10.54) | 105.80$^{e}$ (10.33) | 101.50$^{e}$ (10.12) | 99.63$^{e}$ (10.03) | 13.71 | 109.83$^{e}$ (10.53) | 101.07$^{e}$ (10.10) | 97.33$^{e}$ (9.92) | 92.57$^{e}$ (9.67) | 14.28 | 14.00 |
| Spinosad 2.5 SC | 110.13 (10.54) | 107.37$^{e}$ (10.41) | 106.37$^{f}$ (10.36) | 106.70$^{f}$ (10.38) | 7.67 | 116.07$^{f}$ (10.82) | 108.37$^{e}$ (10.46) | 106.60$^{f}$ (10.37) | 102.70$^{f}$ (10.18) | 10.01 | 8.84 |
| Emamectin Benzoate 5 SG | 109.63 (10.52) | 83.83$^{d}$ (9.21) | 78.60$^{d}$ (8.92) | 79.47$^{d}$ (8.97) | 30.92 | 96.90$^{d}$ (9.89) | 76.37$^{d}$ (8.79) | 71.93$^{d}$ (8.54) | 74.80$^{d}$ (8.71) | 21.49 | 26.21 |
| Indoxacarb 14.5 SC | 110.07 (10.54) | 107.63$^{e}$ (10.42) | 106.50$^{f}$ (10.37) | 107.53$^{f}$ (10.42) | 6.90 | 114.70$^{ef}$ (10.76) | 107.57 (10.42) | 107.33$^{f}$ (10.41) | 100.77$^{ef}$ (10.09) | 10.65 | 8.78 |
| Diafenthiuron 50 WP | 110.07 (10.54) | 73.63$^{c}$ (8.64) | 67.13$^{c}$ (8.25) | 63.40$^{c}$ (8.03) | 45.11 | 85.27$^{c}$ (9.29) | 59.73$^{c}$ (7.79) | 53.27$^{c}$ (7.37) | 48.93$^{c}$ (7.07) | 41.64 | 43.37 |
| Chlorpyriphos 50 EC | 111.93 (10.63) | 52.57$^{b}$ (7.31) | 43.07$^{b}$ (6.64) | 38.90$^{b}$ (6.31) | 66.88 | 68.23$^{b}$ (8.32) | 38.37$^{b}$ (6.26) | 34.00$^{b}$ (5.92) | 31.27$^{b}$ (5.68) | 53.39 | 60.14 |
| Dimethoate 30 EC | 110.33 (10.55) | 33.47$^{a}$ (5.87) | 29.67$^{a}$ (5.54) | 24.70$^{a}$ (5.07) | 78.66 | 56.70$^{a}$ (7.60) | 17.03$^{a}$ (4.25) | 13.83$^{a}$ (3.85) | 12.97$^{a}$ (3.73) | 76.74 | 77.70 |
| Control | 111.60 (10.61) | 115.07 (10.77) | 117.63 (10.89) | 117.13 (10.87) | - | 126.17 (11.28) | 124.17 (11.19) | 125.20 (11.23) | 124.03 (11.18) | - | - |
| C.D. (P≤0.05) | N/S | 0.33 | 0.21 | 0.25 | - | 0.27 | 0.41 | 0.25 | 0.43 | - | - |
| SE(m) (±) | 0.08 | 0.11 | 0.07 | 0.08 | - | 0.09 | 0.13 | 0.08 | 0.14 | - | - |
| SE(d) (±) | 0.11 | 0.15 | 0.10 | 0.11 | - | 0.13 | 0.19 | 0.12 | 0.20 | - | - |
| C.V. (%) | 1.32 | 2.05 | 1.31 | 1.60 | - | 1.58 | 2.69 | 1.69 | 2.96 | - | - |

Figures in parenthesis are square root transformed values;
Treatments denoted with same alphabets within a column are not significant at 5% level; DAS – Days after spray; I – 1$^{st}$ Spraying; II – 2$^{nd}$ Spraying

aphid population. The number of aphids/3 leaves/plant in different treatments were 33.47, 52.57, 73.63, 83.83, 105.80, 107.37, and 107.63, respectively while in control 115.07 aphids/3 leaves/plant were recorded.

Similar trend was noticed on 5$^{th}$ day with dimethoate recording lowest mean number of aphids/3 leaves/plant (29.67) followed by chlorpyriphos (43.07), diafenthiuron (67.13) and emamectin benzoate (78.60). Chlorantraniliprole (101.50), spinosad (106.37) and indoxacarb (106.50) were found to be on par as compared to control (117.63). The mean aphid population on 7$^{th}$ day in dimethoate (24.70) differed significantly from chlorpyriphos (43.07) and diafenthiuron (67.13) while emamectin benzoate (79.47), chlorantraniliprole (99.63), spinosad (106.70) and indoxacarb (107.53) recorded significantly higher mean aphid population. The per cent reduction in aphid population in decreasing order of efficacy 7 days after first spray was dimethoate (78.66%) chlorpyriphos (66.88%), diafenthiuron (45.11%) emamectin benzoate (30.92%), chlorantraniliprole (13.71%), spinosad (7.67%) and indoxacarb (6.90%). Dimethoate recorded highest mean per cent reduction and was significantly different from other treatments.

The mean aphid population one day before second spray ranged from 56.70 to 126.17 aphids/3 leaves/plant (Table 4.10). On 3$^{rd}$ day, lowest mean population of aphids was recorded in dimethoate (17.03 aphids/3 leaves/ plant) and was significantly different from chlorpyriphos (38.37) and diafenthiuron (59.73). The mean number of aphids in emamectin benzoate, chlorantraniliprole, indoxacarb and spinosad were 76.37, 101.07, 107.57 and 108.37, respectively while in control they were 124.17 aphids/3 leaves/ plant. Similar trend was noticed on 5$^{th}$ day with dimethoate recording lowest mean number of aphids/3 leaves/plant (13.83) followed by chlorpyriphos (34.00) and diafenthiuron (53.27). Emamectin benzoate was found to be significantly different from other treatments with 71.93 aphids/3 leaves/plant. Chlorantraniliprole (97.33), spinosad (106.60) and indoxacarb (107.33) were found to be on par as compared to (125.20). The aphid population in dimethoate (12.97) was significantly lower over all the other treatments on 7$^{th}$ day. Chlorpyriphos (31.27) and diafenthiuron (48.93) were next best treatments. All insecticides were superior over control (124.03 aphids/3 leaves/plant). The per cent reduction in decreasing order of efficacy was dimethoate (76.74%), chlorpyriphos (53.39%), diafenthiuron (41.64%) emamectin benzoate (21.49%), chlorantraniliprole (14.28%), indoxacarb (10.65%) and spinosad (10.01%) over control. The overall mean per cent reduction revealed that dimethoate was the most effective insecticide against aphids with highest reduction in population (77.70 %) followed by chlorpyriphos (60.14%) while the remaining treatments recorded less than 50% reduction of aphid population (Fig 4.9).

Thus, from the present studies it is clearly evident that dimethoate was the best treatment in managing aphids followed by chlorpyriphos. Chemical control of aphid is the most effective and quick method especially when the population is more. Dimethoate and chlorpyriphos belong to organophosphorus group of insecticides which act on acetyl choline in the nervous system. They possess broad spectrum insecticidal activity against a number of important insect pests. In the present study, the conventional insecticide dimethoate gave effective control of aphids as compared to the other insecticides.

Yadav *et al.* (2021) recorded lowest pooled mean aphid population of 4.36, 3.85 and 2.83 aphids/10 cm on main apical shoot during *rabi*, 2017-18, 2018-19 and 2019-20 and maximum seed yield of 16.80 q $ha^{-1}$ in dimethoate treated plot in mustard. Sharma *et al.* (2020) reported that among nine insecticides tested against mustard aphid, *L. erysimi*, imidacloprid and thiamethoxam among newer insecticides and oxy demeton methyl and dimethoate among conventional insecticides were effective with imidacloprid recording highest incremental cost benefit ratio (1:13.28) followed by dimethoate (1:9.88) and oxydemeton-methyl (1:9.15). Patel *et al.* (2017) tested two neonicotinoid insecticides *viz.*, imidacloprid and thiamethoxam with some conventional insecticides against *L. erysimi* and reported that dimethoate was highly toxic as compared to the other conventional insecticides while chlorpyriphos was moderately toxic to mustard aphid. Sahoo (2012) evaluated different insecticides for their bio-efficacy against *L. erysimi* and found that the plots treated with dimethoate and oxydemeton-methyl recorded minimum aphid infestation and also recorded higher yield ranging from 1151.6 to 1310.3 kg seed $ha^{-1}$. Incremental cost benefit ratio indicated that most favourable return with dimethoate (1:20.8 & 1:13.3) followed by oxydemeton-methyl 25 EC (1:16.8 & 1:9.1) Earlier, Sinha *et al.* (2001) found that chlorpyriphos 20 EC was very effective for controlling mustard aphid and gave maximum yield. Mandal *et al.* (2012) studied the efficacy of different insecticides for the management of mustard aphid on rapeseed in field and found that chlorpyriphos 20 EC was most effective followed by chlorpyriphos+cypermethrin 55 EC, thiamethoxam 25 WG and imidacloprid 17.8 SL for aphid management but highest yield was recorded from chlorpyriphos+cypermethrin followed by thiamethoxam, chlorpyriphos and imidacloprid treated plot.

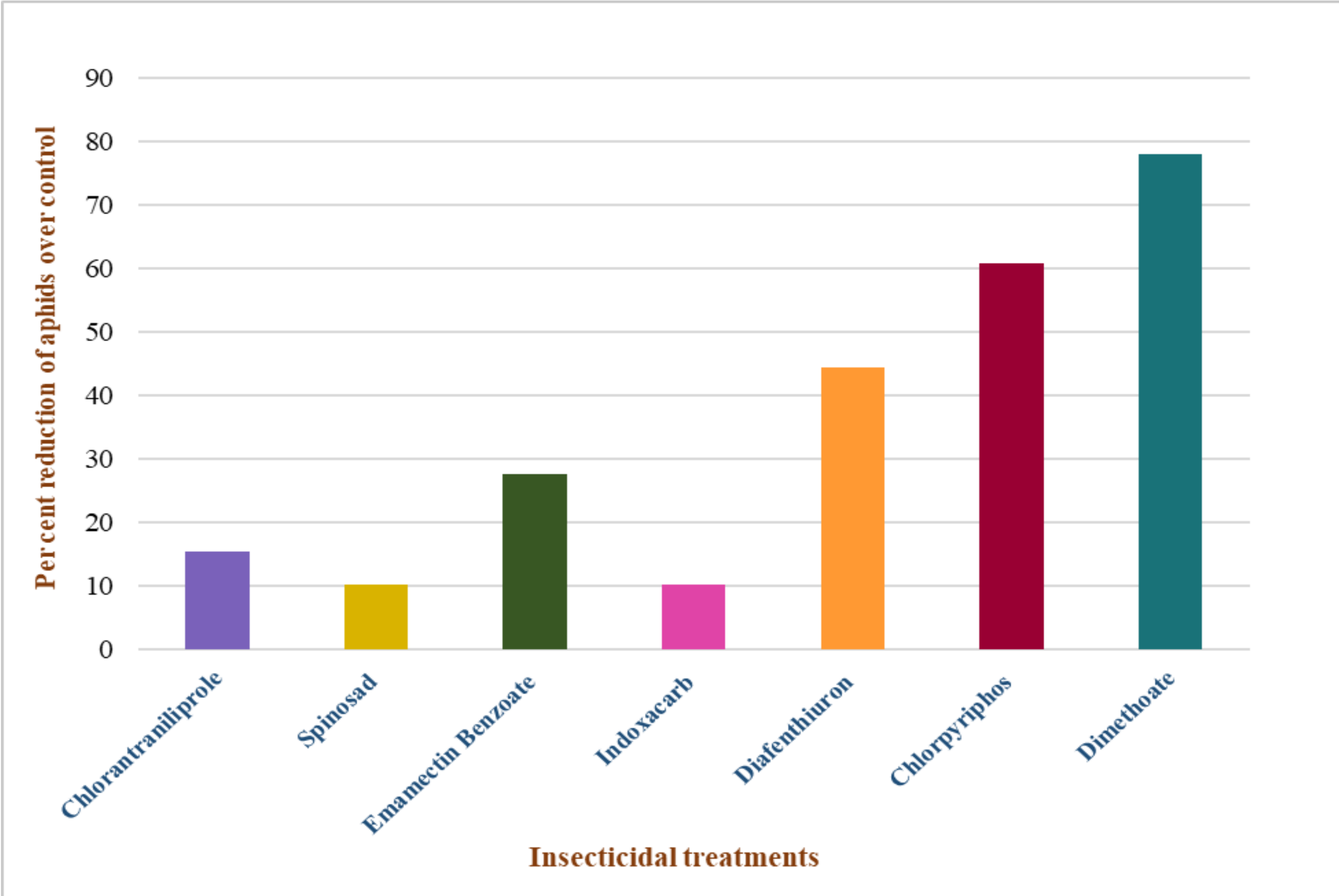



**Fig. 4.9. Efficacy of selected insecticides against aphids in cauliflower**

### 4.2.4. Efficacy of Insecticides against Head Borer Damage in Cauliflower

The data on curd damage at the time of harvesting is presented in Table 4.11. A perusal of the data revealed that all the insecticidal treatments were superior to control in reducing the damage to curd. During 2018-19, chlorantraniliprole was the best treatment with least curd damage of 9.44 per cent followed by emamectin benzoate (10.56 %), spinosad (11.67 %) and indoxacarb (12.22 %) and were on par with each other. The other treatments *viz*., chlorpyriphos, diafenthiuron and dimethoate recorded higher curd damage of 19.44, 20.00 and 22.56 per cent but were significantly superior over control (32.78%) in reducing the per cent curd damage. Similar trend was observed during 2019-20 wherein chlorantraniliprole recorded least curd damage (11.28%) followed by emamectin benzoate 12.31%, spinosad 13.33% and indoxacarb 15.38% which were on par with each other. They were followed by chlorpyriphos, diafenthiuron and dimethoate with 21.03, 22.05 and 25.64 per cent damage while control recorded 39.49% head borer damage.

**Table 4.11. Per cent head borer damage in different insecticidal treatments in cauliflower**

| Treatments | Dose (g or ml/l) | Head borer damage (%) | | |
|---|---|---|---|---|
| | | 2018-19 | 2019-20 | Mean |
| Chlorantraniliprole 18.5 SC | 0.1 | 9.44[a] (17.79) | 11.28[a] (19.56) | 10.36[a] (18.77) |
| Spinosad 2.5 SC | 1.4 | 11.67[a] (19.84) | 13.33[a] (21.28) | 12.50[a] (20.58) |
| Emamectin Benzoate 5 SG | 0.4 | 10.56[a] (18.78) | 12.31[a] (20.43) | 11.43[a] (19.64) |
| Indoxacarb 14.5 SC | 0.55 | 12.22[a] (20.15) | 15.38[a] (23.02) | 13.80[a] (21.75) |
| Diafenthiuron 50 WP | 1.2 | 20.00[b] (26.50) | 22.05[b] (27.98) | 21.03[b] (27.25) |
| Chlorpyriphos 50 EC | 2.0 | 19.44[b] (26.13) | 21.03[b] (27.22) | 20.24[b] (26.69) |
| Dimethoate 30 EC | 1.3 | 20.56[b] (26.84) | 25.64[b] (30.35) | 23.10[b] (28.69) |
| Control | - | 32.78[c] (34.85) | 39.49[c] (38.90) | 36.13[c] (36.92) |
| C.D. ($p \leq 0.05$) | - | 5.86 | 4.07 | 3.48 |
| SE(m) (±) | - | 1.91 | 1.33 | 1.14 |
| SE(d) (±) | - | 2.71 | 1.88 | 1.61 |
| C.V. (%) | - | 13.89 | 8.83 | 7.86 |

Figures in parentheses are angular transformed values

The pooled mean of per cent head damage for the two seasons (2018-19 and 2019-20) revealed that chlorantraniliprole recorded the lowest head borer damage (10.36 %) and was on par with emamectin benzoate (11.43 %), spinosad (12.50 %) and indoxacarb (11.43 %). Dimethoate had significantly higher head borer damage 23.10 per cent and was on par with chlorpyriphos (20.24 %) and diafenthiuron (21.03 %) whereas in control 36.13 per cent head damage was observed (Fig 4.10).

