

**Management of seed midge, *Systole albipennis*
Walker infesting fennel, *Foeniculum vulgare* Miller**

सौंफ, फोइनीकुलम वलगेयर मिलर में सीड मिज, सिस्टोल अल्बेपेनिस

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By

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Date:

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1. Introduction

Spices occupy an important place in the lives of people since Vedic and Biblical times and have been considered indispensable in seasoning of food, flavouring of beverages, perfumery, cosmetics and medicines. The lure of spices prompted explorers like Columbus and Vasco de Gama to undertake hazardous sea journey to discover India “the land of spices” (Sastry and Sharma, 2001). A wide variety of spices are grown in the country including seed spices. Fennel is native of Southern Europe and Mediterranean region. It is cultivated throughout the temperate and sub tropical regions of the globe mainly in Romania, Russia, Hungary, Germany, France, Italy, India, Sri Lanka, Malaysia, Japan, Argentina and USA.

Fennel (*Foeniculum vulgare* Miller) plant is stout, aromatic annual herb of family Apiaceae and commonly known as *saunf*. The plant is pleasantly aromatic and different parts of the plant *viz.*, leaves, stalks, bulbs and seeds are edible. The seed contains about 9.5 per cent protein, 10.0 per cent fat, 42.3 per cent carbohydrate, 18.5 per cent crude fiber and 13.4 per cent minerals. The seed also contains about 0.7 to 6.0 per cent volatile oil depending on the genotype present (Pruthi, 1976). The main constituents of the fennel oil are anethole and fenchone. The fish string like leaves are valued as source of flavour garnish and also possess diuretic properties. The roots are regarded as a purgative while seeds are used in curing diseases like cholera, constipation, dysentery, diarrhea beside bile disturbances and nervous disorders. Seeds are used to control various problems related to chest, lungs, spleen, kidney and chronic pains. In India, the seeds are also used for mastication and chewing either alone or with betel leaves. The volatile oil is used in the manufacture of cordials and fennel water. The essential oil extracted from seeds are used for scenting soaps and flavouring materials for cakes and liquor. The volatile oil is primarily beneficial for digestive system and also exhibits vermifugal, antispasmodic and anti-flatulence properties (Murthy and Sridhar, 2001).

In India, fennel crop is mainly grown in the states of Gujarat and Rajasthan as a cold weather crop and to a limited extent in Uttar Pradesh, Karnataka, Andhra Pradesh, Punjab, Madhya Pradesh, Bihar and Haryana. Total area under the crop in India is about 99723 hectares with a production of 142995 tonnes (Anonymous, 2012-13). In Rajasthan, it occupied an area of 59044 hectares with an annual production of 84070 tonnes (Anonymous, 2011-12). It is mainly cultivated in Sirohi, Jodhpur, Nagaur, Tonk, Dausa, Pali and to a limited extent in Bharatpur, Kota and Ajmer districts of the state.

Insect-pests are one of the major limiting factors for higher production of fennel. Among the insect pests of fennel aphid, *Hydaphis coriandari* (Das) has been reported to be of a regular nature in Rajasthan and other parts of the country (Nayer *et al.*, 1982; Kanwat, 1988; Anonymous, 1991; Jat, 1993; Kumar and Sagar, 1994; Beltrame and Salto, 2000 and Kalra, 2006). Other pests which infest fennel crop include brown wheat mite, *Petrobia latens* (Muller); thrips, *Thrips tabaci* Lindeman; white fly, *Bemisia tabaci* (Genn.); lucern caterpillar, *Spodoptera exigua* (Hub.); pentatomid bug, *Agonoscelis nubila* (F.) (Nayer *et al.*, 1982 and Kanwat, 1988) and seed midges *viz.*, *Systole albipennis* Walker and *Systole coriandri* Gussakovsky (Patel *et al.*, 1986; Kalra, 2006 and 2007).

Seed midge damage cause both qualitative and quantitative losses in seed yield of fennel both in fields as well as in storage. Two species of seed midges reported on fennel crop namely *S. albipennis* and *S. coriandri* of Eurytomidae under Hymenoptera. Out of the two species of seed midge, *S. albipennis* has been found most prevalent causing more than 50 per cent damage in fennel crop in this area and has been a major constraint in producing quantitative and qualitative fennel crop (Agrawal *et al.*, 2004).

A female midge lay eggs in the embryo of grain and developing larva feed, pupate inside the grain and adult emerge from the grains by boring a hole, ultimately resulting in both qualitative and quantitative losses besides reducing the germination percentage (Plate - 1).

It is well known that attack of insect pests depends upon climatic conditions, crop growth stage and incidence of natural enemies at a particular

time. Hence, alterations in sowing time result in significant effect on the infestation of a specific pest on a given crop. Earlier this practice was evaluated by Kashyap *et al.*, 1994 on fennel and other workers on different crops, but due to change in the climatic conditions their effects on pest need reconsideration. In the past some varieties/germplasms were screened against seed midge by many workers (Singh and Baswana, 1984; Lamborot *et al.*, 1995 and Kalra and Sharma, 2001) however, these were replaced by newer higher yielding varieties on which such work is unavailable. Therefore, both the objectives were included in the present study.

The management of seed midge's *viz.*, *S. albipennis* and *S. coriandri* of fennel using chemical pesticides have been suggested by earlier workers (Mittal and Butani, 1995 and Ribeiro *et al.*, 1996). It is general observation that the pest population is brought down by the application of insecticides due to high initial kill of the pest and their natural enemies, but at the same time the surviving individuals soon build up their population because of high rate of multiplication and absence of natural enemies. Keeping this in view, emphasis has been given on the use of safer insecticides and biopesticides.

Practically, very meagre work has been carried out to survey the infestation level, seasonal incidence, extent of losses and management of seed midge, *S. albipennis* infesting fennel from the point of view of effectiveness, economics and safety to plants and consumers in the state of Rajasthan. Keeping the destructive nature and its significance, the present studies were undertaken at Jobner which is a true representative of semi arid region of Rajasthan with the following objectives :

- (i) To survey the infestation level of seed midge, *Systole albipennis* Walker infesting fennel.
- (ii) To study the seasonal incidence of *S. albipennis* on fennel in relation to weather parameters.
- (iii) To estimate the quantitative and qualitative losses in fennel crop.
- (iv) To manage the *S. albipennis* using IPM tools.
- (v) To estimate the residue of effective insecticides.

Plate - 1



(A) Damaged seeds



(B) Grub of *S. albipennis* inside the seed



(C) Copulatory behaviour of *S. albipennis*



(D) Grub of *S. albipennis*



(E) Pupa of *S. albipennis*



(F) Newly emerged adult of *S. albipennis*



(G) Fully grown adult of *S. albipennis*

2. Review of Literature

Scanning of literature indicated that not much work has been done on the bio-ecology and management of seed midge, *Systole albipennis* Walker infesting fennel, either in India or abroad. However, scanty information and related literature pertaining to various aspects of the present study are reviewed under separate heads.

2.1 Survey and losses

Ostrovskii (1940) observed that eurytomid, *Systole coriandri* Nikol'skaya, has been a serious pest of coriander in the Province of Voronezh, sometimes infested upto 86 per cent of the fruits and greatly decreased the yield of oils and reduced the germination power of the seeds.

Batra *et al.* (1959) observed 30 per cent damage in fennel crop as a result of infestation of *S. albipennis* at IARI, New Delhi. They further noticed that the egg was laid inside the tender seeds and the grub fed inside the mericarps and rendered them hollow. The full fed grub pupated inside the seeds. The adult emerged from the seeds after completing its development. The damaged seeds did not germinate. They further reported that some grubs of *S. albipennis* were found to be parasitized by *Tetrastichus* sp. or *Liodontomerus* sp.

The causes of the frequent high percentage of exembryonate seeds in six umbelliferous species have been investigated and dissections of mature seeds revealed the presence of a phytophagous chalcid fly, *S. albipennis*. The chalcid laid eggs between the pericarp and the ovule, the developing larvae fed upon and destroyed the embryo and/or endosperm. Consequently, approximately 40 per cent of the mericarps of *Foeniculum*, 35 per cent of *Daucus*, 30 per cent of *Coriandrum*, 27 per cent of *Anethum*, 20 per cent of *Cuminum* and 10 per cent of *Trachyspermum* lacked the embryo or sometimes even the endosperm. The insect infested fresh mericarps, however increased the percentage of exembryonate seeds during the late season (Gupta, 1962).