The reported results are in line with the findings of Chowdary *et al.* (2015) who also recorded significantly low head damage in chlorantraniliprole at two different doses 30 g *a.i.* ha$^{-1}$ (2.53%), 20 g *a.i.* ha$^{-1}$ (5.39%) followed by emamectin benzoate (10.67%), spinosad (13.89%), flubendiamide (14.38%) and indoxacarb (20.82%). However, Harika *et al*. (2019) reported the lowest per cent head damage (8.48%) in spinosad followed by indoxacarb (12.36), emamectin benzoate (22.44), flubendiamide (33.64), thiodicarb (41.80), lufenuron (51.68) and acephate (56.80).

**4.2.5 Curd Yield and Incremental Cost Benefit Ratio (ICBR) in Cauliflower**

The data on effect of different insecticides on curd yield of cauliflower during *rabi*, 2018-19 and 2019-20 are presented in Table 4.12. During 2018-19, the yield was significantly highest in the chlorantraniliprole treatment (20.03 t ha$^{-1}$) followed by emamectin benzoate (19.50 t ha$^{-1}$) and spinosad (19.29 t ha$^{-1}$) which were on par with each other and also with indoxacarb (18.87 t ha$^{-1}$). Chlorpyriphos recorded 14.63 t ha$^{-1}$ followed by diafenthiuron and dimethoate with 13.53 and 13.09 t ha$^{-1}$, respectively while lowest yield of 8.74 t ha$^{-1}$ was recorded in control.

During 2019-20, similar trend was noticed with the yield being significantly highest in the chlorantraniliprole treatment (19.45 t ha$^{-1}$) followed by emamectin benzoate (18.82 t ha$^{-1}$), spinosad (18.29 t ha$^{-1}$) indoxacarb (17.86 t ha$^{-1}$), chlorpyriphos (13.88 t ha$^{-1}$), diafenthiuron (12.67 t ha$^{-1}$) and dimethoate (11.20 t ha$^{-1}$), respectively while lowest yield of 6.16 t ha$^{-1}$ was recorded in control.

The pooled mean revealed that the insecticides in decreasing order of their efficacy in terms of yield were chlorantraniliprole, emamectin benzoate, spinosad, indoxacarb, chlorpyriphos, diafenthiuron and dimethoate with 19.74, 19.16, 18.79, 18.36, 14.25, 13.10 and 12.15 t ha$^{-1}$ with control recording lowest yield of 7.45 t ha$^{-1}$.

The incremental yield over control, value of incremental yield over control, cost of the treatments, net incremental profit and incremental cost benefit ratio calculated on

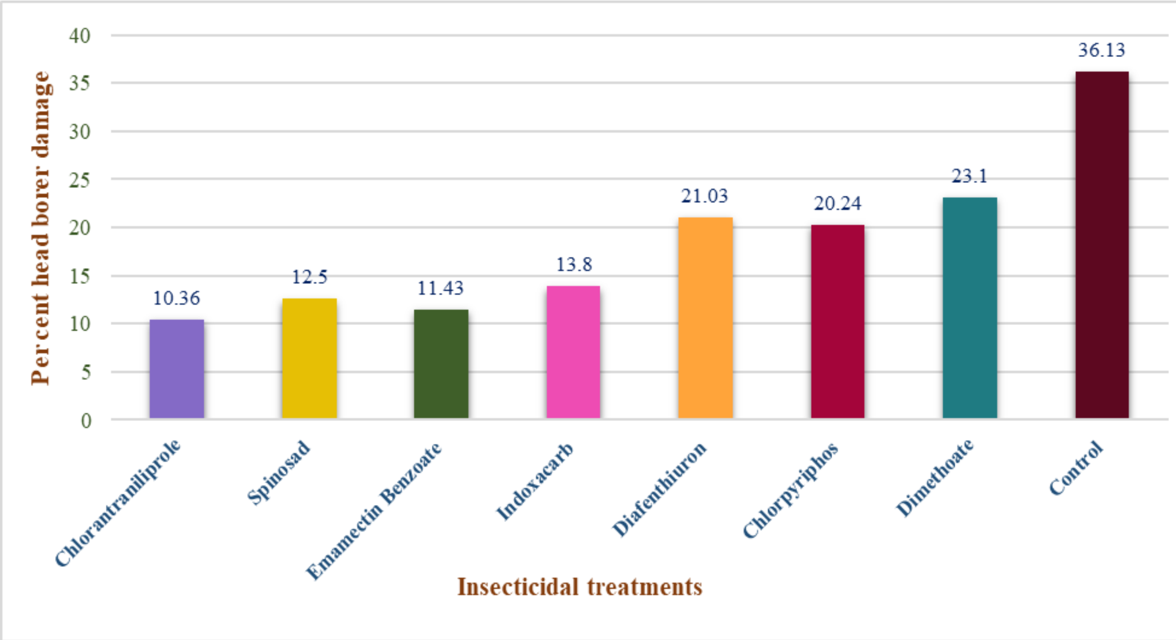



**Fig. 4.10. Mean per cent head borer damage in insecticidal treatments in cauliflower**

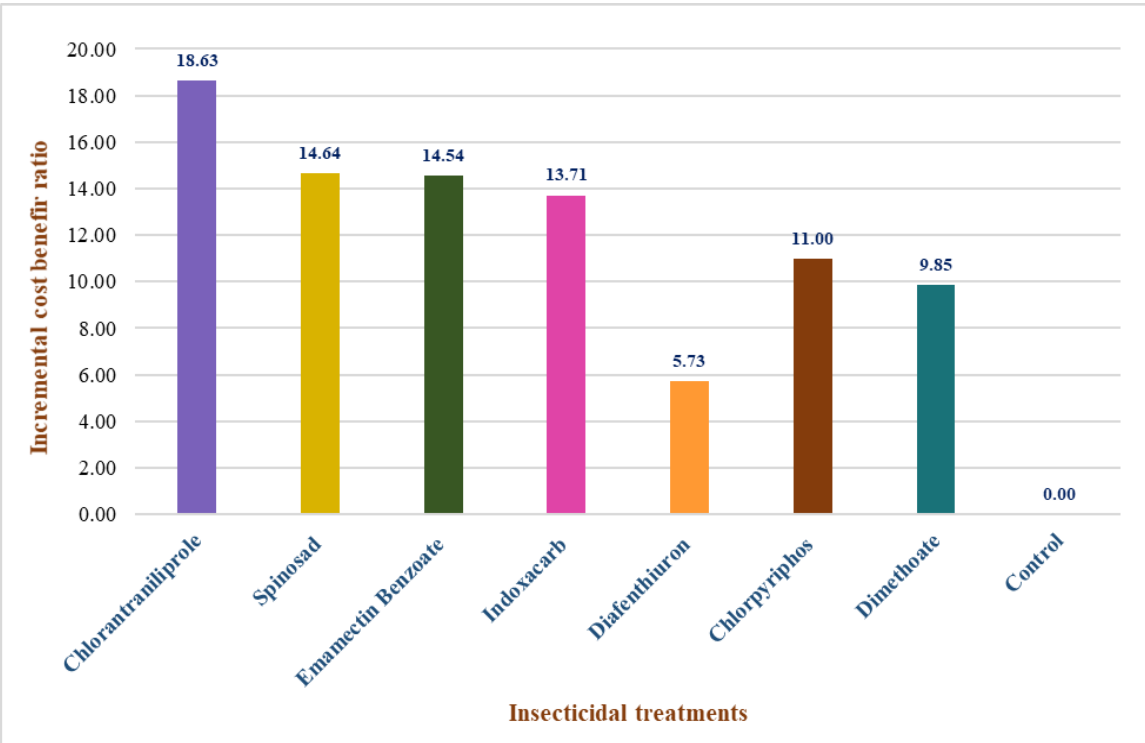



**Fig. 4.11. Incremental cost benefit ratio (ICBR) of selected insecticides in cauliflower**

**Table 4.12. Cauliflower yield in different treatments during *rabi*, 2018-19 and 2019-20 and incremental benefit cost ratio**

| Treatments | Yield ($t\ ha^{-1}$) 2018-19 | Yield ($t\ ha^{-1}$) 2019-20 | Average yield ($t\ ha^{-1}$) | Incremental yield over control ($t\ ha^{-1}$) | Value of incremental yield (Rs.) | Cost of treatments ($Rs\ ha^{-1}$) | Incremental net profit (Rs.) | Incremental Cost Benefit Ratio |
|---|---|---|---|---|---|---|---|---|
| Chlorantraniliprole 18.5 SC | $20.03^{a}$ (26.55) | $19.45^{a}$ (26.15) | $19.74^{a}$ (26.36) | 12.29 | 73745 | 3756 | 69989 | 1:18.41 |
| Spinosad 2.5 SC | $19.29^{a}$ (25.99) | $18.29^{a}$ (25.29) | $18.79^{a}$ (25.67) | 11.34 | 68022 | 4350 | 63672 | 1:14.64 |
| Emamectin Benzoate 5 SG | $19.50^{a}$ (26.12) | $18.82^{a}$ (25.67) | $19.16^{a}$ (25.91) | 11.71 | 70245 | 4520 | 65725 | 1:14.54 |
| Indoxacarb 14.5 SC | $18.87^{ab}$ (25.73) | $17.86^{a}$ (24.96) | $18.36^{a}$ (25.36) | 10.91 | 65465 | 4450 | 61015 | 1:13.71 |
| Diafenthiuron 50 WP | $13.53^{c}$ (21.51) | $12.67^{bc}$ (20.79) | $13.10^{b}$ (21.17) | 5.65 | 33900 | 5040 | 28860 | 1:5.73 |
| Chlorpyriphos 50 EC | $14.63^{bc}$ (22.45) | $13.88^{b}$ (21.83) | $14.25^{b}$ (22.17) | 6.80 | 40820 | 3200 | 37620 | 1:11.76 |
| Dimethoate 30 EC | $13.09^{c}$ (21.19) | $11.20^{c}$ (19.54) | $12.15^{b}$ (20.38) | 4.70 | 28177 | 2600 | 25577 | 1:9.84 |
| Control | $8.74^{d}$ (17.09) | $6.16^{d}$ (14.36) | $7.45^{c}$ (15.80) | - | - | - | - | - |
| C.D. ($P \leq 0.05$) | 3.49 | 2.19 | 2.03 | - | - | - | - | - |
| C.V. (%) | 8.46 | 5.56 | 5.01 | - | - | - | - | - |

Figures in parenthesis are angular transformed values

Cost of treatments for two sprays per ha: 1. Chlorantraniliprole-Rs.1956; 2. Spinosad-Rs.2550; 3. Emamectin benzoate-Rs. 2720; 4. Indoxacarb-Rs.2650; 5. Diafenthiuron- Rs. 3240; 6. Chlorpyriphos-Rs. 1400; 7. Dimethoate-Rs. 800; Labour cost – Rs. 450/day/person; Cost of Cauliflower-Rs.6000/t average yield of the two years *i.e.* 2018-19 and 2019-20 are presented in Table 4.12. The cost of the treatment along with labour charges for two sprays was highest in diafenthiuron followed by emamectin benzoate and indoxacarb and was lowest in dimethoate.

Net profit constitutes the value of yield gain minus cost of treatment. The highest net profit in rupees per hectare was obtained in chlorantraniliprole treatment (Rs. 69,989) followed by emamectin benzoate (Rs. 65,725) and spinosad (Rs. 63,672).

Incremental cost benefit ratio is the ratio of curd yield to the cost of treatment. Maximum benefit from a single rupee was realized with chlorantraniliprole treatment with ICBR of 1:18.63 while lowest in diafenthiuron 1:5.73 (Fig. 4.11).

Thus, from the present studies it can be inferred that chlorantraniliprole can effectively manage insect pests in cauliflower especially leaf webber and head borer giving highest incremental cost benefit ratio. It was followed by spinosad, emamectin benzoate, indoxacarb and chlorpyriphos. In the event of aphid infestation, additional sprayings with dimethoate can effectively check the increase in population.

Earlier, Harika *et al.* (2019) recorded highest yield in cauliflower treated with spinosad (228.80 q $ha^{-1}$) followed by indoxacarb (219.10 q $ha^{-1}$) treatments. However, the C:B ratio was highest for indoxacarb (69.85) followed by emamectin benzoate (60.18) and spinosad (30.13). Gaidkwad *et al.* (2018b) revealed highest curd yield of 17.85 t $ha^{-1}$ was recorded in emamectin benzoate followed by 17.20 and 17.00 t $ha^{-1}$ in flubendiamide and chlorantraniliprole, respectively which were found to be on par with each other. In cabbage, Rabari *et al.* (2016) recorded highest yield in treatment with spinosad (339.26 q $ha^{-1}$) which was on par with emamectin benzoate (334.58 q $ha^{-1}$) and indoxacarb (327.30 q $ha^{-1}$). Vaseem *et al.* (2014) revealed that plots treated with chlorantraniliprole was found to be effective against *P. xylostella* (236.30 q $ha^{-1}$) followed by spinosad (220.74 q $ha^{-1}$) and indoxacarb (204.37 q $ha^{-1}$). Highest cost benefit ratio was realized in chlorantraniliprole (1:10.9) followed by indoxacarb (1:9.18). Also, Sawant and Patil (2018) reported highest yield of 238.15 q $ha^{-1}$ and ICBR of 1:16.40 from chlorantraniliprole treated plots in cabbage.

## 4.3 Dissipation Dynamics of Selected Insecticides in Cauliflower

Dissipation pattern of selected insecticides *viz.*, chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, diafenthiuron, chlorpyriphos and dimethoate were studied after the final application of insecticides at curd stage. The samples of cauliflower were collected from the treated plots and residues were estimated at AINP on Pesticide Residue Laboratory, Rajendranagar, Hyderabad.

The method adopted for analysis on LC-MS/MS for different insecticides was evaluated through linearity, LOD, LOQ, fortification, recovery, repeatability and reproducibility studies.

### 4.3.1 Linearity, recovery and dissipation of chlorantraniliprole

The linearity curve of chlorantraniliprole is depicted in Fig. 4.12. The correlation coefficient ($R^2$) value obtained from the linearity curve was 0.997.

The recovery of chlorantraniliprole in the cauliflower sample fortified at 0.05 mg $kg^{-1}$ ranged from 0.047 mg $kg^{-1}$ to 0.048 mg $kg^{-1}$ with an average of 0.047 mg $kg^{-1}$ while at 0.25 mg $kg^{-1}$ fortification level, the recovery ranged from 0.239 mg $kg^{-1}$ to 0.246 mg $kg^{-1}$ with an average of 0.243 mg $kg^{-1}$. At 0.50 mg $kg^{-1}$ level of fortification, the recovery ranged from 0.515 mg $kg^{-1}$ to 0.527 mg $kg^{-1}$ with an average of 0.520 mg $kg^{-1}$. The average per cent recoveries at fortification levels of 0.05, 0.25 and 0.50 mg $kg^{-1}$ were 94.80, 97.19 and 103.90, respectively. As the recoveries were in the acceptable range of 70-120 as per SANTE, 2017 guidelines, the method was suitable for analysis of chlorantraniliprole residues up to 0.05 mg $kg^{-1}$ and was taken as limit of quantification (LOQ) (Table 4.13).

The dissipation pattern of chlorantraniliprole 18.5% SC @ 10 g *a.i.* $ha^{-1}$ in cauliflower is presented in Table 4.14 and Fig. 4.13. The mean initial deposit of 0.780 mg $kg^{-1}$ recorded at 0 days (2 hrs) after final spray dissipated to 0.540, 0.342, 0.246, 0.180 and 0.111 mg $kg^{-1}$ at 1, 3, 5, 7 and 10 days after second spray. Residues were not found by 15$^{th}$ day after second spray indicating per cent dissipation of 30.73, 56.15, 68.47, 76.94, 85.80 and 100 at 1,3,5,7,10 and 15 days after second spray (Fig. 4.13). The regression equation obtained was Y= -0.0816x + 2.8286 with $R^2$ of 0.982 (Fig 4.14). The calculated half-life was 3.68 days.

**Table 4.13. Recovery of chlorantraniliprole at various fortification levels of cauliflower**

| Replication | Fortified level (mg kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0.05 mg kg$^{-1}$ | | 0.25 mg kg$^{-1}$ | | 0.5 mg kg$^{-1}$ | |
| | Recovered Level (mg kg$^{-1}$) | Per cent recovery | Recovered Level (mg kg$^{-1}$) | Per cent recovery | Recovered Level (mg kg$^{-1}$) | Per cent recovery |
| R1 | 0.047 | 93.54 | 0.246 | 98.20 | 0.527 | 105.31 |
| R2 | 0.048 | 95.73 | 0.245 | 97.95 | 0.517 | 103.37 |
| R3 | 0.048 | 95.12 | 0.239 | 95.42 | 0.515 | 103.04 |
| **Average** | **0.047** | **94.8** | **0.243** | **97.19** | **0.520** | **103.90** |
| **SD (±)** | **0.01** | **1.13** | **0.04** | **1.54** | **0.01** | **1.23** |
| **RSD (%)** | **-** | **1.19** | **-** | **1.59** | **-** | **1.18** |

**Table 4.14. Dissipation pattern of chlorantraniliprole in cauliflower curd**

| Days after final spray | Residues of chlorantraniliprole (mg kg$^{-1}$) | | | | Per cent dissipation |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | Mean | |
| 0 | 0.777 | 0.793 | 0.770 | 0.780 | - |
| 1 | 0.517 | 0.552 | 0.553 | 0.540 | 30.73 |
| 3 | 0.336 | 0.365 | 0.326 | 0.342 | 56.15 |
| 5 | 0.247 | 0.228 | 0.263 | 0.246 | 68.47 |
| 7 | 0.183 | 0.176 | 0.180 | 0.180 | 76.94 |
| 10 | 0.114 | 0.113 | 0.106 | 0.111 | 85.80 |
| 15 | ND | ND | ND | - | 100.0 |
| Regression equation | Y = -0.0816x + 2.8286 | | | | |
| $R^2$ | 0.982 | | | | |
| Half-life (days) | 3.68 | | | | |

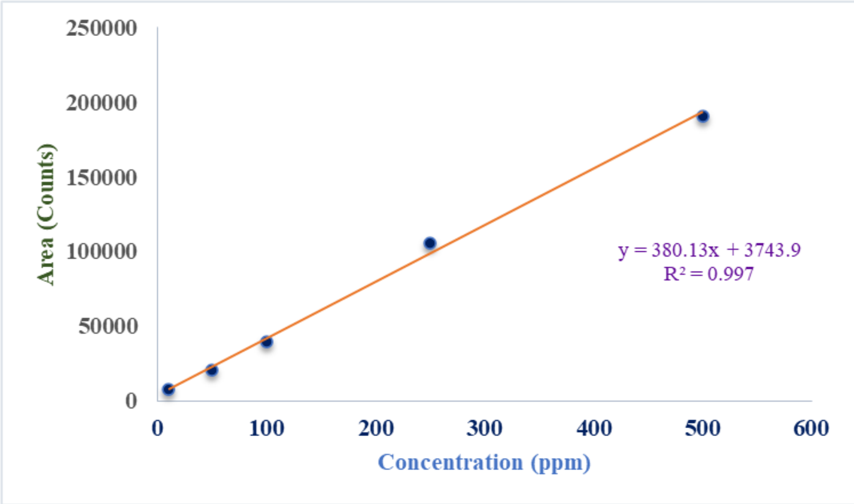



**Fig. 4.12. Linearity graph of chlorantraniliprole**

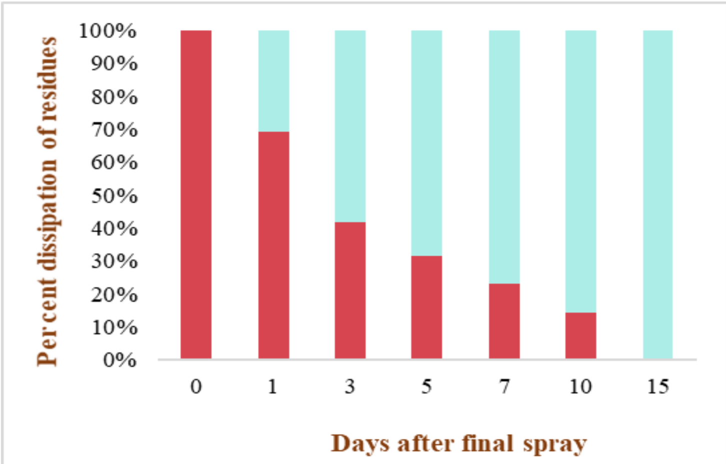



**Fig 4.13. Dissipation pattern of chlorantraniliprole in cauliflower**

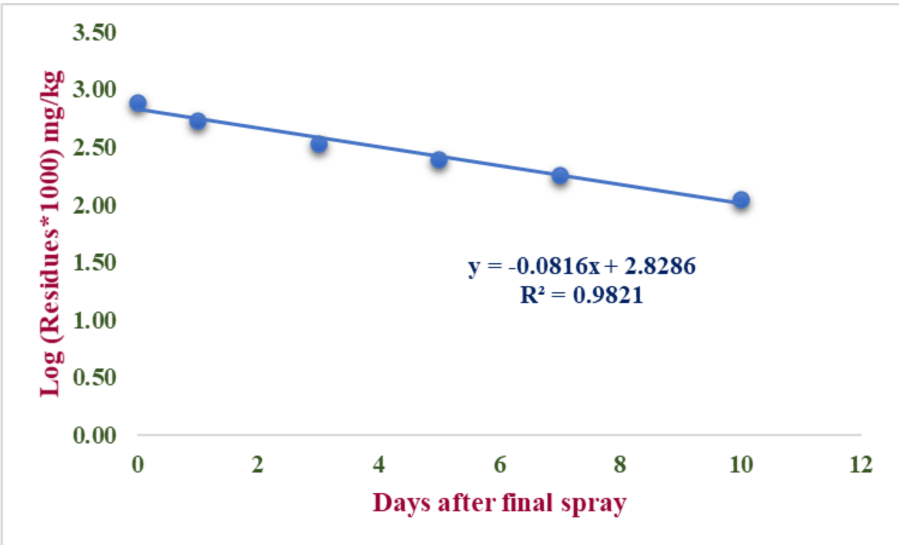



**Fig 4.14. Semi logarithmic graph depicting dissipation kinetics of chlorantraniliprole in cauliflower**

### 4.3.2 Linearity, recovery and dissipation of spinosad

The linearity curve of spinosad is depicted in Fig. 4.15. The correlation coefficient ($R^2$) value obtained from the linearity curve was 0.997.

The recovery of spinosad in the cauliflower sample fortified at 0.05 mg $kg^{-1}$ ranged from 0.057 mg $kg^{-1}$ to 0.058 mg $kg^{-1}$ with an average of 0.057 while at 0.25 mg $kg^{-1}$ fortification level, the recovery ranged from 0.283 mg $kg^{-1}$ to 0.292 mg $kg^{-1}$ with 0.288 mg $kg^{-1}$ average recovery. At 0.50 mg $kg^{-1}$ level of fortification, the recovery ranged from 0.543 mg $kg^{-1}$ to 0.551 mg $kg^{-1}$ with an average of 0.547 mg $kg^{-1}$. The average per cent recoveries at fortification levels of 0.05, 0.25 and 0.50 mg $kg^{-1}$ were 114.72, 115.21 and 109.36, respectively. As the recoveries were in the acceptable range of 70-120 (SANTE, 2017), the method was suitable for analysis of spinosad residues up to 0.05 mg $kg^{-1}$ and was considered as the limit of quantification (LOQ) (Table 4.15).

The dissipation pattern of spinosad 2.5% SC @ 17.5 g *a.i.* $ha^{-1}$ in cauliflower is presented in Table 4.16 and in Figure 4.16. The mean initial deposit of 1.069 mg $kg^{-1}$ recorded at 0 days (2 hrs) after final spray dissipated to 0.516, 0.451, 0.345 and 0.050 mg $kg^{-1}$ at 1, 3,5 and 7 days after second spray. The residues were below LOQ by 10$^{th}$ day after second spray (Fig. 4.16) indicating per cent dissipation of 51.73, 57.84, 67.76, 95.32 and 100 at 1,3,5,7 and 10 days after second spray. The regression equation obtained was Y= -0.1576x+3.0306 with $R^2$ of 0.823 (Fig 4.17). The calculated half-life was 1.91 days.

### 4.3.3 Linearity, recovery and dissipation of emamectin benzoate

The linearity curve of emamectin benzoate is depicted in Fig. 4.18. The correlation coefficient ($R^2$) value obtained from the linearity curve was 0.999.

The recovery of emamectin benzoate in the cauliflower sample fortified at 0.05 mg $kg^{-1}$ ranged from 0.046 mg $kg^{-1}$ to 0.049 mg $kg^{-1}$ with an average 0.047 mg $kg^{-1}$, while at 0.25 mg $kg^{-1}$ fortification level the recovery ranged from 0.233 mg $kg^{-1}$ to 0.252 mg $kg^{-1}$ with average of 0.241 mg $kg^{-1}$. At 0.50 mg $kg^{-1}$ level of fortification, the recovery ranged from 0.490 mg $kg^{-1}$ to 0.534 mg $kg^{-1}$ with an average of 0.506 mg $kg^{-1}$. The average per cent recoveries at fortification levels of 0.05, 0.25 and 0.50 mg $kg^{-1}$ were 94.83, 96.54 and 101.27, respectively.

**Table 4.15. Recovery of spinosad at various fortification levels of cauliflower**

| Replication | Fortified level ($mg\ kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0.05 $mg\ kg^{-1}$ | | 0.25 $mg\ kg^{-1}$ | | 0.5 $mg\ kg^{-1}$ | |
| | Recovered Level ($mg\ kg^{-1}$) | Per cent recovery | Recovered Level ($mg\ kg^{-1}$) | Per cent recovery | Recovered Level ($mg\ kg^{-1}$) | Per cent recovery |
| R1 | 0.057 | 113.46 | 0.283 | 113.03 | 0.551 | 110.21 |
| R2 | 0.057 | 114.39 | 0.292 | 116.93 | 0.543 | 108.64 |
| R3 | 0.058 | 116.31 | 0.289 | 115.65 | 0.546 | 109.25 |
| **Average** | **0.057** | **114.72** | **0.288** | **115.21** | **0.547** | **109.36** |
| **SD (±)** | **0.001** | **1.46** | **0.005** | **1.99** | **0.004** | **0.79** |
| **RSD (%)** | **-** | **1.27** | **-** | **1.72** | **-** | **0.72** |

**Table 4.16. Dissipation pattern of spinosad in cauliflower curd**

| Days after final spray | Residues of spinosad ($mg\ kg^{-1}$) | | | | Per cent dissipation |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | Mean | |
| 0 | 1.049 | 1.109 | 1.049 | 1.069 | - |
| 1 | 0.509 | 0.524 | 0.515 | 0.516 | 51.73 |
| 3 | 0.450 | 0.449 | 0.453 | 0.451 | 57.84 |
| 5 | 0.346 | 0.340 | 0.348 | 0.345 | 67.76 |
| 7 | 0.050 | 0.050 | 0.050 | 0.050 | 95.32 |
| 10 | <LOQ | <LOQ | <LOQ | <LOQ | - |
| 15 | ND | ND | ND | - | - |
| Regression equation | Y=-0.1576x + 3.0306 | | | | |
| $R^2$ | 0.823 | | | | |
| Half-life (days) | 1.91 | | | | |

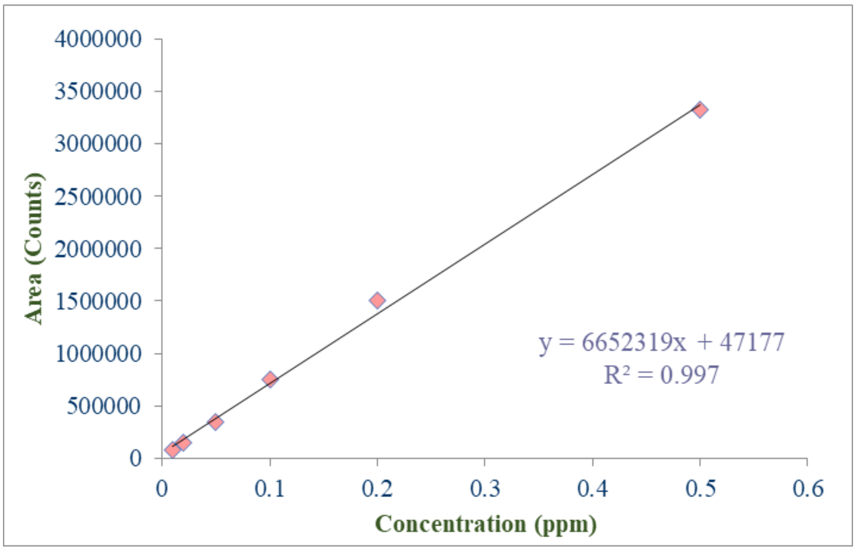



**Fig 4.15. Linearity graph of spinosad**

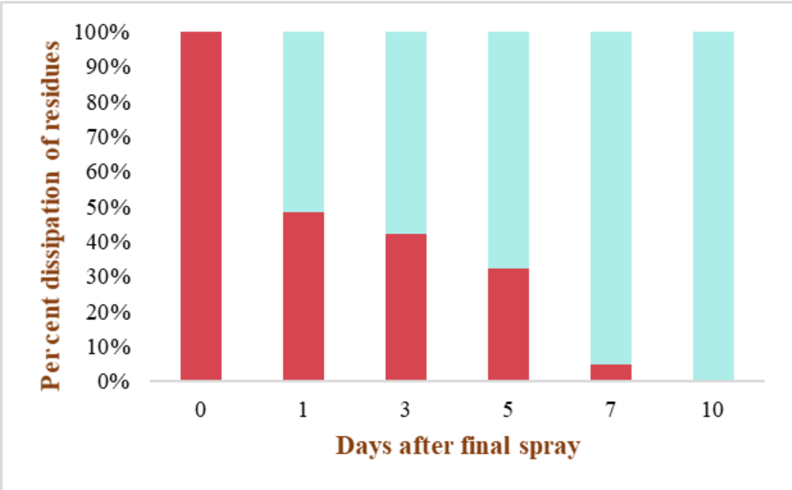



**Fig 4.16. Dissipation kinetics of spinosad in cauliflower**

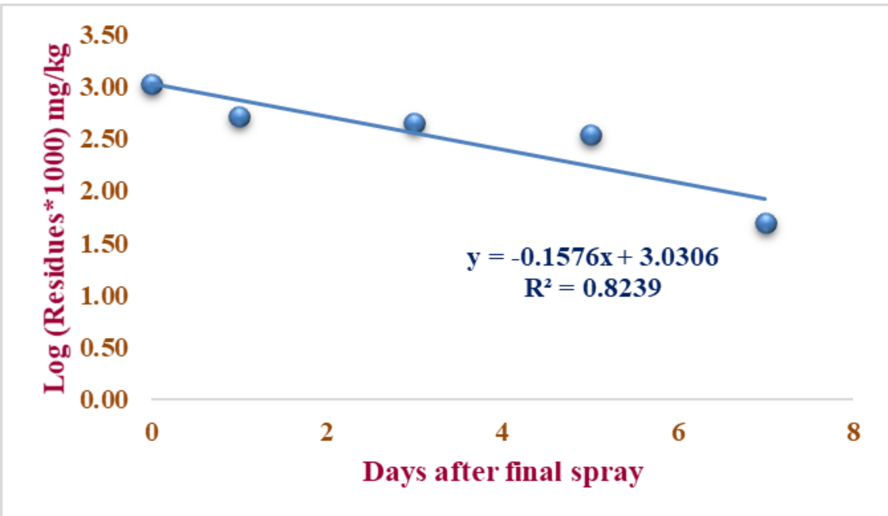



**Fig 4.17. Semi logarithmic graph depicting dissipation kinetics of spinosad in cauliflower**

As the recoveries were in the acceptable range of 70-120 (SANTE, 2017), the method was suitable for analysis of emamectin benzoate residues up to 0.05 mg $kg^{-1}$ and hence 0.05 mg $kg^{-1}$ was taken as the limit of quantification (LOQ) (Table 4.17).

The dissipation pattern of emamectin benzoate 5% SG @ 10 g *a.i.* $ha^{-1}$ in cauliflower is presented in Table 4.18 and in Figure 4.19. The mean initial deposit of 0.168 mg $kg^{-1}$ recorded at 0 days (2 hrs) after final spray dissipated to 0.119 mg $kg^{-1}$ at 1 day and to less than LOQ at 3 days after second spray indicating per cent dissipation of 29.29 by $1^{st}$ day after spray. The regression equation obtained was Y= -0.15x+2.23 with $R^2$ of 1.0 (Fig. 4.20). The calculated half-life was 2.01 days.