Sehgal (1966) reported that seed set and germination have been a serious problem in umbellifers. Embryolessness in the seeds of umbellifers, studied from various parts of India, were due to the infestation of a phytophagous fly, *S. albipennis* which laid an egg (rarely two or three) in the maturing fruits in the vicinity of endosperm or embryo. The egg developed into an adult fly from the endosperm, embryo, or both and finally emerged out by boring a hole in the pericarp. He further reported that *S. albipennis* was parasitized by *Liodontomerus* or *Tetrastichus*. The parasite laid egg in the infested ovaries and the egg developed into an adult at the cost of the larvae of *S. albipennis*. Finally, the parasite also escaped from the seed by boring a hole in the seed wall.

Popov (1979) studied that seeds of fennel have been attacked by eurytomid pest, *S. albipennis* and the pest species was fairly widespread in Europe and Soviet Asia and has also been observed in Bulgaria near Sofia (Kostinbrod and Varna). Observations in Bulgaria showed that the percentage of infested seeds varied from 5 to 17, and the value of infested seeds was reduced by some 40 per cent.

Systole albipennis was observed infesting grains of fennel under field conditions in Gujarat. Adults emerged from the harvested grains during storage. The percent weight loss of grains was reported to be highest (20.7 %) in January and lowest (5.64 %) in March (Patel *et al.*, 1986).

Santis *et al.* (1989) collected seeds of wild and cultivated umbellifers in Chile during 1986-87 to observe emergence of *S. albipennis*. The seed midge, associated with seeds of parsley, poison hemlock, carrot and fennel was reported to be *S. albipennis*. The damage caused by the pest was 3.5 per cent in parsley and carrot, 4.0 per cent in poison hemlock and 5.5 per cent in fennel.

Bamborot *et al.* (1993) studied infestation of seeds of *Coriandrum sativum* L. with *Systole coriandri* (Gussakovsky) during 1985-87 at various locations in Chile. The infestation varied from year to year and among localities. They further reported no infestation in Puangue, 49.5 and 60.3 per

cent in Quillota in 1985-86 and 1986-87, respectively. They found that cultivation of *C. sativum* in the same field for two consecutive years led to increased infestation levels.

Lambrot *et al.* (1995) found that infestation of coriander seeds by *S. coriandri* and germination percentage varied among different locations in Chile. Dissection of seeds revealed an infestation level of 3.8-14.0 per cent in apparently undamaged fruits with a significant negative correlation between infestation and germination. Fruits with both mericarps damaged did not germinate, however damage to 1 or 2 mericarps resulted in a reduction in oil content of 16.7 and 42.0 per cent, respectively as compared to undamaged fruits.

Agrawal *et al.* (2004) observed the infestation of *S. albipennis* in fennel crop during a field survey in 2003 and reported more than 50 per cent damage. The symptoms included small hole on the seed indicating the emergence of adult, however papery coat remained intact.

Kalra (2006, 2007) reported that the egg of seed midge, *S. albipennis* was laid in the developing fruit under field conditions. The larva on hatching, fed on embryo/endosperm within the fruit or seed before entering for pupation. He further reported that the adult wasp came out of the seed by making minute hole which could be 1 or 2 in each seed. The adult emergence continued up to September – October.

Singh (2008) reported that *S. albipennis* have been found infesting coriander and fennel seeds during storage. He further reported that most of the adults emerged between September to December.

Patil (2009) carried out farmer level surveys of four major coriander growing districts of Rajasthan for the infestation of *S. albipennis* and found maximum damage (21.70 %) in district Kota while such damage was minimum (17.42 %) in district Jhalawar.

2.2 The seasonal incidence of *S. albipennis* on fennel in relation to weather parameters

Patel and Patel (2003) carried out studies in Gujarat to observe the intensity of seed midge, *S. albipennis* in fennel crop during 1997-98 and found that the infestation started with the initiation of seed setting in the umbel *i.e.* second week of December 1997 and continued up to harvest (April 1998). The incidence of the pest was observed with a infestation range of 0.01 to 23.08 per cent from the first week of December 1997 to last week of January 1998. On the other hand such damage in fennel crop was found to be lowest (5.4%) in January and highest (20.7%) in March (Patel *et al.*, 2009).

2.3 Management of *S. albipennis* using IPM tools

2.3.1 Impact of sowing dates on the incidence

Baswana *et al.* (1989) carried out studies on the infestation of *S. albipennis* on coriander at Hisar during 1983-85 to observe the effect of date of sowing and row spacing on the incidence of the pest and found a significant impact of sowing dates on all growth characters whereas row spacing had no effect. The highest plant heights, number of primary branches/plant and numbers of umbels/plant were observed in crop sown on 10th October in both seasons. However, the highest seed yields 14.2 and 19.6 q h⁻¹ were obtained from the crop sown on 30th October during 1983-84 and 1984-85 respectively. Fruit borer, *S. albipennis* infestation increased significantly with each delay in sowing with the highest per cent infestation (13.5 and 23.4%) in the crop sown on 29 December during 1983-84 and 1984-85, respectively.

Kashyap *et al.* (1994) carried out field studies in Haryana to assess the impact of management practices on the incidence of *S. albipennis* in seeds of fennel and observed that the crop sown during December-January had the maximum seed infestation (up to 17%), with the minimum yield (1.1 q/ha) as compared to October sown crop which had the lowest seed infestation (4%) with the maximum yield (32 q/ha).

2.3.2 Varietal screening of fennel against seed midge, *S. albipennis*

Singh and Baswana (1984) screened 88 different coriander varieties/cultivars against the infestation of *S. albipennis* and reported that the infestation on number and weight basis varied from 1.5 to 28.3 and 1.8 to 17.7 per cent, respectively. None of the variety/cultivar was found immune, however cultivars H-116, H-6, H-39, H-13, HE-29 and HC-143 suffered less than five per cent infestation.

Kalra and Sharma (2001) screened different fennel cultivars/varieties against seed midge, *S. albipennis* and reported JF-192 least susceptible with seven per cent seed damage. In another study, Kalra (2003) reported that on the basis of season's average, UF-178 with an average five per cent seed damage was observed to be most susceptible whereas in case of variety HF-33 no damage had been recorded.

Patil (2009) screened 10 coriander variety/cultivars for their relative susceptibility against *S. albipennis* and revealed that none was found immune. The variety RCr-436 (<31.44 damaged seeds/15 umbels) proved less susceptible, whereas RCr-20, RCr-41, RCr-435, RCr-446, RCr-480, RCr-684, UD-728 and UD-796 (31.44 to 66.03 damaged seeds/15 umbels) emerged as moderately susceptible.

The relative incidence of seed midge, *S. albipennis* was studied on 15 varieties/cultivars of coriander and found that the incidence of seed midge commenced in first week of February with a peak during the second fortnight of February. On the basis of seasons' average, the maximum incidence (23.75%) was recorded on JCO-327 and the minimum (5.84%) on DH-13 (Singh *et. al.*, 2009).

2.3.3 Efficacy of the insecticides/biopesticides against seed midge, *S. albipennis*

Virtually meagre work has been done on chemical control of *S. albipennis* infesting fennel under field conditions however, Mittal and Butani (1995) evaluated six different insecticides *viz.*, Monocrotophos, endosulfan, methyl parathion, methyl-o-demeton, thiometon and DDVP against

S. albipennis and showed that applications of parathion-methyl (0.025%) and endosulfan (0.07%) at the flowering stage of fennel minimized infestation during seed storage.

Ribeiro *et al.* (1996) carried out field studies during 1987-88 to control *S. coriandri* in the seeds of coriander and found two applications of monocrotophos effective.

Patil (2009) evaluated six insecticides including two botanicals against the infestation of *S. albipennis* on coriander and reported endosulfan (0.07%) most effective followed by cartap hydrochloride (0.06%) and carbaryl (0.10%). The treatments of spinosad (0.01%) and neem oil (2%) showed medium order of effectiveness, whereas, the treatment of NSKE (5%) proved least effective.

Field experiments were conducted for the integrated management of seed wasp, *S. albipennis* infesting coriander using manipulation in date of sowing, applications of plant products and synthetic insecticides. The results revealed that plant products NSKE (5%), neem oil (1&2%) and karanj seed powder extract (5%) gave maximum protection against the pest and recorded less than three per cent seed damage. Maximum seed yield of 9.4 and 9.0 q ha⁻¹ was obtained from neem oil (2%) and NSKE (5%) treatments respectively whereas, in synthetic insecticides, applications of thiamethoxam (0.025%) gave maximum protection (2.7% damage) as well as seed yield 12.7 q h⁻¹ (Kant *et al.*, 2011).

2.4 Residue analysis

The scanning of literature indicated no reports on this aspect, hence remained unreviewed.