### 4.3.4 Linearity, recovery and dissipation of indoxacarb

The linearity curve of indoxacarb is depicted in Fig. 4.21. The correlation coefficient ($R^2$) value obtained from the linearity curve was 0.998.

The recovery of indoxacarb in cauliflower sample fortified at 0.05 mg $kg^{-1}$ ranged from 0.051 mg $kg^{-1}$ to 0.054 mg $kg^{-1}$ with an average of 0.053 mg $kg^{-1}$, while at 0.25 mg $kg^{-1}$ fortification level the recovery ranged from 0.230 mg $kg^{-1}$ to 0.251 mg $kg^{-1}$ with an average recovery of 0.243 mg $kg^{-1}$. At 0.50 mg $kg^{-1}$ level of fortification, the recovery ranged from 0.482 mg $kg^{-1}$ to 0.498 mg $kg^{-1}$ with an average recovery of 0.491 mg $kg^{-1}$. The average per cent recoveries at fortification levels of 0.05, 0.25 and 0.50 mg $kg^{-1}$ were 105.63, 97.28 and 98.28, respectively. As the recoveries were in the acceptable range of 70-120 (SANTE, 2017), the method was suitable for analysis of indoxacarb residues up to 0.05 mg $kg^{-1}$ and was considered as limit of quantification (LOQ) (Table 4.19).

The dissipation pattern of indoxacarb 14.5% SC @ 40 g *a.i.* $ha^{-1}$ in cauliflower is presented in the Table 4.20 and in Figure 4.22. The mean initial deposit of 1.334 mg $kg^{-1}$ recorded at 0 days (2 hrs) after final spray dissipated to 1.183, 0.909, 0.841, 0.375, 0.292 and 0.109 mg $kg^{-1}$ at 1, 3, 5, 7, 10 and 15 days after second spray indicating per cent dissipation of 11.33, 31.87, 36.93, 71.91, 78.11, 91.86 and 100 at 1,3,5,7,10,15 and 20 days after second spray. Residues were not found by $20^{th}$ day after second spray (Fig. 4.23). The regression equation obtained was Y= -0.0736x + 3.1675 with $R^2$ of 0.972. The calculated half-life was 4.09 days.

**Table 4.17. Recovery of emamectin benzoate at various fortification levels of cauliflower**

| Replication | Fortified level (mg $kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0.05 mg $kg^{-1}$ | | 0.25 mg $kg^{-1}$ | | 0.5 mg $kg^{-1}$ | |
| | Recovered Level (mg $kg^{-1}$) | Per cent recovery | Recovered Level (mg $kg^{-1}$) | Per cent recovery | Recovered Level (mg $kg^{-1}$) | Per cent recovery |
| R1 | 0.047 | 93.53 | 0.252 | 100.92 | 0.534 | 106.70 |
| R2 | 0.046 | 92.43 | 0.233 | 93.13 | 0.496 | 99.22 |
| R3 | 0.049 | 98.52 | 0.239 | 95.58 | 0.490 | 97.90 |
| **Average** | **0.047** | **94.83** | **0.241** | **96.54** | **0.506** | **101.27** |
| **SD (±)** | **0.002** | **3.24** | **0.010** | **3.98** | **0.024** | **4.75** |
| **RSD (%)** | **-** | **3.42** | **-** | **4.13** | **-** | **4.69** |

**Table 4.18. Dissipation pattern of emamectin benzoate in cauliflower curd**

| Days after final spray | Residues of emamectin benzoate (mg $kg^{-1}$) | | | | Per cent dissipation |
|---|---|---|---|---|---|
| | **R1** | **R2** | **R3** | **Mean** | |
| 0 | 0.175 | 0.161 | 0.168 | 0.168 | - |
| 1 | 0.126 | 0.105 | 0.125 | 0.119 | 29.37 |
| 3 | <LOQ | <LOQ | <LOQ | - | - |
| 5 | <LOQ | <LOQ | <LOQ | - | - |
| 7 | ND | ND | ND | - | - |
| Regression equation | Y=-0.15x + 2.23 | | | | |
| $R^2$ | 1 | | | | |
| Half-life (days) | 2.01 | | | | |

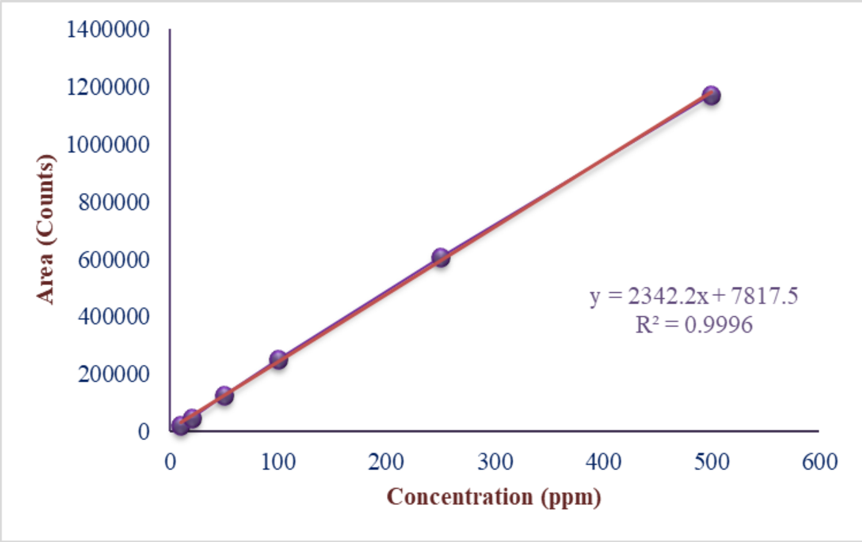



**Fig. 4.18. Linearity graph of emamectin benzoate**

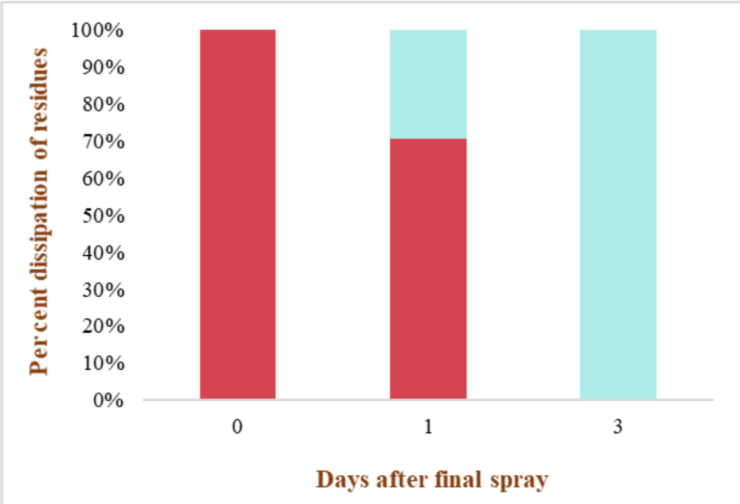



**Fig 4.19. Dissipation pattern of emamectin benzoate in cauliflower**

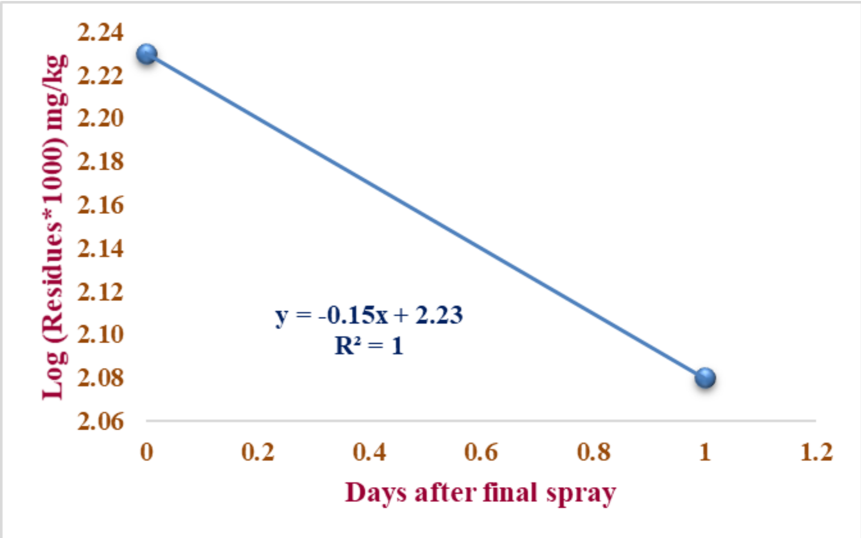



**Fig 4.20. Semi logarithmic graph depicting dissipation kinetics of emamectin benzoate in cauliflower**

**Table 4.19. Recovery of indoxacarb at various fortification levels of cauliflower**

| Replication | Fortified level ($mg\ kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | **0.05 $mg\ kg^{-1}$** | | **0.25 $mg\ kg^{-1}$** | | **0.5 $mg\ kg^{-1}$** | |
| | **Recovered Level ($mg\ kg^{-1}$)** | **Per cent recovery** | **Recovered Level ($mg\ kg^{-1}$)** | **Per cent recovery** | **Recovered Level ($mg\ kg^{-1}$)** | **Per cent recovery** |
| R1 | 0.054 | 107.70 | 0.230 | 92.19 | 0.482 | 96.38 |
| R2 | 0.051 | 102.55 | 0.251 | 100.50 | 0.495 | 98.95 |
| R3 | 0.053 | 106.63 | 0.248 | 99.14 | 0.498 | 99.53 |
| **Average** | **0.053** | **105.63** | **0.243** | **97.28** | **0.491** | **98.28** |
| **SD (±)** | **0.001** | **2.72** | **0.011** | **4.46** | **0.008** | **1.68** |
| **RSD (%)** | **-** | **2.57** | **-** | **4.58** | **-** | **1.71** |

**Table 4.20. Dissipation pattern of indoxacarb in cauliflower curd**

| Days after final spray | Residues of indoxacarb ($mg\ kg^{-1}$) | | | | Per cent dissipation |
|---|---|---|---|---|---|
| | **R1** | **R2** | **R3** | **Mean** | |
| 0 | 1.324 | 1.418 | 1.260 | 1.334 | - |
| 1 | 1.155 | 1.266 | 1.128 | 1.183 | 11.33 |
| 3 | 0.918 | 0.880 | 0.929 | 0.909 | 31.87 |
| 5 | 0.842 | 0.827 | 0.854 | 0.841 | 36.93 |
| 7 | 0.392 | 0.353 | 0.379 | 0.375 | 71.91 |
| 10 | 0.293 | 0.310 | 0.273 | 0.292 | 78.11 |
| 15 | 0.103 | 0.118 | 0.104 | 0.109 | 91.86 |
| 20 | ND | ND | ND | - | - |
| Regression equation | Y = -0.0736x + 3.167 | | | | |
| $R^2$ | 0.972 | | | | |
| Half-life | 4.09 | | | | |

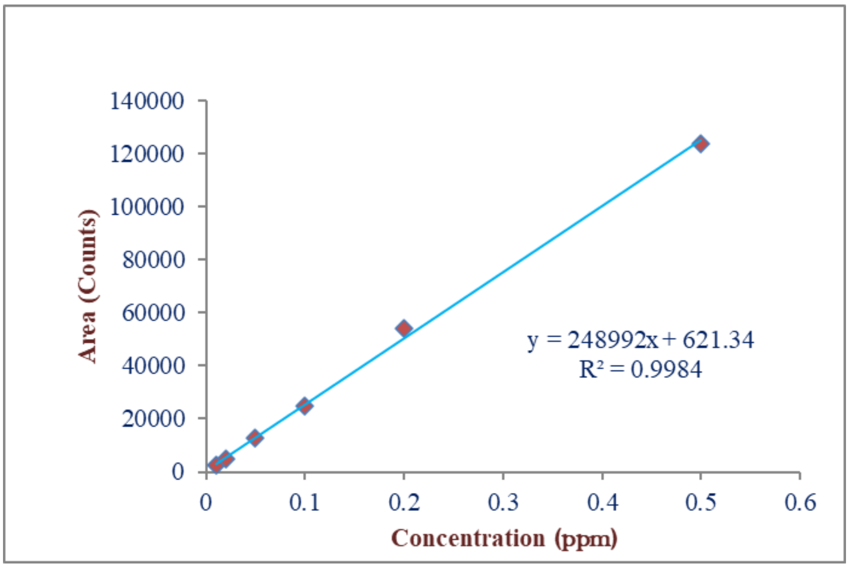



**Fig. 4.21. Linearity graph of indoxacarb**

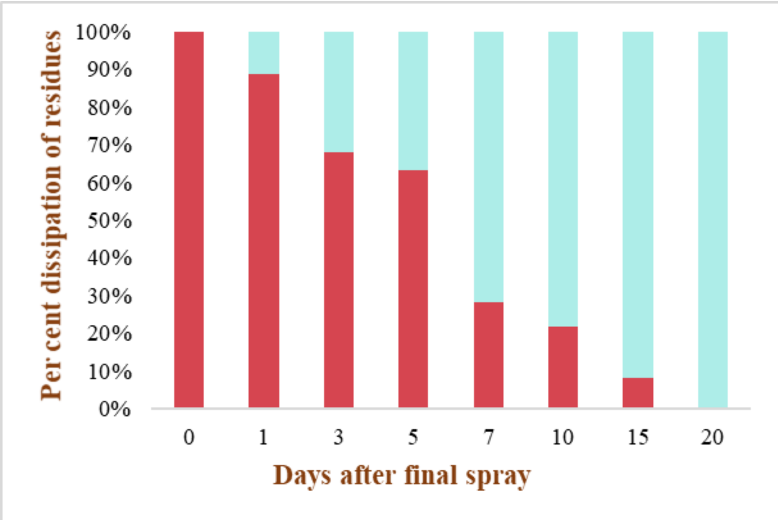



**Fig. 4.22. Dissipation pattern of indoxacarb in cauliflower**

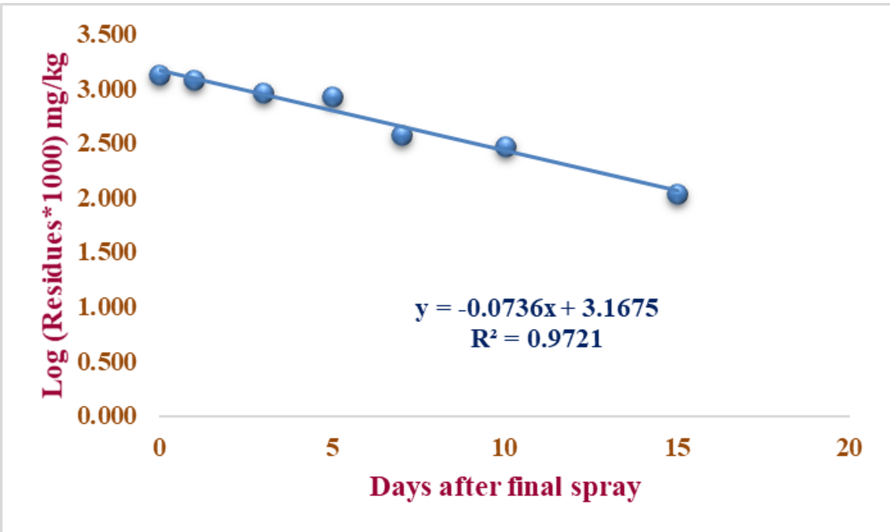



**Fig 4.23. Semi logarithmic graph depicting dissipation kinetics of indoxacarb in cauliflower**

### 4.3.5 Linearity, recovery and dissipation of diafenthiuron

The linearity curve of diafenthiuron is depicted in Fig. 4.24. The correlation coefficient ($R^2$) value obtained from the linearity curve was 0.998.

The recovery of diafenthiuron in cauliflower sample fortified at 0.05 mg $kg^{-1}$ ranged from 0.050 mg $kg^{-1}$ to 0.051 mg $kg^{-1}$ with an average per cent recovery of 0.051 mg $kg^{-1}$, while at 0.25 mg $kg^{-1}$ fortification level the recovery ranged from 0.242 mg $kg^{-1}$ to 0.248 mg $kg^{-1}$ with 0.246 mg $kg^{-1}$average recovery. At 0.50 mg $kg^{-1}$ level the recovery ranged from 0.504 mg $kg^{-1}$ to 0.510 mg $kg^{-1}$ with an average recovery of 0.507 mg $kg^{-1}$. The mean per cent recoveries at fortification levels of 0.05, 0.25 and 0.50 mg $kg^{-1}$ were 101.52, 98.31 and 101.4, respectively. As the recoveries were in the acceptable range of 70-110 (SANTE, 2017), the method was suitable for analysis of diafenthiuron residues up to 0.05 mg $kg^{-1}$ and was fixed as limit of quantification (LOQ) (Table 4.21).

The dissipation pattern of diafenthiuron 50% WP @ 300 g *a.i.* $ha^{-1}$ in cauliflower is presented in the Table 4.22 and in Figure 4.25. The mean initial deposit of 5.356 mg $kg^{-1}$ recorded at 0 days (2 hrs) after final spray dissipated to 1.886, 1.422, 0.874, 0.338 and 0.227 mg $kg^{-1}$ at 1, 3, 5, 7 and 10 days after second spray. Residues were not found by 15$^{th}$ day after second spray (Fig. 4.25) indicating per cent dissipation of 64.97, 73.45, 83.68, 93.69, 95.75 and 100 at 1,3,5,7 and 10 days after second spray. The regression equation obtained was $Y= -0.1293x + 3.5575$ with $R^2$ of 0.938 (Fig. 4.26). The calculated half-life was 2.33 days.

### 4.3.6 Linearity, recovery and dissipation of chlorpyriphos

The linearity curve of chlorpyriphos is depicted in Fig. 4.27. The correlation coefficient ($R^2$) value obtained from linearity curve was 0.999.

The recovery chlorpyriphos in cauliflower sample fortified 0.05 mg $kg^{-1}$ ranged from 0.055 mg $kg^{-1}$ to 0.057 mg $kg^{-1}$ with an average recovery of 0.056 mg $kg^{-1}$, while at 0.25 mg $kg^{-1}$ fortification level, the recovery ranged from 0.243 mg $kg^{-1}$ to 0.247 mg $kg^{-1}$ with average recovery of 0.245 mg $kg^{-1}$. At 0.50 mg $kg^{-1}$ level the recoveries of concentration ranged from 0.486 mg $kg^{-1}$ to 0.487 mg $kg^{-1}$ with an average of 0.486 mg $kg^{-1}$. The average per cent recoveries at fortification levels of 0.05, 0.25 and 0.50 mg $kg^{-1}$ were 111.80, 98.03 and 97.28, respectively (Table 4.23).

**Table 4.21. Recovery of diafenthiuron at various fortification levels of cauliflower**

| Replication | Fortified level (mg kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0.05 mg kg$^{-1}$ | | 0.25 mg kg$^{-1}$ | | 0.5 mg kg$^{-1}$ | |
| | Recovered Level (mg kg$^{-1}$) | Per cent recovery | Recovered Level (mg kg$^{-1}$) | Per cent recovery | Recovered Level (mg kg$^{-1}$) | Per cent recovery |
| R1 | 0.051 | 102.96 | 0.248 | 99.30 | 0.510 | 101.99 |
| R2 | 0.051 | 102.60 | 0.247 | 98.83 | 0.504 | 100.74 |
| R3 | 0.050 | 99.01 | 0.242 | 96.79 | 0.507 | 101.48 |
| **Average** | **0.051** | **101.52** | **0.246** | **98.31** | **0.507** | **101.40** |
| **SD (±)** | 0.001 | 2.18 | 0.003 | 1.34 | 0.003 | 0.63 |
| **RSD (%)** | - | 2.15 | - | 1.36 | - | 0.62 |

**Table 4.22. Dissipation pattern of diafenthiuron in cauliflower curd**

| Days after final spray | Residues of diafenthiuron (mg kg$^{-1}$) | | | | Per cent dissipation |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | Mean | |
| 0 | 5.258 | 5.531 | 5.280 | 5.356 | - |
| 1 | 1.838 | 2.028 | 1.791 | 1.886 | 64.79 |
| 3 | 1.411 | 1.453 | 1.401 | 1.422 | 73.45 |
| 5 | 0.924 | 0.775 | 0.923 | 0.874 | 83.68 |
| 7 | 0.312 | 0.378 | 0.324 | 0.338 | 93.69 |
| 10 | 0.236 | 0.219 | 0.227 | 0.227 | 95.75 |
| 15 | ND | ND | ND | - | - |
| Regression equation | Y = -0.1293x + 3.5575 | | | | |
| $R^2$ | 0.938 | | | | |
| Half-life (days) | 2.33 | | | | |

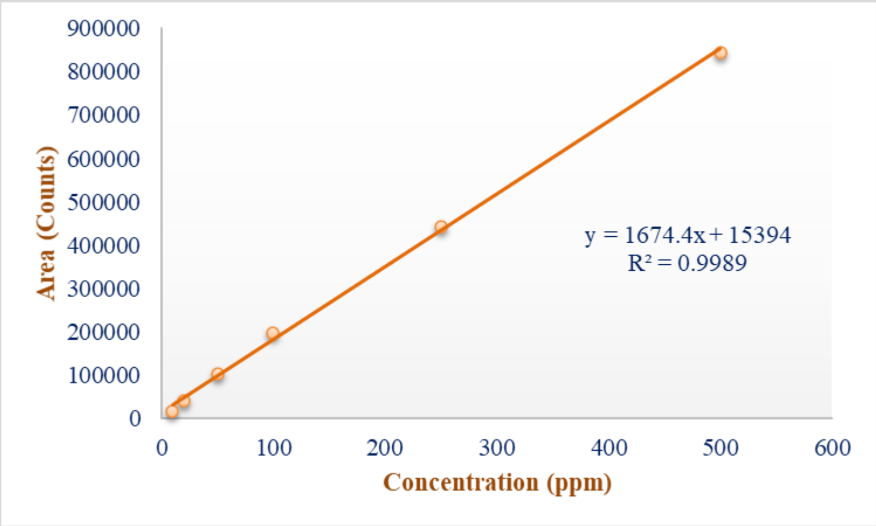



**Fig.4.24. Linearity graph of diafenthiuron**

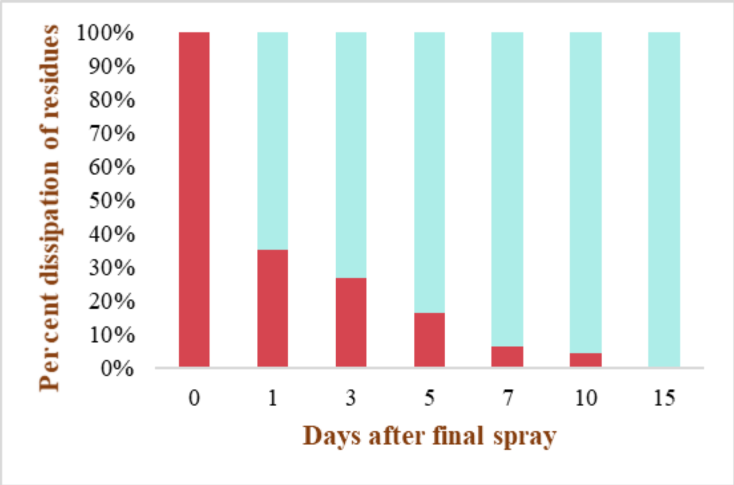



**Fig 4.25. Dissipation pattern of diafenthiuron residues in cauliflower**

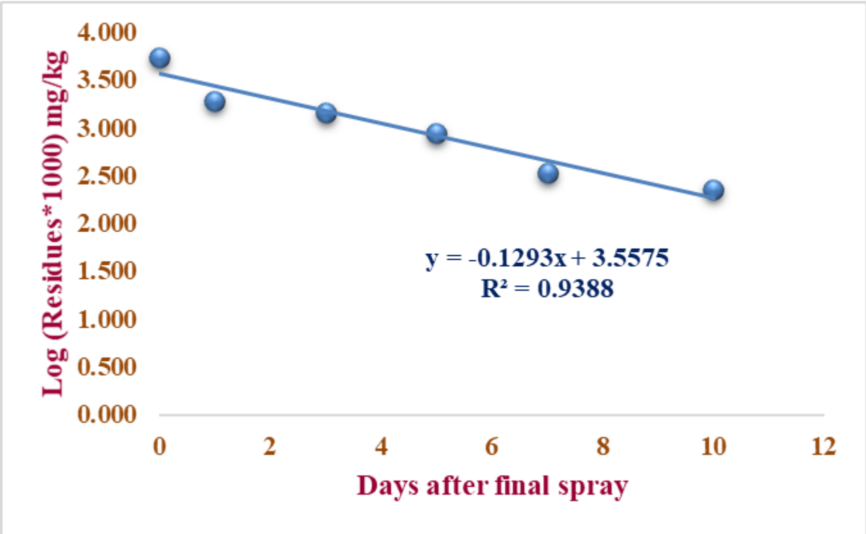



**Fig 4.26. Semi logarithmic graph depicting dissipation kinetics of diafenthiuron in cauliflower**

As the recoveries were in the acceptable range of 70-120 (SANTE, 2017), the method was suitable for analysis of chlorpyriphos residues up to 0.05 mg $kg^{-1}$ and fixed as the limit of quantification (LOQ) (Table 4.23).

The dissipation pattern of chlorpyriphos 50% EC @ 500 g *a.i.* $ha^{-1}$ in cauliflower is presented in the Table 4.24 in Figure 4.28. The mean initial deposit of 9.924 mg $kg^{-1}$ recorded at 0 days (2 hrs) after final spray dissipated to 5.211, 2.332, 2.060, 0.784, 0.408 and 0.029 mg $kg^{-1}$ at 1, 3, 5, 7 and 10 days. At 15 days after second spray, it was below LOQ. Residues were not found by 20$^{th}$ day after second spray (Fig. 4.28) indicating per cent dissipation of 47.49, 76.50, 79.24, 92.10, 95.88 and 100 at 1,3,5,7,10 and 15 days after final spray. The regression equation obtained was Y= -0.1328x+3.8924 with $R^2$ of 0.967 (Fig. 4.29). The calculated half-life was 2.28 days.

### 4.3.7 Linearity and recovery studies for dimethoate

The linearity curve of dimethoate is presented in Fig. 4.30. The correlation coefficient ($R^2$) value obtained from linearity curve was 0.996.

The recovery of dimethoate in cauliflower sample fortified at 0.05 mg $kg^{-1}$ ranged from 0.045 mg $kg^{-1}$ to 0.049 mg $kg^{-1}$ with an average recovery of 0.047 mg $kg^{-1}$, while at 0.25 mg $kg^{-1}$ fortification level, the recovery ranged from 0.257 mg $kg^{-1}$ to 0.271 mg $kg^{-1}$ with average of 0.266 mg $kg^{-1}$. At 0.50 mg$kg^{-1}$ the recovery ranged from 0.415 mg $kg^{-1}$ to 0.455 mg $kg^{-1}$ with an average recovery of 0.438 mg $kg^{-1}$. The average per cent recoveries at fortification levels of 0.05, 0.25 and 0.50 mg $kg^{-1}$ were 94.07, 106.31 and 87.64, respectively. As the recoveries were in the acceptable range of 70-120 (SANTE, 2017), the method was suitable for the analysis of dimethoate residues up to 0.05 mg $kg^{-1}$ and was considered as limit of quantification (LOQ) (Table 4.25).

The dissipation pattern of dimethoate 30% EC @ 200 g *a.i.* $ha^{-1}$ in cauliflower is presented in the Table 4.26 and in Figure 4.31. The mean initial deposit of 5.132 mg $kg^{-1}$ recorded at 0 days (2 hrs) after final spray dissipated to 4.341, 0.875, 0210 and 0.150 mg $kg^{-1}$ at 1, 3, 5 and 7 days after second spray. Residues were not found by 10$^{th}$ day after second spray (Fig. 4.31). The regression equation obtained was Y= -0.2444x + 3.7396 with $R^2$ of 0.958 (Fig 4.32). The calculated half-life was 1.23 days.

**Table 4.23. Recovery of chlorpyriphos at various fortification levels of cauliflower**

| Replication | Fortified level (mg kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0.05mg kg$^{-1}$ | | 0.25 mg kg$^{-1}$ | | 0.5mg kg$^{-1}$ | |
| | Recovered Level (mg kg$^{-1}$) | Per cent recovery | Recovered Level (mg kg$^{-1}$) | Per cent recovery | Recovered Level (mg kg$^{-1}$) | Per cent recovery |
| R1 | 0.056 | 111.95 | 0.245 | 98.11 | 0.486 | 97.20 |
| R2 | 0.055 | 109.54 | 0.247 | 98.60 | 0.487 | 97.46 |
| R3 | 0.057 | 113.92 | 0.243 | 97.37 | 0.486 | 97.19 |
| **Average** | **0.056** | **111.80** | **0.245** | **98.03** | **0.486** | **97.28** |
| **SD (±)** | **0.001** | **2.20** | **0.002** | **0.62** | **0.001** | **0.15** |
| **RSD (%)** | **-** | **1.96** | **-** | **0.63** | **-** | **0.16** |

**Table 4.24. Dissipation pattern of chlorpyriphos in cauliflower curd**

| Days after final spray | Residues of chlorpyriphos (mg kg$^{-1}$) | | | | Per cent dissipation |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | Mean | |
| 0 | 9.683 | 10.297 | 9.793 | 9.924 | 0.00 |
| 1 | 5.315 | 4.938 | 5.380 | 5.211 | 47.49 |
| 3 | 2.209 | 2.534 | 2.254 | 2.332 | 76.50 |
| 5 | 2.107 | 2.017 | 2.056 | 2.060 | 79.24 |
| 7 | 0.784 | 0.800 | 0.767 | 0.784 | 92.10 |
| 10 | 0.407 | 0.418 | 0.401 | 0.408 | 95.88 |
| 15 | <LOQ | <LOQ | <LOQ | - | - |
| 20 | ND | ND | ND | - | - |
| Regression equation | Y = -0.1328x + 3.9824 | | | | |
| $R^2$ | 0.967 | | | | |
| Half-life (days) | 2.28 | | | | |