3. Material and Methods

The materials used and methodology adopted during the course of investigations on “Management of seed midge, *Systole albipennis* Walker infesting fennel, *Foeniculum vulgare* Miller” as envisaged in the plan of work has been described in this chapter.

3.1 General details of the experiments

3.1.1 Experimental site and climatic conditions

The field experiments were conducted on the Horticulture farm and laboratory studies were done in the Department of Entomology, S.K.N. College of Agriculture, Jobner during 2011-12 and 2012-13. Geographically, Jobner is situated at 75° 28' East longitude, 26° 05' North latitude and at an altitude of 427 meters above Mean Sea Level and is located in Jaipur district of Rajasthan. The climate of this region is typically semi-arid, characterized by extremes of temperature both during the summer and winter with low rainfall and moderate humidity. Maximum temperature in summer reaches as high as 47°C and minimum temperature in winter falls down below 0°C. The average annual rainfall of locality varies from 400-500 mm occurring mostly from the last week of June to September.

3.1.2 Preparation of land and manuring

The experimental plots were ploughed twice with disc plough and levelled with heavy wooden plank before sowing the crop. One third of the recommended dose of nitrogenous fertilizers (90 kg N ha⁻¹) and full dose of phosphatic fertilizers (40 kg P₂O₅ ha⁻¹) were applied in the soil at the time of last ploughing and half dose of nitrogenous fertilizer was applied through top dressing in two split doses first after 45 days of sowing and remaining at the time of flowering.

3.1.3 Seed rate and method of sowing

The seed rate for sowing fennel varieties was kept @ 10 kg ha⁻¹ as per package of practices recommended for the region. Before sowing, the seeds were treated with carbendazim @ 2 g kg⁻¹ seed. The seeds were sown in furrows, opened with manually operated hand driven plough with row to row distance of 45 cm and plant to plant distance of 20 cm. After sowing, the seeds were covered with a thin layer of soil.

3.1.4 Irrigation schedule and cultural practices

During the entire crop season eight irrigations were applied at various recommended crop growth stages. First irrigation was applied just after sowing and second 10 days after first and remaining after 15 days intervals. Thinning was done after 30 days of sowing, keeping plant to plant distance of 20 cm. Other agronomical practices were followed from time to time as per recommendation of package of practices for the region.

3.1.5 Method of observations

Frequent visits to the field were made to observe the first appearance of damage seeds on the plants. Five plants were randomly selected from each plot and tagged when the crop was 40 days old. Further nine umbels (three umbels each from upper, middle and lower), from each of the same five tagged plants, were labeled to record the seed midge damage. Total number of seeds/umbel and damaged seeds present on selected umbel were thoroughly checked and counted with the help of magnifying glass (10x). The appearance of black spot or insect exit hole on the seeds were considered as damaged seeds and percent infestation was calculated accordingly (Plate – 2).

3.1.6 Seed yield of fennel

The crop was harvested when seeds were fully matured. The harvested plants were kept separately plot wise in gunny bags for sun drying. The dried plants were threshed manually, cleaned and weighed. Seed yield per plot was converted into yield/ hectare and yield data were statistically analysed.

Plate - 2



(A) General view of experimental field



(B) Healthy umbel of fennel



(C) Damaged umbel of fennel (exit holes)

3.1.7 Meteorological data

Weekly data of key weather factors viz., minimum and maximum temperatures, relative humidity and rainfall were collected from the Meteorological Section, Department of Agronomy, S.K.N. College of Agriculture, Jobner. The meteorological data of both the years (2011-12 and 2012-13) are presented in table 3.1 and 3.2 and figure 3.1 and 3.2.

Table 3.1 Meteorological observations recorded during the course of study (October, 2011 to May, 2012)

| Standard Meteorological weeks | Period | | Temperature (°C) | | Average relative humidity (%) | Total rainfall (mm) |
|-------------------------------|------------|------------|------------------|---------|-------------------------------|---------------------|
| | From | To | Maximum | Minimum | | |
| 40 | 01/10/2011 | 07/10/2011 | 34.0 | 16.9 | 51.0 | 000.0 |
| 41 | 08/10/2011 | 14/10/2011 | 35.4 | 17.7 | 45.0 | 000.0 |
| 42 | 15/10/2011 | 21/10/2011 | 34.7 | 13.3 | 43.0 | 000.0 |
| 43 | 22/10/2011 | 28/10/2011 | 33.5 | 13.3 | 49.0 | 000.0 |
| 44 | 29/10/2011 | 04/11/2011 | 32.3 | 11.2 | 52.0 | 000.0 |
| 45 | 05/11/2011 | 11/11/2011 | 32.5 | 13.0 | 51.0 | 000.0 |
| 46 | 12/11/2011 | 18/11/2011 | 31.5 | 11.0 | 53.0 | 000.0 |
| 47 | 19/11/2011 | 25/11/2011 | 30.0 | 11.0 | 56.0 | 000.0 |
| 48 | 26/11/2011 | 02/12/2011 | 27.3 | 08.2 | 57.0 | 000.0 |
| 49 | 03/12/2011 | 09/12/2011 | 29.8 | 11.6 | 59.0 | 000.0 |
| 50 | 10/12/2011 | 16/12/2011 | 24.6 | 02.0 | 57.5 | 000.0 |
| 51 | 17/12/2011 | 23/12/2011 | 24.3 | 04.5 | 58.0 | 000.0 |
| 52 | 24/12/2011 | 31/12/2011 | 22.2 | 03.5 | 66.0 | 000.0 |
| 1 | 01/01/2012 | 07/01/2012 | 21.1 | 06.6 | 68.0 | 000.0 |
| 2 | 08/01/2012 | 14/01/2012 | 19.7 | 01.9 | 63.0 | 000.0 |
| 3 | 15/01/2012 | 21/01/2012 | 21.5 | 03.7 | 61.0 | 000.0 |
| 4 | 22/01/2012 | 28/01/2012 | 20.8 | 04.4 | 61.0 | 000.0 |
| 5 | 29/01/2012 | 04/02/2012 | 22.1 | 05.0 | 53.0 | 000.0 |
| 6 | 05/02/2012 | 11/02/2012 | 21.7 | 04.1 | 60.0 | 000.0 |
| 7 | 12/02/2012 | 18/02/2012 | 23.3 | 06.3 | 53.0 | 000.0 |
| 8 | 19/02/2012 | 25/02/2012 | 28.1 | 08.5 | 51.0 | 000.0 |
| 9 | 26/02/2012 | 04/03/2012 | 28.1 | 07.1 | 47.0 | 000.0 |
| 10 | 05/03/2012 | 11/03/2012 | 28.3 | 08.6 | 42.0 | 000.0 |
| 11 | 12/03/2012 | 18/03/2012 | 30.3 | 11.5 | 41.0 | 000.0 |
| 12 | 19/03/2012 | 25/03/2012 | 32.9 | 11.2 | 37.0 | 000.0 |
| 13 | 26/03/2012 | 01/04/2012 | 36.4 | 17.0 | 39.5 | 000.0 |
| 14 | 02/04/2012 | 08/04/2012 | 39.0 | 19.4 | 32.5 | 000.0 |
| 15 | 09/04/2012 | 15/04/2012 | 36.6 | 18.9 | 45.0 | 004.8 |
| 16 | 16/04/2012 | 22/04/2012 | 34.0 | 18.7 | 41.5 | 003.0 |
| 17 | 23/04/2012 | 29/04/2012 | 34.8 | 18.4 | 38.0 | 000.0 |
| 18 | 30/04/2012 | 06/05/2012 | 38.7 | 19.8 | 31.5 | 000.0 |

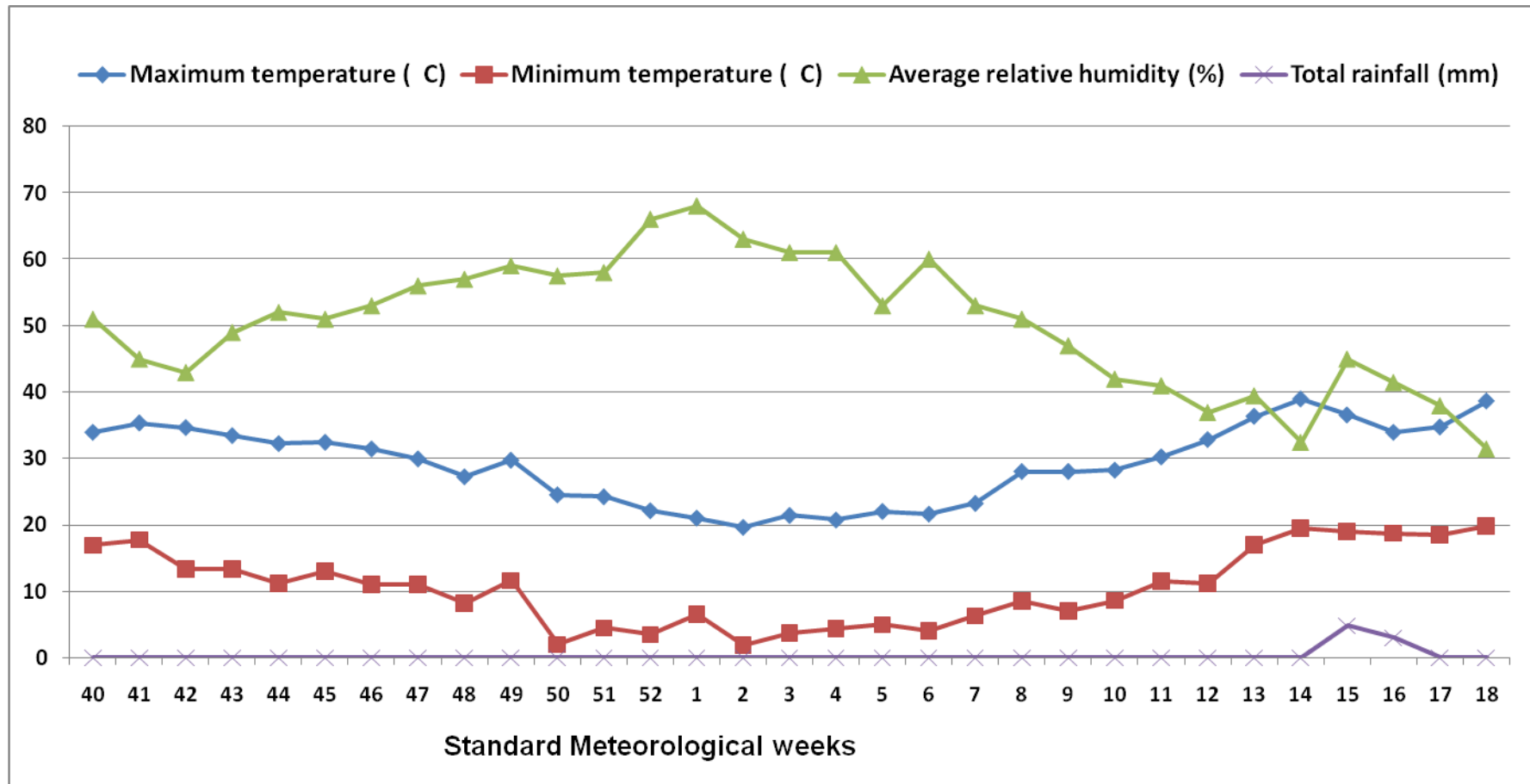


Fig. 3.1 Meteorological observations recorded during the course of study (October, 2011 to May, 2012)

Table 3.2 Meteorological observations recorded during the course of study (October, 2012 to May, 2013)

| Standard Meteorological weeks | Period | | Temperature (°C) | | Average relative humidity (%) | Total rainfall (mm) |
|-------------------------------|------------|------------|------------------|---------|-------------------------------|---------------------|
| | From | To | Maximum | Minimum | | |
| 40 | 01/10/2012 | 07/10/2012 | 36.1 | 17.9 | 43.0 | 000.0 |
| 41 | 08/10/2012 | 14/10/2012 | 35.0 | 15.3 | 49.0 | 000.0 |
| 42 | 15/10/2012 | 21/10/2012 | 33.9 | 16.6 | 53.0 | 001.4 |
| 43 | 22/10/2012 | 28/10/2012 | 30.7 | 13.0 | 52.0 | 000.0 |
| 44 | 29/10/2012 | 04/11/2012 | 30.7 | 11.3 | 55.0 | 000.0 |
| 45 | 05/11/2012 | 11/11/2012 | 29.7 | 10.6 | 55.0 | 000.0 |
| 46 | 12/11/2012 | 18/11/2012 | 29.3 | 09.2 | 53.0 | 000.0 |
| 47 | 19/11/2012 | 25/11/2012 | 28.2 | 08.7 | 55.0 | 000.0 |
| 48 | 26/11/2012 | 02/12/2012 | 26.4 | 07.6 | 56.0 | 000.0 |
| 49 | 03/12/2012 | 09/12/2012 | 26.9 | 06.4 | 56.0 | 000.0 |
| 50 | 10/12/2012 | 16/12/2012 | 25.3 | 09.5 | 63.0 | 000.0 |
| 51 | 17/12/2012 | 23/12/2012 | 24.1 | 05.8 | 59.0 | 000.0 |
| 52 | 24/12/2012 | 31/12/2012 | 23.2 | 04.4 | 59.0 | 000.0 |
| 1 | 01/01/2013 | 07/01/2013 | 20.5 | 05.0 | 64.0 | 000.0 |
| 2 | 08/01/2013 | 14/01/2013 | 23.1 | 04.9 | 59.0 | 000.0 |
| 3 | 15/01/2013 | 21/01/2013 | 20.2 | 06.5 | 69.0 | 008.8 |
| 4 | 22/01/2013 | 28/01/2013 | 20.9 | 03.3 | 60.0 | 000.0 |
| 5 | 29/01/2013 | 04/02/2013 | 23.5 | 07.8 | 64.0 | 000.0 |
| 6 | 05/02/2013 | 11/02/2013 | 21.5 | 08.1 | 69.0 | 010.0 |
| 7 | 12/02/2013 | 18/02/2013 | 22.5 | 08.5 | 70.0 | 009.8 |
| 8 | 19/02/2013 | 25/02/2013 | 24.1 | 12.1 | 66.0 | 002.6 |
| 9 | 26/02/2013 | 04/03/2013 | 26.7 | 09.2 | 55.0 | 000.0 |
| 10 | 05/03/2013 | 11/03/2013 | 32.3 | 11.0 | 46.0 | 000.0 |
| 11 | 12/03/2013 | 18/03/2013 | 31.7 | 13.9 | 50.0 | 000.0 |
| 12 | 19/03/2013 | 25/03/2013 | 34.2 | 15.2 | 50.0 | 000.0 |
| 13 | 26/03/2013 | 01/04/2013 | 31.7 | 15.0 | 48.5 | 000.0 |
| 14 | 02/04/2013 | 08/04/2013 | 33.8 | 15.2 | 49.5 | 002.2 |
| 15 | 09/04/2013 | 15/04/2013 | 35.8 | 18.2 | 43.5 | 000.0 |
| 16 | 16/04/2013 | 22/04/2013 | 37.1 | 18.2 | 40.5 | 000.4 |
| 17 | 23/04/2013 | 29/04/2013 | 36.7 | 20.8 | 43.5 | 000.0 |
| 18 | 30/04/2013 | 06/05/2013 | 39.1 | 20.0 | 30.0 | 000.0 |