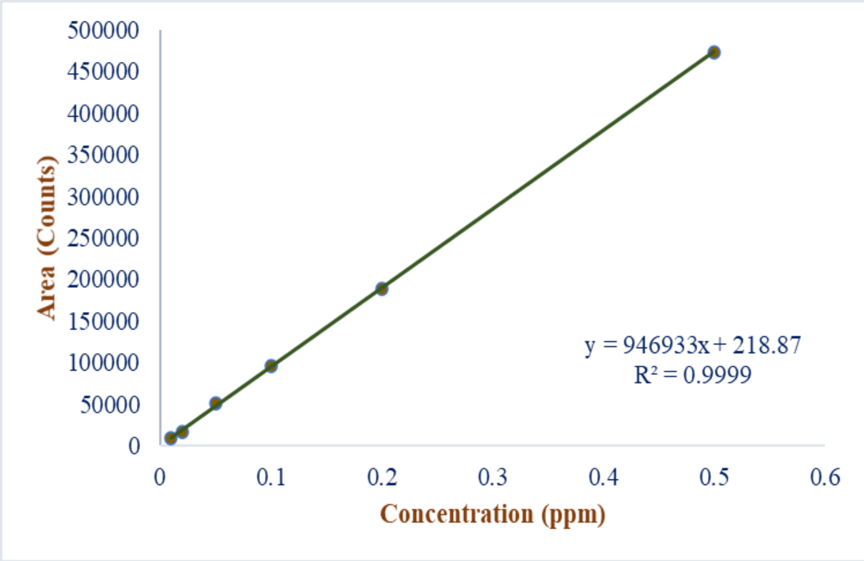



**Fig 4.27. Linearity graph of chlorpyriphos**

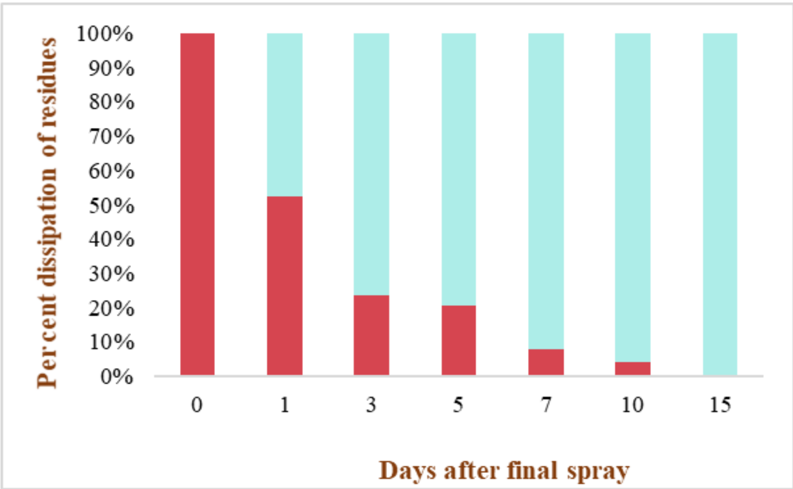



**Fig 4.28. Dissipation pattern of chlorpyriphos in cauliflower**

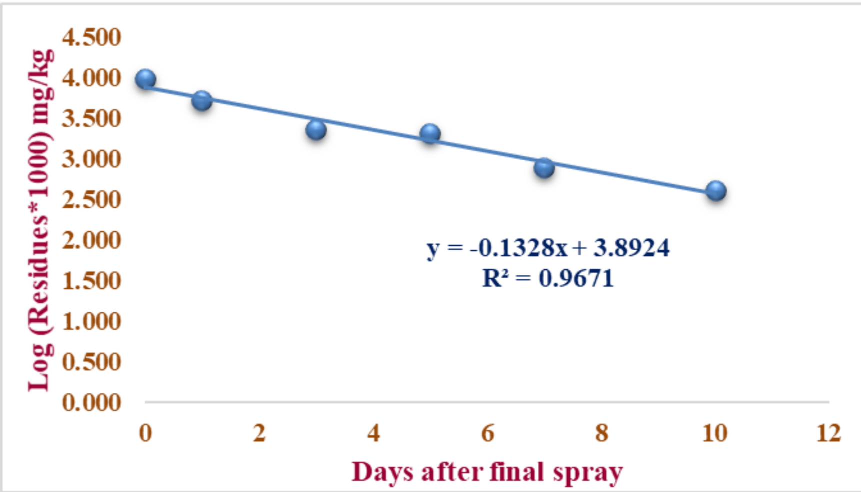



**Fig 4.29. Semi logarithmic graph depicting dissipation kinetics of chlorpyriphos in cauliflower**

**Table 4.25. Recovery of dimethoate at various fortification levels in cauliflower**

| Replication | Fortified level (mg $kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0.05 mg $kg^{-1}$ | | 0.25 mg $kg^{-1}$ | | 0.5 mg $kg^{-1}$ | |
| | Recovered Level (mg $kg^{-1}$) | Per cent recovery | Recovered Level (mg $kg^{-1}$) | Per cent recovery | Recovered Level (mg $kg^{-1}$) | Per cent recovery |
| R1 | 0.045 | 90.46 | 0.271 | 108.54 | 0.444 | 88.90 |
| R2 | 0.049 | 98.97 | 0.257 | 102.95 | 0.415 | 82.96 |
| R3 | 0.046 | 92.80 | 0.269 | 107.45 | 0.455 | 91.08 |
| **Average** | **0.047** | **94.07** | **0.266** | **106.31** | **0.438** | **87.64** |
| **SD (±)** | **0.002** | **4.40** | **0.007** | **2.96** | **0.021** | **4.20** |
| **RSD (%)** | **-** | **4.67** | **-** | **2.78** | **-** | **4.80** |

**Table 4.26. Dissipation pattern of dimethoate in cauliflower curd**

| Days after final spray | Residues of dimethoate (mg $kg^{-1}$) | | | | Per cent dissipation |
|---|---|---|---|---|---|
| | R1 | R2 | R3 | Mean | |
| 0 | 4.935 | 5.603 | 4.857 | 5.132 | - |
| 1 | 4.478 | 4.069 | 4.477 | 4.341 | 15.40 |
| 3 | 0.839 | 0.939 | 0.847 | 0.875 | 82.95 |
| 5 | 0.237 | 0.167 | 0.227 | 0.210 | 95.90 |
| 7 | 0.151 | 0.136 | 0.164 | 0.150 | 97.07 |
| 10 | <LOQ | <LOQ | <LOQ | <LOQ | 100.0 |
| 15 | ND | ND | ND | - | - |
| Regression equation | Y = -0.2444x + 3.7396 | | | | |
| $R^2$ | 0.958 | | | | |
| Half-life (days) | 1.23 | | | | |

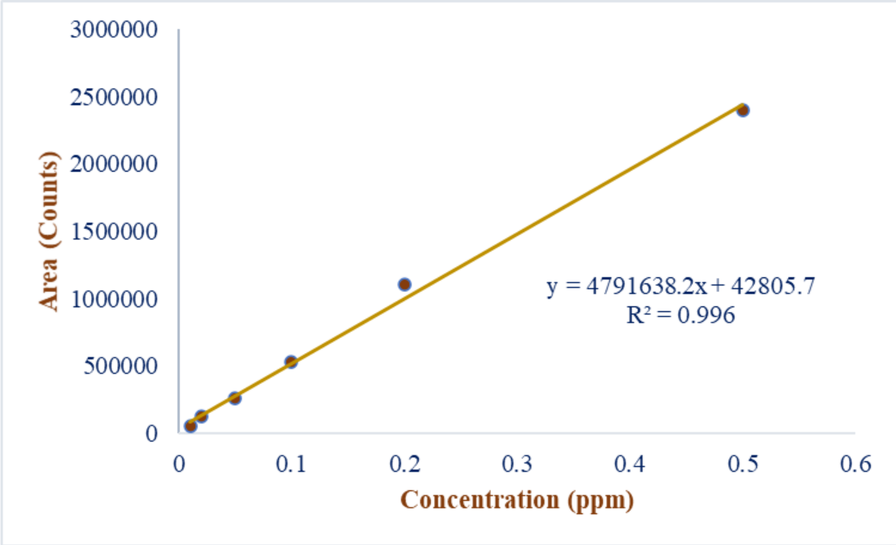



**Fig 4.30. Linearity graph of dimethoate**

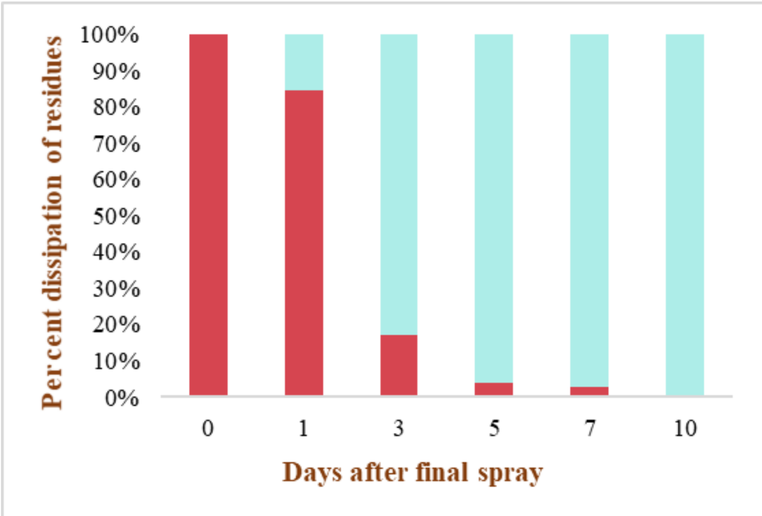



**Fig. 4.31. Dissipation pattern of dimethoate in cauliflower**

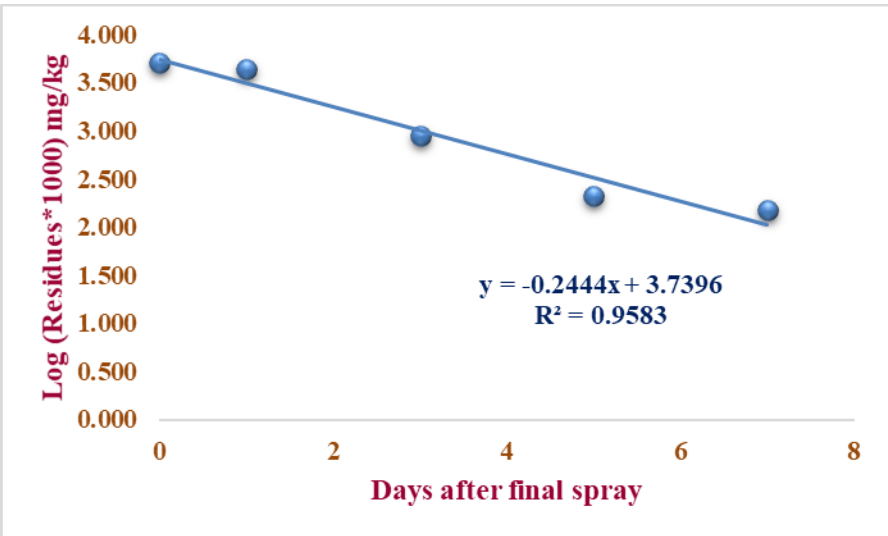



**Fig 4.32. Semi logarithmic graph depicting dissipation kinetics of dimethoate in cauliflower**

### 4.3.8 Comparison of Persistence, Half-life and Waiting period of selected insecticides in cauliflower

Based on the dissipation of selected insecticides against insect pests of cauliflower, persistence, half-life and waiting period of these insecticides were compared as shown in Table 4.27. The persistence of various insecticides ranged from 1 to 15 days (Fig. 4.33). Although the initial deposits of the pesticides in the present investigation were higher, their half-life periods ranged from 1.23 to 4.09 days. Insecticides when sprayed on the crops to manage insect pests start dissipating after they are sprayed. The rate at which they dissipate varies with the physico-chemical parameters of the insecticide and also on the environmental conditions. The retention depends on physico-chemical properties of the insecticide and the crop on which it is sprayed. The ability to resist degradation (persistence) under various conditions is measured as half-life of the pesticide (Bajwa and Sadhu, 2014). Half-life of a pesticide can range from hours or days to years for more persistent ones. Pesticides can be degraded by photolysis, hydrolysis, oxidation and reduction, metabolism (plants, animals, microbes), temperature and pH (Helfrich, 2009).

In case of chlorantraniliprole, the residues were found to persist for 10 days with half-life of 3.68 days. However, the initial deposits were found to be below MRL of 2.0 mg $kg^{-1}$ prescribed by the Codex Alimentarius Commission. Earlier, Kar *et al.* (2013) reported that chlorantraniliprole residues in cauliflower were 0.18 and 0.29 μg $g^{-1}$, one hour after spraying @ 9.25 g *a.i.* $ha^{-1}$ and 18.50 g *a.i.* $ha^{-1}$, respectively and reached BDL on 3 and 5 days after treatment with half-live of 1.36 and 1.25 days, respectively. Preethi *et al.* (2019) reported that the mean initial deposits of chlorantraniliprole were 0.24 and 0.41 μg $g^{-1}$ at 10 g *a.i.* $ha^{-1}$ and 20 g *a.i.* $ha^{-1}$, respectively and reached BDL of 0.05 μg $g^{-1}$ on 7 and 10 days after application, respectively. Dissipation of chlorantraniliprole followed first order reaction kinetics and the calculated half-lives were 2.29 to 2.53 days at Coimbatore, Tamil Nadu.

Spinosad residues persisted upto 5 days with half-life of 1.88 days. Sharma *et al.* (2007) evaluated the persistence of spinosad in soil, cabbage and cauliflower at two application rates (17.5 and 35.0 g *a.i.* $ha^{-1}$) by high performance liquid chromatography and found that the initial deposits of 0.82, 2.97 and 2.66 mg $kg^{-1}$ at 17.5 g *a.i.* $ha^{-1}$ persisted up to 7 days in soil, cabbage and cauliflower, respectively. However, at 35.0 g *a.i.* $ha^{-1}$, spinosad residues persisted up to 7 days in soil and 10 days in cabbage and cauliflower in Punjab.

**Table 4.27. Persistence, half-life and waiting periods of various insecticides in cauliflower**

| Insecticides | Dose (g *a.i.* ha$^{-1}$) | Residues (mg/kg) | | Persistence (days) | Half-life (days) | MRL (mg kg$^{-1}$) | Waiting period (days) |
|---|---|---|---|---|---|---|---|
| | | Initial | Final | | | | |
| Chlorantraniliprole 18.5 SC | 10 | 0.780 | 0.111 | 10 | 3.68 | 2* | - |
| Spinosad 2.5 SC | 17.5 | 1.069 | 0.345 | 5 | 1.88 | 0.02** | 10.97 |
| Emamectin Benzoate 5 SG | 10 | 0.168 | 0.119 | 1 | 2.01 | - | - |
| Indoxacarb 14.5 SC | 40 | 1.334 | 0.109 | 15 | 4.09 | 0.2* | 11.77 |
| Diafenthiuron 50 WP | 300 | 5.356 | 0.227 | 10 | 2.33 | - | - |
| Chlorpyriphos 50 EC | 500 | 9.924 | 0.408 | 10 | 2.28 | 1** | 6.71 |
| Dimethoate 30 EC | 200 | 5.132 | 0.150 | 7 | 1.23 | 2** | 1.79 |

***Codex value**

**** FSSAI value**


**Fig. 4.33. Persistence (in days) of selected insecticides in cauliflower**

Mandal *et al*. (2009) reported that average initial deposits of spinosad as 0.57 and 1.34 mg $kg^{-1}$, at 15 and 30 g *a.i.* $ha^{-1}$ respectively, which dissipated below the limit of quantification (LOQ) of 0.02 mg $kg^{-1}$ after 10 days at both the dosages with half-live of 1.20 and 1.58 days, respectively, and suggested a waiting period of 6 days for the safe consumption of spinosad treated cauliflower. Singh and Battu (2012) reported average initial deposits of 0.33 and 0.56 mg $kg^{-1}$ of spinosad which dissipated to below LOQ (0.01 mg $kg^{-1}$) after 5 and 7 days when applied @ 15 g *a.i.* $ha^{-1}$ and 30 g *a.i.* $ha^{-1}$, respectively in cabbage. In the present study the waiting period was calculated and was found to be 10.97 days as the codex MRL value is 0.02 mg $kg^{-1}$.

Least persistence (1 day) was found in case of emamectin benzoate while indoxacarb was found to persist up to 15 days with respective half- life of 2.01 and 4.09 days. Chahil *et al.* (2014) reported average initial deposits of 0.22 and 0.30 mg $kg^{-1}$ of emamectin benzoate when applied @ 8.5 and 17 g *a.i.* $ha^{-1}$, respectively and dissipated to below LOQ of 0.05 mg $kg^{-1}$ in 5 and 7 days with half-life of 1.72 and 2.26 days, respectively. In contrary to our findings Takkar *et al.* (2011) reported the average initial deposits of 0.23 and 0.45 mg $kg^{-1}$ of indoxacarb when applied @ 52.2 and 104.4 g. *a.i.* $ha^{-1}$, respectively. The residues in cauliflower dissipated below its LOQ of 0.01 mg $kg^{-1}$ after 7 days and its half-life periods were observed to be 1.12 and 1.31 days, respectively. Urvashi *et al.* (2012) reported average deposits of 0.18 and 0.39 mg $kg^{-1}$ of indoxacarb on cabbage at two doses (52.2 and 104.4 g *a.i.* $ha^{-1}$) which dissipated to below LOQ of 0.01 mg $kg^{-1}$ after 7 and 10 days with half-life of 2.88 and 1.92 days, respectively.

The insecticides diafenthiuron and chlorpyriphos persisted up to ten days each with half-life of 2.33 and 2.38 days, respectively. Anusha *et al.* (2018) reported initial deposits of 1.35 and 2.40 mg $kg^{-1}$ of diafenthiuron when sprayed at 1 and 2 g $l^{-1}$ in chilli at fruiting stage. The calculated half-life was 0.684 and 1.168 mg $kg^{-1}$ with waiting periods of 9.76 and 11.31 days, respectively. Stanley *et al.* (2014) reported that the initial deposits of diafenthiuron in green cardamom capsules @ 400 g *a.i.* $ha^{-1}$ was 3.82 and 4.10 μg $g^{-1}$ while that of the higher dose of diafenthiuron (800 g *a.i.* $ha^{-1}$) was as high as 6.61 and 7.32 μg $g^{-1}$. The residues of diafenthiuron and their metabolites in green capsules of cardamom dissipated to below the detectable level (BDL) at 15 DAT in both the doses. Raina and Raina (2008) reported initial deposits of chlorpyriphos of 0.56 to 0.86 mg $kg^{-1}$ in recommended (500 g *a.i.* $ha^{-1}$) and 1.29 to1.43 mg $kg^{-1}$ in double dose (1000 g *a.i.* $ha^{-1}$) in cauliflower. Half-lives varied from 1.4 to 1.5 and 1.5 to1.6

days and reached below MRL (0.05 mg kg$^{-1}$) in 5 to 6.3 and 7.1 to 7.3 days for recommended and double doses, respectively.