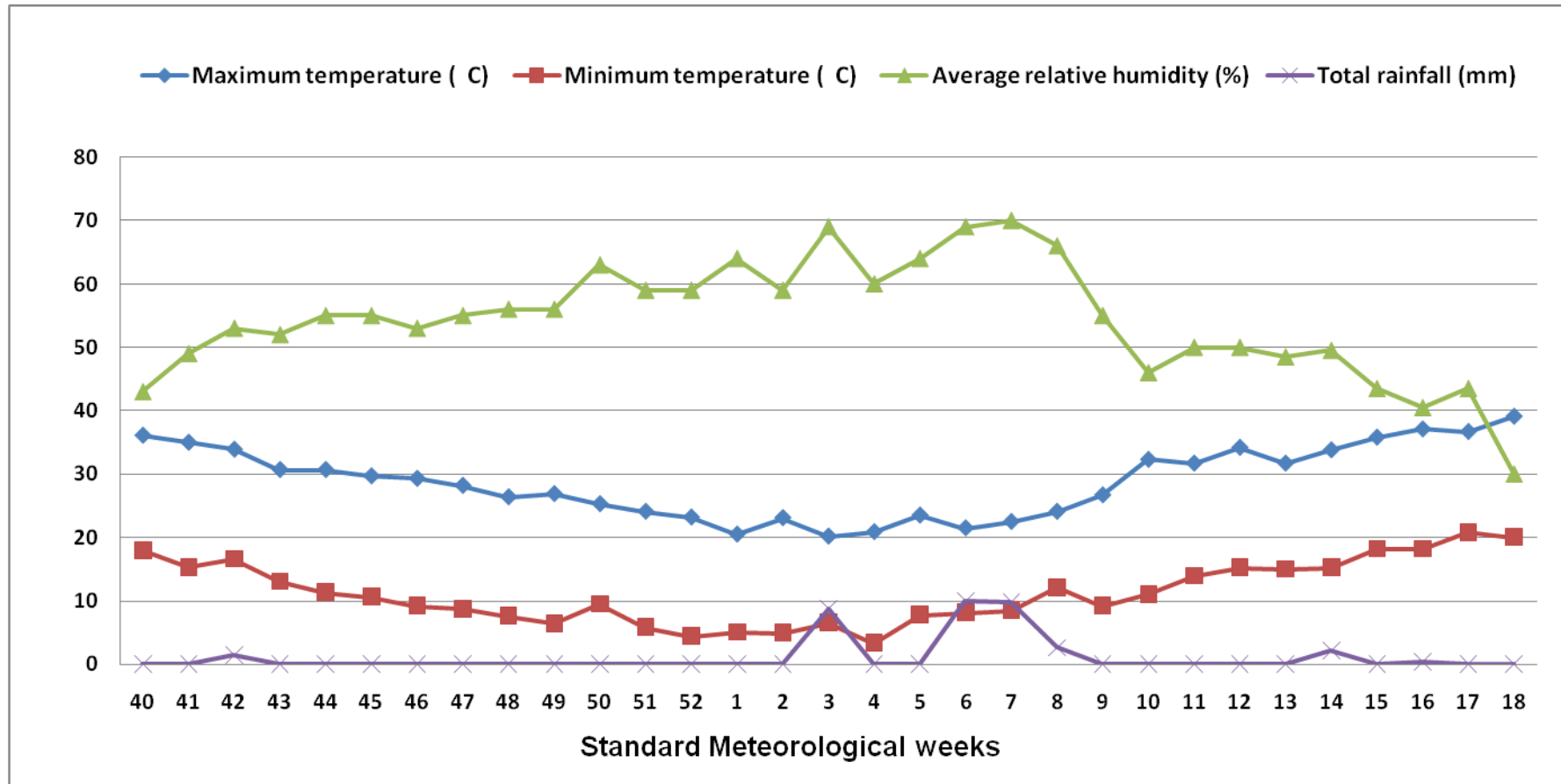


Fig. 3.2 Meteorological observations recorded during the course of study (October, 2012 to May, 2013)

3.1.8 Interpretation of data

The seed midge damage recorded on five plants was used for statistical analysis in all the experiments. The data on seed damage were first transferred into angular transformation values (Bliss, 1937) and then were subjected to statistical analysis.

The materials used and methodology mentioned above were general for all experiments and specific materials and methodology used for individual experiment are described below.

3.2 Specific details of the experiments

3.2.1 Survey for the infestation level of seed midge, *Systole albipennis* Walker infesting fennel

Field surveys for two consecutive years (2011-12 and 2012-13) were carried out in Sirohi, Nagaur and Dausa districts of Rajasthan because of highest area and production of fennel crop.

Table 3.3 : Area and production of fennel crop in selected districts

| S. No. | Name of district | Area (ha) | Production (tonnes) |
|--------|------------------|-----------|---------------------|
| 1. | Sirohi | 4095 | 4236 |
| 2. | Nagaur | 22114 | 26998 |
| 3. | Dausa | 6263 | 5872 |

(Anonymous, 2011-12)

Sirohi, Nagaur and Dausa consists of 5, 10 and 6 tehsils, out of which Reodar tehsil (from Sirohi), Nagaur and Degana tehsils (from Nagaur) and Lalsot tehsil (from Dausa) were selected for study purpose. From each selected tehsil, five fennel growers having 1.5 to 10 ha area under fennel cultivation were randomly selected.

3.2.1.1 Observations

The field surveys were carried out at seed formation stage of fennel. From each selected field, five plants were selected randomly. From each plant three umbels each from upper, middle and lower parts of plant were selected. Total numbers of seeds/umbel were counted and damaged seeds present on selected umbel were thoroughly checked with the help of magnifying glass (10x). The seed with appearance of black spot or insect exit hole was considered as damaged seed and percent infestation was calculated accordingly.

3.2.2 The seasonal incidence of *S. albipennis* on fennel in relation to weather parameters

3.2.2.1 Layout and design

To study the seasonal incidence of seed midge on fennel in relation to weather parameters, RF-125 a commonly grown and recommended variety in this area was sown in the third week of October in both the seasons *i.e.* 2011-12 and 2012-13 in four plots of 2 X 2.25 m² size keeping row to row and plant to plant distance of 45 cm and 20 cm respectively.

3.2.2.2 Observations

To record the incidence of *S. albipennis*, the crop was left for natural infestation. The seeds with appearance of black spot or insect exit hole were recorded at weekly intervals from the appearance till harvesting of the crop *vide supra* 3.2.1.1. The data recorded on damaged seeds and meteorological parameters were used for statistical analysis.

3.2.2.3 Interpretation of data

The data recorded on seed midge damage were subjected to analyses of variance after transferring them into angular transformation values (Bliss, 1937). The simple correlation was computed between damaged seeds and

abiotic factors, viz., maximum and minimum temperatures, relative humidity and rainfall.

3.2.3 The quantitative and qualitative losses in fennel crop

3.2.3.1 Layout and design

The experiments were laid out in simple paired plot design with two treatments, viz., treated and untreated and each replicated 10 times. Fennel variety RF-125 was sown in the third week of October during both the years. The plot size was 2x2.25 m² with row to row and plant to plant distance of 45 cm and 20 cm respectively.

3.2.3.2 Observations

The plots were treated with alternate sprays of malathion 50 EC (0.05%) and freshly prepared NSKE (5%), at weekly intervals. The seed yields of treated and untreated plots were recorded and converted into quintal per hectare.

3.2.3.2.1 Quantitative losses

The observations on number of damaged seeds per umbel were recorded *vide supra* 3.2.1.1.

3.2.3.2.2 Qualitative losses

(A) Effect on oil content of the seeds

Volatile oil content in fennel grains (seeds) was estimated using essential oil distillation assembly *i.e.* Clevenger apparatus (AOAC, 1970). A sample of one hundred grains was weighed and grinded finely with electric grinder. The seed powder was transferred in assembly flask (1 litre) and 540 ml water was added to fill the flask up to half of its capacity and placed on heating mantle. Heating was done for 5-6 hours continuously. The volatile oil was collected in the graduated side arms of the assembly. Three consecutive readings were taken at 30 minutes interval until there was no change in oil content. The volume of volatile oil obtained in terms of millilitre per hundred gram grains sample directly revealed per cent oil content in the seeds.

(B) Determination of total carbohydrate

Total carbohydrate was estimated using anthrone reagent method (Hedge and Hofreiter, 1962).

Weighed sample (100 mg) was taken in a tube and hydrolysed with 5 ml of 2.5 N-HCl by keeping it on a boiling water bath for three hrs and cooled to room temperature. After cooling, it was neutralised with solid sodium carbonate until the effervescence cease. The volume was made to 100 ml with distilled water and centrifuged. The supernatant was collected and 0.5 to 1 ml aliquots were taken for analysis. The standards were prepared taking 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard in separate tubes. The volumes in all tubes were made to 1 ml including the sample tubes by adding distilled water. The tube containing 1 ml distilled water served as control. Four millimeter of anthrone reagent was added to each tube and the tubes were kept for eight minutes on a boiling water bath. The tubes were cooled rapidly and readings were taken at 630 nm when the green colour changed to dark green. Finally standard graph was drawn by plotting concentration of the standard on the X-axis verses absorbance on the Y-axis and from the graph, amount of carbohydrate present in the samples was calculated.

$$\text{Amount of carbohydrate} = \frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100$$

(C) Determination of protein

Nitrogen content in fennel seeds was determined by Kjeldal and colorimetric method (Snell and Snell, 1949). For which 0.1 g of well grinded and dried seed samples was taken in a 100 ml Kjeldal flask. Two milliliter concentrated H₂SO₄ was added to the Kjeldal flask carefully, content was mixed and placed on digestion assembly and heated till the sample material was digested. After cooling, 0.5 ml of H₂O₂ (30%) was added and the content was again heated till it became colourless (H₂O₂ was again added if content did not become colourless). The digested content was transferred after washing 2-3 times to volumetric flask and volume was made to 100 ml by

adding water. Five milliliter of digested content was taken into 50 ml volumetric flask and few drops of water were added. Two milliliter of NaOH (10%) and one milliliter of sodium silicate (10%) was added. After adding few milliliter of water the content was mixed using 1.6 ml of Nessler's reagent during shaking and the volume was made up. The absorption reading was taken with the help of spectrophotometer at a wave length of 420 nm. For standard curve the blank using standard nitrogen solution was run employing similar procedure. Standard nitrogen solution was prepared by dissolving 0.1179 g of $(\text{NH}_4)_2\text{SO}_4$ AR grade in water and one litre volume was made in volumetric flask.

Protein content (%) in fennel seeds was calculated by multiplying N content (%) in grains by 6.25.

(D) Effect on germination of the seeds

The germination test was carried out according to the rolled paper towel method (Khare and Bhale, 2000).

3.2.4 Management of *S. albipennis* using IPM tools

3.2.4.1 Impact of sowing dates on the incidence

3.2.4.1.1 Layout and design

The experiment was laid out in simple randomized block design with five treatments (sowing dates), each replicated four times. The seeds of fennel variety RF-125 were sown on respective five dates in the plots measuring 2 x 2.25 m², with row to row and plant to plant distance of 45 cm and 20 cm respectively. There were five different dates of sowing of fennel crop during both the years' viz., *rabi* 2011-12 and 2012-13. The first sowing was done on 6th October and subsequent sowings were done on 13th, 20th and 27th October and 3rd November. The crop was allowed for natural infestation.

3.2.4.1.2 Observations

The observations on seed midge damage were recorded *vide supra* 3.2.1.1.

3.2.4.1.3 Interpretation of data

The data recorded on seed midge damage were subjected to analyses of variance after transferring them into angular transformation values (Bliss, 1937). The correlation coefficient (r) between date of sowing and seed midge damage; date of sowing and yield and seed midge damage and yield were computed.

3.2.4.2 Varietal screening of fennel against seed midge, *S. albipennis*

3.2.4.2.1 Layout and design

The crop was grown in a simple randomized block design. The seeds of seven varieties were sown in the third week of October in both the years *i.e.*, 2011-12 and 2012-13, each replicated thrice. The plots size was 2 x 2.25 m² with row to row and plant to plant distance of 45 cm and 20 cm respectively.

3.2.4.2.2 Treatments

Seven fennel varieties screened for relative susceptibility against *S. albipennis* were considered as treatments.

Table 3.4 : Varieties of fennel and their sources of supply

| Varieties | Source of supply |
|--|--|
| RF-101, RF-125, RF- 143, RF-145, RF-178 and RF-205 | AICRP on Seed Spices, Department of Plant Breeding & Genetics, S.K.N. College of Agriculture, Jobner |
| Local cultivar | Local market, Jobner |

3.2.4.2.3 Observations

The observations *viz.*, morphological characters (days to 50% flowering, plant height, colour of flowers, seeds per umbel, damage seeds) were recorded during the crop growth from five randomly selected plants. Oil

content was estimated after harvest of the crop by employing standard method.

The observations on damaged seeds and oil content were recorded *vide supra* 3.2.1.1 and 3.2.3.2.2 (A).

3.2.4.2.4 Interpretation of data

The data obtained on seed midge damage from the experimental field of both the years were subjected to analysis of variance after transferring them into angular transformation values (Bliss, 1937). On the basis of damage, susceptibility of fennel varieties to seed midge were determined. The fennel varieties were categorized on the basis of seed midge damage during the crop season, using following formula :

$$\bar{X} \pm \sigma$$

Where,

\bar{X} = Mean of seed midge damage

σ = Standard deviation

So the categories made were :

1. Highly susceptible
2. Moderately susceptible and
3. Least susceptible

The data obtained after recording morphological and oil content parameters of fennel varieties were used to find out the correlation.

3.2.4.3 Efficacy of the insecticides/biopesticides against seed midge, *S. albipennis*

3.2.4.3.1 Layout and design

The experiment was laid out in simple randomized block design with eight treatments including untreated check, each replicated thrice. The plot size was 2 x 2.25 m² with row to row and plant to plant distance of 45 cm and 20 cm respectively. The fennel variety RF-125 recommended for this region

was used for the experiment and was sown in third week of October during both the years.

3.2.4.3.2 Details of insecticides/ biopesticides used

The details of insecticides/ biopesticides used to test their effectiveness against *S. albipennis* are given in table 3.5.

Table 3.5 Details of insecticides/biopesticides used

| S. No. | Common name | Formulation | Trade Name | Concentration (%) or Dose |
|--------|--|-------------|------------|---------------------------|
| 1. | NSKE (Freshly prepared) | - | - | 5.00% |
| 2. | Azadirachtin + neem limonoids based botanicals | 0.5 % | Achook | 1 ml/lit |
| 3. | Karanj seed extract (Freshly prepared) | - | - | 5.00% |
| 4. | Spinosad | 2.5 SC | Success | 0.01% |
| 5. | Malathion | 50 EC | Devimalt | 0.05% |
| 6. | Abamectin | 1.9 EC | Abacin | 0.5 ml/lit |
| 7. | Cartap hydrochloride | 50 SP | Padan | 0.05% |

3.2.4.3.2.1 Preparation of neem seed kernel extract (NSKE-5%) and karanj seed extract (KSE - 5%)

Half kilogram of seed kernels of neem and karanj each were powdered well using wooden beam and were soaked separately in one litre of water over night. After 12 hrs, the filtrate was made up to 10 litres. Before spraying 5 ml liquid soap was added and fresh extract was used (Jhala *et al.*, 1998).

3.2.4.3.2.2 Method of spray

All the insecticides/biopesticides were applied as a foliar spray using pre-calibrated knapsack sprayer. The first spray was made on 20th March and 25th March during 2011-12 and 2012-13 respectively after initiation of seed set. An untreated check was maintained for comparison. The second spray was repeated after 15 days of the first. The insecticidal solution was prepared according to the following formula.

$$C_1V_1 = C_2V_2$$

Where,

C_1 = Concentration of given formulation (%)

V_1 = Volume/amount of formulation required (ml or g)

C_2 = Concentration of spray fluid required (%)

V_2 = Volume/amount of spray fluid required (800 lit.)

3.2.4.3.2.3 Observations

The observations on seed midge damage were recorded *vide supra* 3.2.1.1.

3.2.4.3.2.4 Interpretation of data

The data on per cent damage were subjected to statistical analysis after transformation into angular transformation values (Bliss, 1937). The avoidable loss and increase in yield of seed over untreated check were calculated for each treatment by the following formula:

$$\text{Avoidable loss (\%)} = \frac{\text{Highest yield in treated plot} - \text{Yield in the treatment}}{\text{Highest yield in treated plot}} \times 100$$

$$\text{Increase in yield (\%)} = \frac{\text{Yield in treatment} - \text{Yield in untreated check}}{\text{Yield in untreated check}} \times 100$$

These formulae do not give the exact loss/ increase in yield because even in the best treatment some damage occurs. However, this is considered to be the most feasible method for working out the per cent loss due to the insect pests in any treatment (Pradhan, 1964).

To determine the most effective and economical treatment, the net profit and benefit-cost ratio was worked out by taking the expenditure on the individual insecticidal treatment and the corresponding yield into account.

4. Results

The experiments on “Management of seed midge, *Systole albipennis* Walker infesting fennel, *Foeniculum vulgare* Miller” were conducted during 2011-12 and 2012-13. The results obtained on different aspects are presented in this chapter.

4.1 Survey for the infestation level of seed midge, *Systole albipennis* Walker infesting fennel

In view of changing scenario of different insect pests at different locations, surveillance of key, minor and sporadic pests needs to be undertaken. As such, programme on surveys were carried out on farmers fields in Sirohi, Nagaur and Dausa districts of Rajasthan for two consecutive years (2011-12 and 2012-13) for estimating the per cent infestation caused by seed midge, *S. albipennis* in fennel crop.

The data presented in Table 4.1 and Fig. 4.1 revealed that, the maximum infestation of seed midge (17.82%) was found in Degana tehsil followed by Nagaur tehsil (16.43%) of Nagaur district. The minimum infestation (11.82%) was found in Reodar tehsil of Sirohi district followed by 14.32 per cent in Lalsot tehsil of Dausa district during *Rabi* 2011-12.

Table 4.1 Per cent infestation of *S. albipennis* in fennel crop*

| S.No. | Districts | Tehsils | Per cent seed infestation | | |
|-------|-----------|---------|---------------------------|---------|--------|
| | | | 2011-12 | 2012-13 | Pooled |
| 1. | Nagaur | Nagaur | 16.43 | 17.36 | 16.89 |
| | | Degana | 17.82 | 20.25 | 19.04 |
| 2. | Dausa | Lalsot | 14.32 | 16.76 | 15.54 |
| 3. | Sirohi | Reodar | 11.82 | 12.63 | 12.23 |

* Data based on five farmers' field

The data presented in Table 4.1 and Fig. 4.1 revealed a similar trend of seed midge infestation in second year (*Rabi* 2012-13) as observed during 2011-12. The maximum infestation of 20.25 per cent was recorded in Degana

tehsil followed by 17.36 per cent in Nagaur tehsil of Nagaur district. The minimum infestation (12.63%) was recorded in Reodar tehsil of Sirohi district.