Lu *et al.* (2014) studies the residue behavior of chlorpyrifos in six vegetable crops under greenhouse conditions in China at vegetative stage after foliar spray with chlorpyrifos 40 EC @ 0.97 kg *a.i.* ha$^{-1}$. The initial deposits of chlorpyrifos showed differences among the six selected vegetable plants, ranging from 16.5±0.9 mg kg$^{-1}$ (*Brassica chinensis*) to 74.0±5.9 mg kg$^{-1}$ (pepper plant). At pre-harvest interval of 21 days, the chlorpyrifos residues in edible parts of the crops were <0.01 (eggplant fruit), <0.01 (pepper fruit), 0.56 (lettuce), 0.97 (*B. chinensis*), 1.47 (asparagus lettuce), and 3.50 mg kg$^{-1}$ (celery), respectively. The half-lives of chlorpyrifos were found to be 7.79 (soil), 2.64 (pepper plants), 3.90 (asparagus lettuce), 3.92 (lettuce), 5.81 (*B. chinensis*), 3.00 (eggplant plant), and 5.45 days (celery), respectively. The dissipation of chlorpyrifos in soil and the six selected plants was different, indicating that the persistence of chlorpyrifos residues strongly depends upon leaf characteristics of the selected vegetables. Antonious *et al.* (2017) investigated the persistence of chlorpyrifos and its metabolites when sprayed at 946.4 ml per acre in kale and collard leaves. The initial deposits of chlorpyrifos were higher on collard (14.5 µg g$^{-1}$) than kale (8.2 µg g$^{-1}$) with half-lives of 7.4 and 2.2 days, respectively.

Dimethoate residues persisted upto 7 days with half-life of 1.23 days. The initial deposits of dimethoate (1.25 ml l$^{-1}$) were 2.46 mg kg$^{-1}$ which dissipated to 0.018 by 30$^{th}$ day after spray in cabbage with half-life of 4.59 days while in case of double dose (2.5 ml l$^{-1}$) the initial deposits of 4.89 mg kg$^{-1}$ dissipated to 0.047 by 30$^{th}$ day after spray in cabbage with half-life of 4.50 days (Pandey *et al.,* 2004). Gopalakrishnan *et al.* (2018) reported that the mean initial deposit (1 h after spraying) of dimethoate at 200 and 400 g a.i ha$^{-1}$ were 7.25 µg g$^{-1}$ and 19.51 µg g$^{-1}$ for foxtail amaranthus and 18.37 µg g$^{-1}$ and 29.46 µg g$^{-1}$ for spinach, respectively. The residues reached below detectable level of < 0.05 µg g$^{-1}$ at 10 days after treatment in foxtail amaranthus and 15 and 20 DAT in spinach for both doses. Half-life of dimethoate residues were 0.85 and 0.86 days in foxtail amaranthus; 2.22 and 1.12 days in spinach at 200 and 400 g *a.i* ha$^{-1}$, respectively.

Thus, the studies on dissipation pattern of selected insecticides in cauliflower curd revealed that emamectin benzoate persisted for one day in cauliflower head while spinosad and dimethoate persisted for 5-7 days. Persistence of chlorantraniliprole, diafenthiuron and chlorpyriphos was observed for 10 days while the highest persistence was noticed for indoxacarb. Based on the designated MRL values (Codex/FSSAI), the calculated waiting periods were found to be lowest for dimethoate (1.79 days) followed by chlorpyriphos (6.71 days), spinosad (10.97 days) and indoxacarb (11.77 days).

## 4.4 Decontamination of Selected Insecticide Residues in Cauliflower

The results of decontamination studies are presented in Table 4.28. The initial deposits of all the seven insecticides when subjected to various decontamination methods showed reduction compared to treated control (without washing).

A perusal of the Table 4.28 clearly indicated that by cooking in pressure cooker, the residues were found to be lowest *i.e* 0.022 mg $kg^{-1}$ (chlorantraniliprole), 0.174 mg $kg^{-1}$ (spinosad), 0.0 mg $kg^{-1}$ (emamectin benzoate), 0.455 mg $kg^{-1}$ (indoxacarb), 0.325 mg $kg^{-1}$ (diafenthiuron), 8.520 mg $kg^{-1}$ (chlorpyriphos) and 2.35 mg $kg^{-1}$ (dimethoate) when compared to the other decontamination methods. The per cent reduction of residues of chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, diafenthiuron, chlorpyriphos and dimethoate by cooking in pressure cooker over treated control were 95.66, 91.36, 100, 70.89, 89.59, 50.60 and 73.75, respectively (Fig 4.34). Cooking in pressure cooker was on par with boiling in open vessel in case of emamectin benzoate, chlorpyriphos and dimethoate recording per cent reduction of 100, 46.98 and 69.94, respectively.

Boiling in open vessel in case of chlorantraniliprole, spinosad, indoxacarb and diafenthiuron was the next best method for reduction of residues with 79.08, 77.13, 63.09 and 79.89 per cent reduction. Thanki *et al*. (2012) reported that boiling and cooking processes minimized the residues of nine pesticides in the range of 21.08 to 70.67 and 31.63 to 85.30 per cent, respectively. Also, Tomer and Sangha (2013) observed that organophosphates reduced by 92 per cent in cauliflower after boiling.

Soaking in 4% acetic acid for 10 min led to per reduction of residues up to 100 (indoxacarb), 75.34 (chlorantraniliprole), 73.92 (spinosad), 65.72 (emamectin benzoate), 62.84 (diafenthiuron), 45.16 (chlorpyriphos) and 40.70 (dimethoate). Amir *et al*. (2019) reported that soaking in acetic acid (2%, 4%, 6%, 10%) showed greatest reduction of pesticide residues of organophosphate (chlorpyrifos) which degraded more rapidly followed by pyrethroids (deltamethrin and cypermethrin) and the lowest decrease was in organochlorine (endosulfan). 4% Acetic acid recorded 30.47 per cent

## Table 4.28. Decontamination methods for selected insecticides in cauliflower curd

| Decontamination method | Chlorantraniliprole | | Spinosad | | Emamectin benzoate | | Indoxacarb | | Diafenthiuron | | Chlorpyriphos | | Dimethoate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residues | Per cent reduction | Residues | Per cent reduction | Residues | Per cent reduction | Residues | Per cent reduction | Residues | Per cent reduction | Residues | Per cent reduction | Residues | Per cent reduction |
| Tap water | 0.210 | 56.40 $^{f}$ (48.70) | 1.211 | 39.73 $^{f}$ (39.05) | 0.104 | 33.61 $^{d}$ (35.37) | 0.70 | 55.09 $^{e}$ (47.91) | 1.430 | 54.19 $^{e}$ (47.40) | 13.120 | 23.98 $^{d}$ (29.31) | 5.516 | 34.05$^{c}$ (35.36) |
| 2% salt | 0.185 | 61.64 $^{e}$ (51.73) | 1.065 | 46.98 $^{e}$ (43.25) | 0.092 | 41.81 $^{c}$ (40.25) | 0.564 | 63.72 $^{d}$ (52.96) | 0.776 | 75.12 $^{c}$ (60.08) | 11.010 | 36.09 $^{c}$ (36.90) | 5.29 | 37.53$^{bc}$ (37.60) |
| 0.1% Sodium bicarbonate | 0.154 | 68.10 $^{d}$ (55.60) | 0.958 | 52.25 $^{d}$ (46.27) | 0.098 | 37.98 $^{d}$ (38.02) | 0.646 | 58.39$^{e}$ (49.84) | 0.883 | 71.70 $^{c}$ (57.88) | 9.380 | 45.57$^{b}$ (42.44) | 5.22 | 37.21$^{b}$ (37.33) |
| 4% Acetic acid | 0.119 | 75.34 $^{c}$ (60.22) | 0.524 | 73.92 $^{c}$ (59.27) | 0.054 | 65.72 $^{b}$ (54.14) | 0.0 | 100 $^{a}$ (90.00) | 1.160 | 62.84 $^{d}$ (52.45) | 9.450 | 45.16$^{b}$ (42.21) | 4.84 | 40.70$^{b}$ (39.43) |
| Boiling in open vessel | 0.100 | 79.08$^{b}$ (62.81) | 0.456 | 77.13$^{b}$ (61.50) | 0.0 | 100 $^{a}$ (90.00) | 0.577 | 63.09$^{c}$ (52.57) | 0.628 | 79.89 $^{b}$ (63.33) | 9.133 | 46.98 $^{ab}$ (43.25) | 2.44 | 69.94 $^{a}$ (57.01) |
| Cooking in pressure cooker | 0.022 | 95.53$^{a}$ (77.77) | 0.174 | 91.33 $^{a}$ (72.85) | 0.0 | 100 $^{a}$ (90.00) | 0.455 | 70.85$^{b}$ (57.30) | 0.325 | 89.59$^{a}$ (71.15) | 8.520 | 50.62 $^{a}$ (45.34) | 2.35 | 70.93 $^{a}$ (57.66) |
| Treated control | 0.497 | 0.0 | 2.013 | 0.0 | 0.157 | 0.0 | 1.563 | 0.0 | 3.122 | 0.0 | 17.24 | 0.0 | 8.95 | 0.0 |
| C.D.( $P \leq 0.05$) | - | 2.23 | - | 2.31 | - | 3.63 | - | 2.58 | - | 4.71 | - | 2.52 | - | 3.84 |
| SE(m) (±) | - | 0.70 | - | 0.724 | - | 1.14 | - | 0.81 | - | 1.48 | - | 0.79 | - | 1.20 |
| SE(d) (±) | - | 0.99 | - | 1.024 | - | 1.61 | - | 1.14 | - | 2.09 | - | 1.12 | - | 1.70 |
| C.V. (%) | - | 2.04 | - | 2.335 | - | 3.40 | - | 2.40 | - | 4.36 | - | 3.43 | - | 4.73 |

Figures in parenthesis are angular transformed values

Treatments denoted with same alphabets within a column are not significant at 5% level

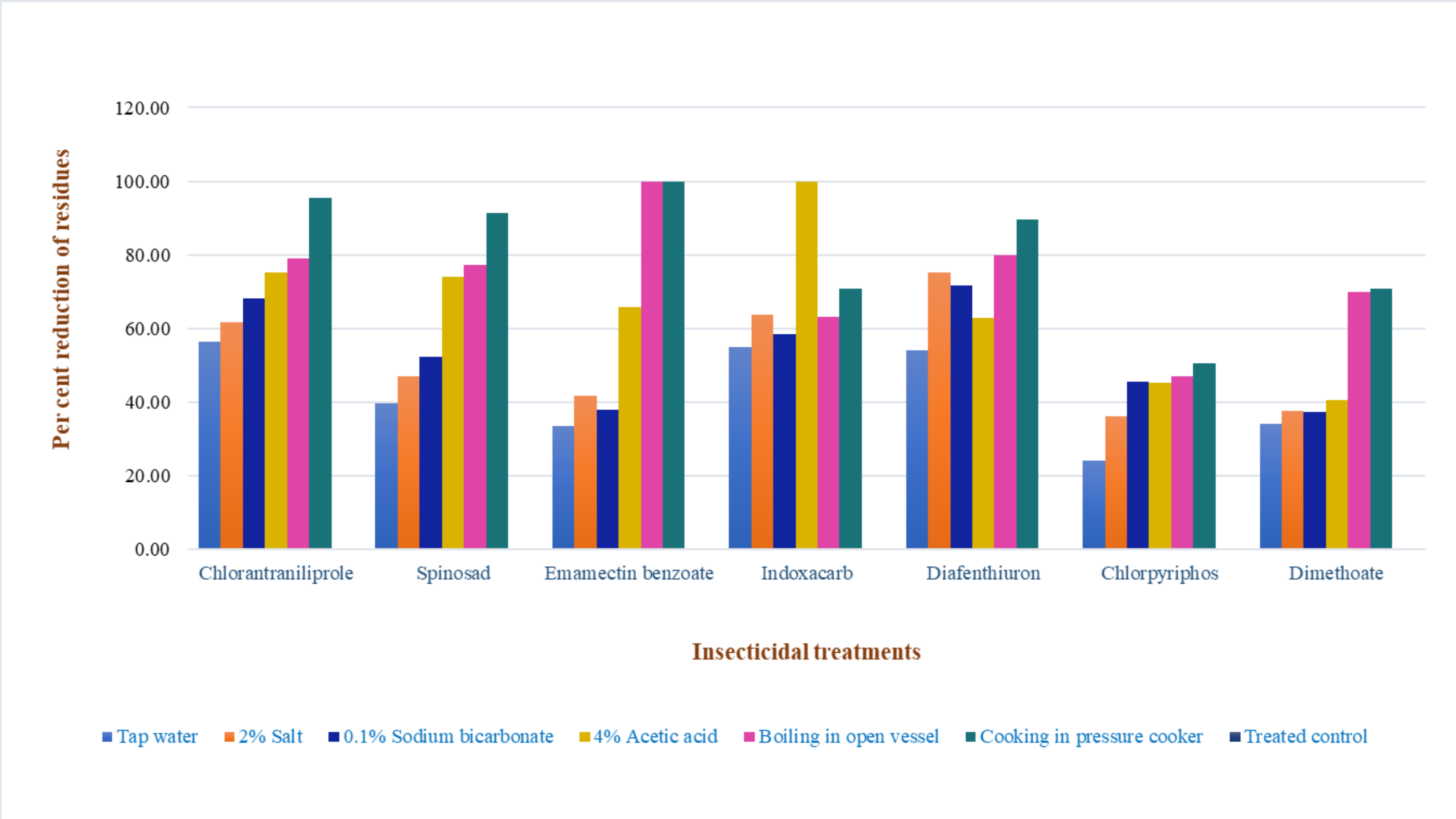



**Fig. 4.34. Efficacy of decontamination methods for selected insecticides in cauliflower**

reduction in endosulfan, 32.21% in deltamethrin, 47.04% in cypermethrin and 48.39% in chlorpyriphos.

Soaking in 2% salt solution for 10 min led to 36.09 to 75.12 per cent reduction of residues of various insecticides while 0.1% sodium bicarbonate recorded a reduction of 37.12 to 71.70 per cent. Among various decontamination methods, washing in tap water gave 23.98 to 56.40 per cent reduction of residues and was significantly superior over untreated control. Similarly, Thanki *et al.* (2012) recorded a reduction of residues of nine pesticides in the range of 3.32 to 70.0 per cent by washing. Dhiman and Hiremath (2014) observed maximum reduction in concentration of indoxacarb (79.24%) and moderate reduction in chlorpyrifos (67.16%) by traditional processes *i.e.* washing with tap water. Washing with boiled water significantly reduced indoxacarb (95.59%) while moderately reducing chlorpyriphos (55.02%) residues. Liang *et al.* (2012) recorded highest reduction by washing with 5% sodium carbonate solution for trichlorfon and dimethoate and by 5% sodium bicarbonate solution for dichlorvos, fenitrothion and chlorpyrifos. The residues of these organophosphorous pesticides were reduced from 31.1% to 98.8% after washing with these solutions for 20 min.

The decontamination techniques bring down the concentration of pesticides and the extent of reduction depends on the initial deposits at harvest and also on the substrate and the type of pesticide. Most of the pesticides are confined to outer surfaces and undergo limited penetration and can be easily dislodged by washing. Thus, loosely held residues of pesticides are easily removed by various types of washing (Street, 1969). Panhwar and Sheik (2013) analyzed the effect of traditional methods on reduction of pesticide residues and reported that water soluble pesticides *i.e.* emamectin benzoate and diafenthiuron were reduced most efficiently by detergent washing with reduction up to 45.93 and 55.69 while simple washing reduced the residues by 40.69 and 39.07 per cent, respectively.

Thus, in the present study, cooking in pressure cooker and boiling in open vessel for 10 minutes lead to reduction of insecticide residues to an extent of and 50-100 and 46-100 per cent, respectively while soaking in 4% acetic acid was the next best treatment recording reduction of residues from 40 to 100 per cent for various insecticides in cauliflower.