The pooled data revealed that the minimum infestation of seed midge (12.23%) was recorded from Reodar tehsil of Sirohi district while, maximum infestation of 19.04 per cent was recorded from Degana tehsil followed by 16.89 per cent from Nagaur tehsil of Nagaur district.

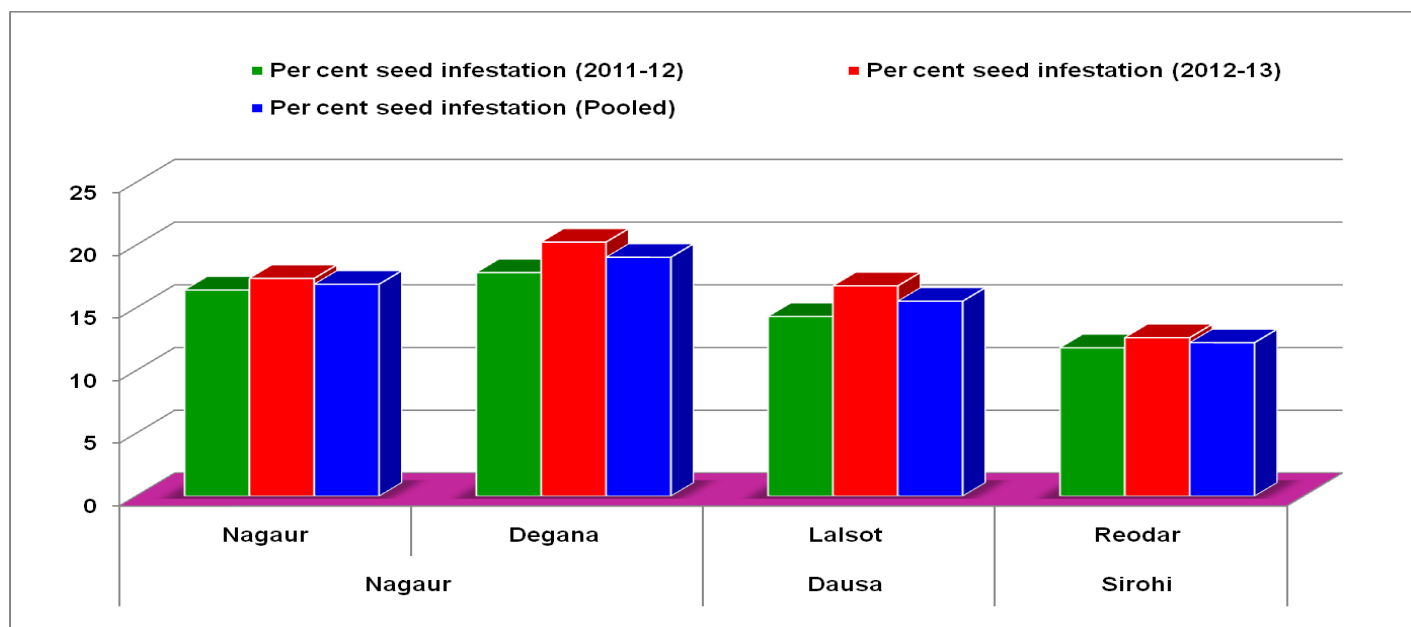


Fig. 4.1 Per cent infestation of *S. albipennis* in fennel crop

4.2 The seasonal incidence of *S. albipennis* on fennel in relation to weather parameters

With a view to provide a sound base for the management of insect pests of fennel, studies were carried out on the quantitative estimation of seed midge infestation in relation to key abiotic factors, viz., maximum and minimum temperatures, relative humidity and rainfall under the prevailing agroclimatic conditions.

The data presented in the Table 4.2 and Fig. 4.2 showed that infestation of the seed midge during *rabi*, 2011-12 commenced in the last week of March (13 SMW) and continued upto crop harvest i.e. first week of May (18 SMW). Initially, the infestation was recorded to be 0.50 per cent which increased gradually and reached to maximum 15.50 per cent at 38.7 °C maximum, 19.8 °C minimum temperatures and 31.5 per cent relative humidity in the first week

of May (18 SMW). The maximum and minimum temperatures, average relative humidity and total rainfall had non-significant correlation with seed midge damage ($r= 0.239, 0.524, -0.346$ and -0.124 respectively). The result showed that the seed midge infestation was not affected by key weather parameters.

The infestation of seed midge during *rabi*, 2012-13 (Table 4.3 and Fig. 4.3) started in the first week of April (14 SMW). The infestation gradually increased and reached to maximum (17.50 %) at 39.1 °C maximum, 20.0 °C minimum temperature and 30.0 per cent relative humidity in the first week of May (18 SMW). The data also indicated comparatively higher seed midge damage during *rabi*, 2012-13 as compared to *rabi*, 2011-12 and the seed midge damage also started one week later than first year. The maximum and minimum temperatures had positive significant correlation with seed midge infestation ($r= 0.889$ and 0.914 respectively), while average relative humidity had negative significant correlation ($r= -0.873$). Total rainfall had non-significant correlation with seed midge damage ($r= -0.263$).

A parasitic wasp, *Tetrastichus* sp. was reported to parasitized seed midge, *S. albipennis* under field conditions. The incidence of *Tetrastichus* sp. commenced in the third week of April and continued upto crop harvest during both the years. The parasitic wasp laid eggs (generally one or two) in the seeds already infested by *S. albipennis* and developed into adult which emerged out of the seed by boring a hole in the seed wall. It was worthy to mention that the hole on seed wall made by *S. albipennis* was comparatively larger in size as compared to hole made by *Tetrastichus* sp. (Plate – 3).

Table 4.2 Seasonal incidence of *S. albipennis* infesting fennel crop during *rabi*, 2011-12

| S. No. | Standard Meteorological weeks | Date of observations | Temperature (⁰ C) | | Average relative humidity (%) | Total rainfall (mm) | Per cent seed damage |
|---|-------------------------------|----------------------|-------------------------------|---------|-------------------------------|---------------------|----------------------|
| | | | Maximum | Minimum | | | |
| 1. | 12 | 20.03.2012 | 32.9 | 11.2 | 37.0 | 000.0 | 0.00 |
| 2. | 13 | 27.03.2012 | 36.4 | 17.0 | 39.5 | 000.0 | 0.50 |
| 3. | 14 | 03.04.2012 | 39.0 | 19.4 | 32.5 | 000.0 | 1.50 |
| 4. | 15 | 10.04.2012 | 36.6 | 18.9 | 45.0 | 004.8 | 3.00 |
| 5. | 16 | 17.04.2012 | 34.0 | 18.7 | 41.5 | 003.0 | 6.50 |
| 6. | 17 | 24.04.2012 | 34.8 | 18.4 | 38.0 | 000.0 | 11.25 |
| 7. | 18 | 01.05.2012 | 38.7 | 19.8 | 31.5 | 000.0 | 15.50 |
| Correlation coefficient with per cent seed damage | | | 0.239 | 0.524 | -0.346 | -0.124 | - |