# Chapter V

# SUMMARY AND CONCLUSIONS

Cauliflower (*Brassica oleraceae* L *var. botrytis*) is one of the most important winter vegetables. It is consumed as vegetable in curries, soups and pickles. It is low in fat and is rich source of dietary fibre, vitamins and minerals. Bihar, Uttar Pradesh, West Bengal, Orissa, Assam, Haryana, Rajasthan and Maharashtra are the major cauliflower growing states. In Telangana, the area under cauliflower is 2.2 thousand ha with a total production of 3.39 lakh mt and average productivity of 15.43 mt $ha^{-1}$.

The present studies on "Seasonal incidence of insect pests, bioefficacy and dissipation pattern of selected insecticides in cauliflower" was undertaken during *rabi*, 2018-19 and 2019-20 with the objectives *viz*.,

1. To study the seasonal incidence of insect pests in cauliflower and their correlation with weather factors
2. Bio-efficacy of selected insecticides against insect pest complex in cauliflower
3. Dissipation pattern and residue dynamics of selected insecticides and
4. Methods for decontamination of insecticide residues in cauliflower

Field trials were taken up during *rabi*, 2018-19 and 2019-20 at College Farm, College of Agriculture, Rajendranagar (17.32' N, 78.40' E). The cauliflower nursery was sown in the second fortnight of September using var. Dhaval $F_1$ 043 and after one month seedlings were transplanted in the main field. The crop was raised as per the recommended package of practices. In case of seasonal incidence studies, insecticidal sprays were not given while for bio-efficacy trials, selected insecticides were sprayed twice at 15 days interval the first spray commencing at curd initiation stage against leaf webber and aphids. Curds from bio-efficacy trials were collected to study the dissipation pattern, half-life and waiting periods of selected insecticides at AINP on Pesticide Residues, Rajendranagar. The effectiveness of various methods in decontaminating the residues of selected insecticides in cauliflower at zero day after spray was also carried out.

The seasonal incidence of insect pests revealed that aphid and leaf webber were the major biotic constraints in cauliflower. Although the incidence of diamondback moth, painted bug and tobacco caterpillar were noticed, it was very low during the period of study in both 2018-19 and 2019-20. The incidence of aphids was noticed during 47$^{th}$ SMW during both the years *i.e* 2018-19 and 2019-20. In the first year, there was a gradual increase in aphid population peaking during 1$^{st}$ SMW (115/3leaves/plant) while in the second year, there was a sudden increase in population peaking early *i.e.* by 51$^{st}$ SMW (122.2/3leaves/plant) with a slight decline before reaching the second peak (142.6/3leaves/plant) during 2$^{nd}$ SMW. In case of leaf webber, incidence was noticed during 48$^{th}$ SMW in both the years. However, in 2018-19 single peak occurred in the 52$^{nd}$ SMW (4.8 larvae/plant) while in 2019-20, two peaks were noticed, the first during 51$^{st}$ SMW (5.4 larvae/plant) and the second during 2$^{nd}$ SMW (6.4 larvae/plant). The head borer damage was noticed during 2$^{nd}$ SMW during both the years. The peak damage was attained by the end of 6$^{th}$ SMW recording 30 per cent damage during 2018-19 and 38 per cent damage during 2019-20.

The natural enemies *i.e.* coccinellids and syrphids were observed feeding on aphids. The incidence of coccinellids initiated during 50$^{th}$ SMW, increased gradually and attained peak in the 2$^{nd}$ SMW (1.20/plant) during 2018-19 and during 1$^{st}$ SMW (1.40/plant) in 2019-20. The incidence of syrphids initiated in the 49$^{th}$ SMW and increased gradually reaching peak of 2.40 and 2.90 per plant during 2$^{nd}$ SMW in first and second seasons, respectively.

Aphids and leaf webber showed a negative correlation with temperature, windspeed and evaporation and positive correlation with morning RH and sunshine. The predators *viz.*, coccinellids and syrphids exhibited a negative correlation with maximum and minimum temperatures and windspeed while showing positive correlation with morning RH and evaporation. The predators were found to be dependent on the density of aphids and showed positive correlation with aphid population.

The bioefficacy studies revealed that chlorantraniliprole was the most effective insecticide against leaf webber with 84.03 per cent reduction in population followed by spinosad (79.10%), emamectin benzoate (78.99%) and indoxacarb (73.25%). Chlorpyriphos, diafenthiuron and dimethoate were less effective with 52.97, 40.96 and 31.19 per cent reduction over control, respectively. All these four insecticides have a novel mode of action targeting insect ryanodine receptors, nicotinic acetyl choline receptors, GABA receptors and blocking sodium channels, respectively.

In case of aphids, per cent reduction by various insecticides revealed that dimethoate was the most effective with highest overall reduction in population (77.70%) followed by chlorpyriphos (60.14%) while the remaining treatments recorded less than 50 per cent reduction of aphid population. The mean head borer per cent damage was lowest in chlorantraniliprole treated plots (10.36%) while it was highest in control (36.13%).

Among the selected insecticides, the mean highest yield of 19.74 t $ha^{-1}$ was recorded from chlorantraniliprole treated plots while emamectin benzoate (19.16 t $ha^{-1}$), spinosad (18.79 t $ha^{-1}$) and indoxacarb (18.36 t $ha^{-1}$) were found to be on par. Highest incremental cost-benefit ratio of 1:18.63 was also obtained in chlorantraniliprole treatment.

The studies on dissipation pattern of selected insecticides in cauliflower curd revealed that emamectin benzoate persisted for one day in cauliflower head while spinosad and dimethoate persisted for 5-7 days. Persistence of chlorantraniliprole, diafenthiuron and chlorpyriphos was observed for 10 days while the highest persistence was noticed for indoxacarb (15 days). Based on the designated MRL values (Codex/FSSAI), the calculated waiting periods were found to be lowest for dimethoate (1.79 days) followed by chlorpyriphos (6.71 days), spinosad (10.97 days) and indoxacarb. In case of chlorantraniliprole, the initial deposits were less than MRL values while in case of emamectin benzoate and diafenthiuron, MRL values are unavailable.

The decontamination techniques bring down the concentration of pesticides and the extent of reduction depends on the initial deposits at harvest and also on the substrate and the type of pesticide. The per cent reduction of residues of chlorantraniliprole, spinosad, emamectin benzoate, indoxacarb, diafenthiuron, chlorpyriphos and dimethoate by cooking in pressure cooker over treated control were 95.66, 91.36, 100, 70.89, 89.59, 50.60 and 73.75, respectively. Boiling in open vessel in case of chlorantraniliprole, spinosad, indoxacarb and diafenthiuron was the next best method for reduction of residues by 79.08, 77.13, 63.09 and 79.89, respectively.

Based on the results obtained from the present study, the following conclusions can be drawn

1. The incidence of aphids and leaf webber was noticed while other insect pests were low in the late sown crop.

2. The number of peaks observed in insect population depended on lowest minimum temperature.
3. The leaf webber and head borer can be effectively managed by two sprays of novel insecticides (chlorantraniliprole, spinosad, emamectin benzoate and indoxacarb) while dimethoate proved effective against aphids.
4. From the point of food safety, it was observed that though chlorantraniliprole persisted for 10 days, its residues were below MRL within one day after spray. Also, emamectin benzoate dissipated to below LOQ within 3 days.
5. The dissipation studies, half-lives and waiting periods would help in expansion of label claim of insecticides on new crops.
6. Simple cooking processes involving pressure cooking and boiling in open vessel can dislodge residues of insecticides effectively. Apart from cooking, using easily available household material like acetic acid (vinegar), salt and sodium bicarbonate can further aid in decontaminating the insecticide residues in vegetables.

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The pattern of 'Literature cited' presented above is in accordance with the 'Guidelines' for thesis presentation for Professor Jayashankar Telangana State Agricultural University, Hyderabad.

# APPENDIX – A

**Meteorological data during *rabi*, 2018-19**

| Standard Meteorological Weeks (SMW) | Date | Temperature | | Relative Humidity (%) | | Rainfall (mm) | Rainy days | Sun shine (hrs.) | Wind speed (km/hr) | Evaporation (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Maximum | Minimum | I | II | | | | | |
| 43 | 22-28 Oct | 32.21 | 14.9 | 87 | 32 | 0.0 | 0 | 7.2 | 2.6 | 4.3 |
| 44 | 29-4 Nov | 30.14 | 14.4 | 87 | 43 | 0.0 | 0 | 8.0 | 3.4 | 3.9 |
| 45 | 5-11 Nov | 32.7 | 14.4 | 89 | 34 | 0.0 | 0 | 9 | 2.7 | 4 |
| 46 | 12-18 Nov | 32.1 | 12.7 | 81 | 32 | 0.0 | 0 | 8.8 | 2.5 | 4.3 |
| 47 | 19-25 Nov | 31.1 | 15.0 | 89 | 41 | 0.0 | 0 | 7.2 | 3.7 | 4.0 |
| 48 | 26-02 Dec | 29.4 | 9.5 | 87 | 41 | 0.0 | 0 | 9.0 | 1.6 | 3.7 |
| 49 | 03-09 Dec | 29.1 | 15.7 | 91 | 53 | 0.0 | 0 | 4.3 | 2.7 | 2.9 |
| 50 | 10-16 Dec | 28.7 | 15.6 | 89 | 48 | 11.2 | 1 | 3.0 | 3.2 | 2.6 |
| 51 | 17-23 Dec | 24.6 | 12.4 | 92 | 57 | 2.4 | 0 | 4.3 | 4.3 | 2.2 |
| 52 | 24-31 Dec | 28.7 | 8.7 | 89 | 32 | 0.0 | 0 | 8.4 | 1.3 | 3.3 |
| 1 | 01-07 Jan | 28.7 | 05.5 | 88 | 30 | 0.0 | 0 | 9.2 | 1.0 | 3.4 |
| 2 | 08-14 Jan | 29.3 | 07.6 | 94 | 37 | 0.0 | 0 | 8.4 | 1.1 | 3.3 |
| 3 | 15-21 Jan | 29.6 | 08.0 | 90 | 40 | 0.0 | 0 | 8.6 | 1.4 | 3.7 |
| 4 | 22-28 Jan | 28.7 | 12.9 | 88 | 55 | 25.2 | 2 | 6.3 | 2.8 | 3.8 |
| 5 | 29-4 Feb | 27.0 | 09.4 | 95 | 48 | 0.0 | 0 | 8.0 | 2.3 | 3.5 |
| 6 | 5-11 Feb | 30.4 | 13.4 | 81.0 | 46.6 | 0.0 | 0.0 | 8.8 | 2.2 | 4.5 |

# APPENDIX – B

**Meteorological data during *rabi*, 2019-20**

| Standard Meteorological Weeks (SMW) | Date | Temperature (°C) | | Relative Humidity (%) | | Rainfall (mm) | Rainy days | Sun shine (hrs.) | Wind speed (km/hr) | Evaporation (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Maximum | Minimum | I | II | | | | | |
| 43 | 22-28 Oct | 29.0 | 18.2 | 88 | 68 | 20.0 | 3 | 6.0 | 0.2 | 2.7 |
| 44 | 29-4 Nov | 30.1 | 20.5 | 90 | 60 | 10.0 | 1 | 7.5 | 0.2 | 3.0 |
| 45 | 5-11 Nov | 31.1 | 18.8 | 94 | 47 | 0.0 | 0 | 7.7 | 0.0 | 3.1 |
| 46 | 12-18 Nov | 29.6 | 17.4 | 88 | 49 | 0.0 | 0 | 7.5 | 0.0 | 2.9 |
| 47 | 19-25 Nov | 29.4 | 16.6 | 90 | 49 | 0.0 | 0 | 7.6 | 0.0 | 3.1 |
| 48 | 26-02 Dec | 28.8 | 16.9 | 92 | 53 | 0.6 | 0 | 7.3 | 0.0 | 2.9 |
| 49 | 03-09 Dec | 26.8 | 16.4 | 93 | 55 | 8.2 | 1 | 4.8 | 0.1 | 2.4 |
| 50 | 10-16 Dec | 28.7 | 14.9 | 91 | 45 | 0.0 | 0 | 8.3 | 0.0 | 2.8 |
| 51 | 17-23 Dec | 28.0 | 14.1 | 95 | 48 | 0.0 | 0 | 7.5 | 0.0 | 2.7 |
| 52 | 24-31 Dec | 27.6 | 16.8 | 88 | 56 | 0.0 | 0 | 5.5 | 0.0 | 2.5 |
| 1 | 01-07 Jan | 27.9 | 18.6 | 87.4 | 58.6 | 10.6 | 1.0 | 5.2 | 0.1 | 2.6 |
| 2 | 08-14 Jan | 27.9 | 14.7 | 90.7 | 54.6 | 0.0 | 0.0 | 6.7 | 0.0 | 3.0 |
| 3 | 15-21 Jan | 29.8 | 16.3 | 87.6 | 42.7 | 0.0 | 0.0 | 8.7 | 0.0 | 3.7 |
| 4 | 22-28 Jan | 30.7 | 14.4 | 90 | 41 | 0.0 | 0 | 9.3 | 0.3 | 4.0 |
| 5 | 29-4 Feb | 31.0 | 17.6 | 85 | 49 | 0.0 | 0 | 7.4 | 4.7 | 3.9 |
| 6 | 5-11 Feb | 31.1 | 18.4 | 93 | 51 | 5.0 | 1 | 6.7 | 4.8 | 3.7 |

# APPENDIX – C

## Repeatability of insecticides under study in cauliflower at 0.25 mg kg$^{-1}$

| Replication | Chlorantraniliprole | | Spinosad | | Emamectin benzoate | | Indoxacarb | | Diafenthiuron | | Chlorpyriphos | | Dimethoate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery |
| R1 | 0.246 | 98.20 | 0.283 | 113.03 | 0.252 | 100.92 | 0.230 | 92.19 | 0.248 | 99.30 | 0.245 | 98.11 | 0.271 | 108.54 |
| R2 | 0.245 | 97.95 | 0.292 | 116.93 | 0.233 | 93.13 | 0.251 | 100.50 | 0.247 | 98.83 | 0.247 | 98.60 | 0.257 | 102.95 |
| R3 | 0.239 | 95.42 | 0.289 | 115.65 | 0.239 | 95.58 | 0.248 | 99.14 | 0.242 | 96.79 | 0.243 | 97.37 | 0.269 | 107.45 |
| **Average** | **0.243** | **97.19** | **0.288** | **115.21** | **0.241** | **96.54** | **0.243** | **97.28** | **0.246** | **98.31** | **0.245** | **98.03** | **0.266** | **106.31** |
| **SD (±)** | **0.004** | **1.541** | **0.005** | **1.99** | **0.01** | **3.98** | **0.011** | **4.46** | **0.003** | **1.34** | **0.002** | **0.620** | **0.007** | **2.96** |
| **RSD (%)** | **-** | **1.58** | **-** | **1.72** | **-** | **4.13** | **-** | **4.58** | **-** | **1.36** | **-** | **0.63** | **-** | **2.78** |

## Reproducibility of insecticides under study in cauliflower at 0.25 mg kg$^{-1}$

| Replication | Chlorantraniliprole | | Spinosad | | Emamectin benzoate | | Indoxacarb | | Diafenthiuron | | Chlorpyriphos | | Dimethoate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery | Recovered Level (mg kg$^{-1}$) | Per cent Recovery |
| R1 | 0.250 | 100.05 | 0.266 | 106.33 | 0.257 | 102.67 | 0.226 | 90.54 | 0.247 | 98.78 | 0.244 | 97.47 | 0.273 | 109.32 |
| R2 | 0.250 | 100.13 | 0.267 | 106.94 | 0.250 | 100.14 | 0.248 | 99.11 | 0.249 | 99.47 | 0.245 | 97.92 | 0.260 | 104.19 |
| R3 | 0.247 | 98.78 | 0.279 | 111.56 | 0.247 | 98.82 | 0.245 | 97.95 | 0.244 | 97.56 | 0.241 | 96.58 | 0.272 | 108.99 |
| **Average** | **0.249** | **99.65** | **0.271** | **108.28** | **0.251** | **100.54** | **0.240** | **95.87** | **0.247** | **98.60** | **0.243** | **97.33** | **0.269** | **107.50** |
| **SD (±)** | **0.002** | **0.761** | **0.007** | **2.86** | **0.005** | **1.96** | **0.012** | **4.65** | **0.002** | **0.970** | **0.002** | **0.68** | **0.007** | **2.87** |
| **RSD (%)** | **-** | **0.76** | **-** | **2.64** | **-** | **1.94** | **-** | **4.85** | **-** | **0.98** | **-** | **0.70** | **-** | **2.67** |