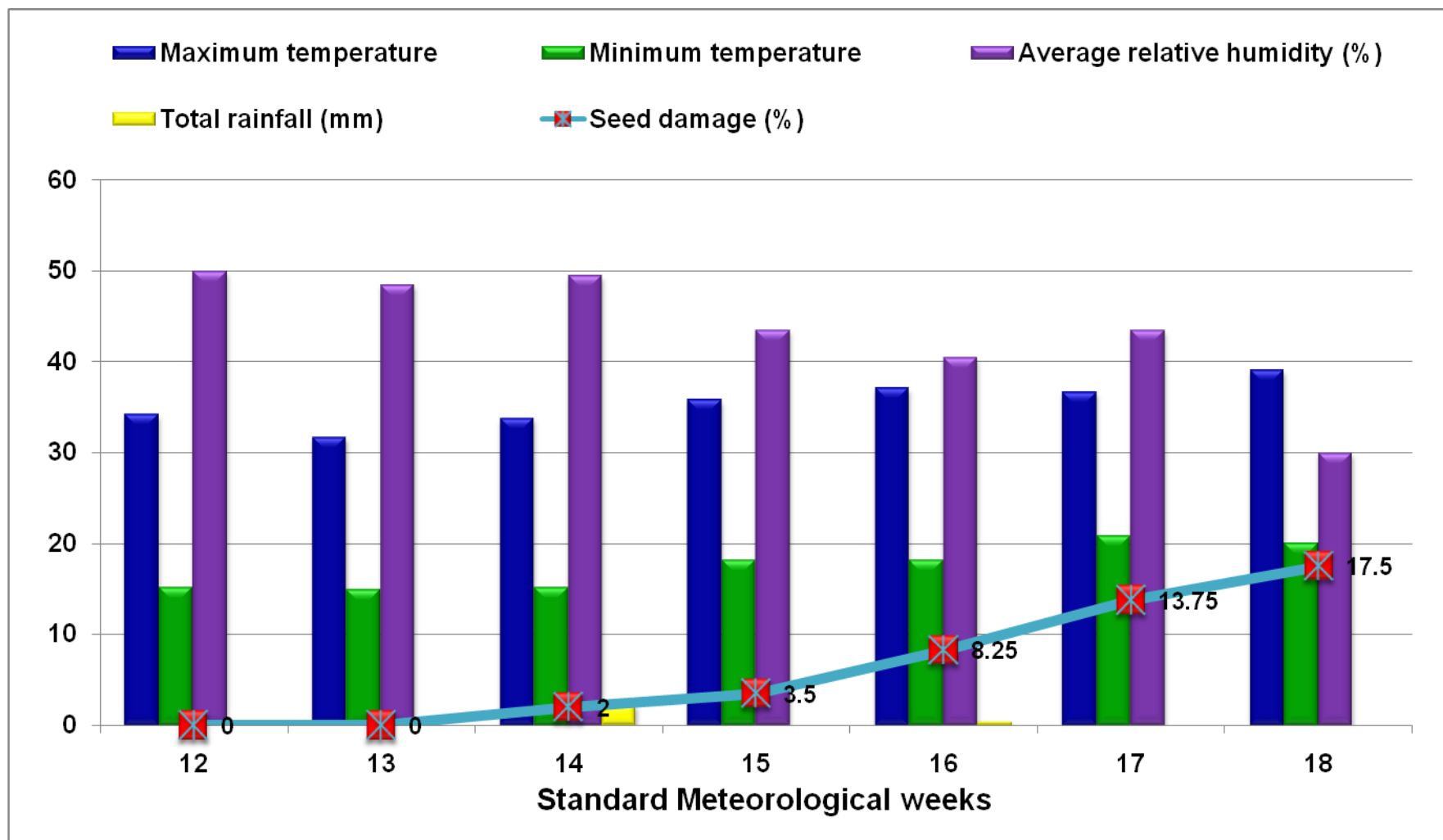


Fig. 4.2 Seasonal incidence of *S. albipennis* infesting fennel crop during *rabi*, 2011-12

Table 4.3 Seasonal incidence of *S. albipennis* infesting fennel crop during *rabi*, 2012-13

| S. No. | Standard Meteorological weeks | Date of observations | Temperature (°C) | | Average relative humidity (%) | Total rainfall (mm) | Per cent seed damage |
|---|-------------------------------|----------------------|------------------|---------|-------------------------------|---------------------|----------------------|
| | | | Maximum | Minimum | | | |
| 1. | 12 | 22.03.2013 | 34.2 | 15.2 | 50.0 | 000.0 | 0.00 |
| 2. | 13 | 29.03.2013 | 31.7 | 15.0 | 48.5 | 000.0 | 0.00 |
| 3. | 14 | 05.04.2013 | 33.8 | 15.2 | 49.5 | 002.2 | 2.00 |
| 4. | 15 | 12.04.2013 | 35.8 | 18.2 | 43.5 | 000.0 | 3.50 |
| 5. | 16 | 19.04.2013 | 37.1 | 18.2 | 40.5 | 000.4 | 8.25 |
| 6. | 17 | 26.04.2013 | 36.7 | 20.8 | 43.5 | 000.0 | 13.75 |
| 7. | 18 | 03.05.2013 | 39.1 | 20.0 | 30.0 | 000.0 | 17.50 |
| Correlation coefficient with per cent seed damage | | | 0.889** | 0.914** | -0.873* | -0.263 | - |

* Significant at 5% level

** Significant at 1% level

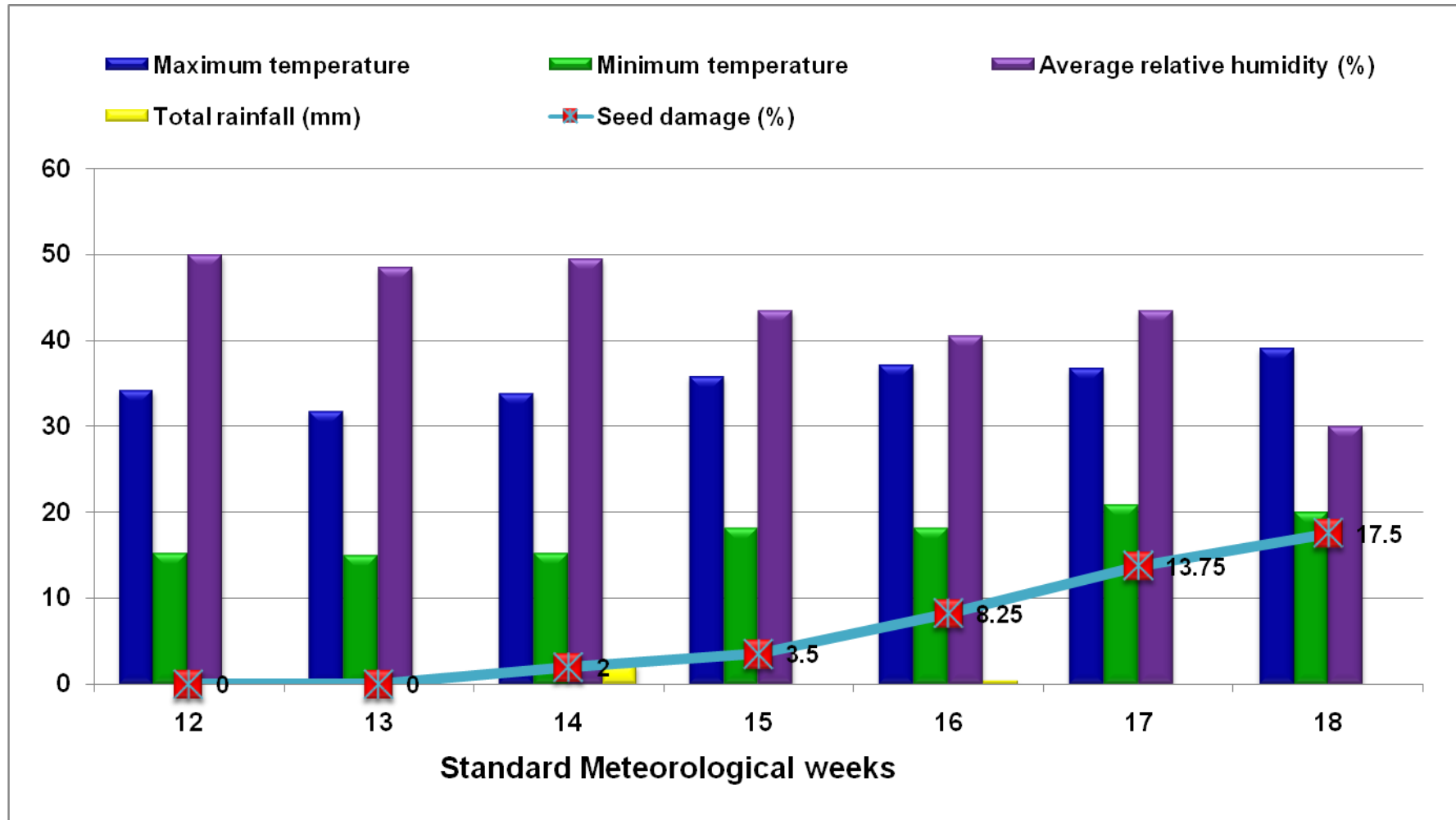


Fig. 4.3 Seasonal incidence of *S. albipennis* infesting fennel crop during *rabi*, 2012-13

Plate – 3



(A) Adult of *Tetrastichus* sp. on damaged fennel seed



(B) Adult of *Tetrastichus* sp.

4.3 The quantitative and qualitative losses in fennel crop

A female of *S. albipennis* laid egg in the embryo of grain and developing larva fed, pupate inside the grain and adult emerged from the grain by making hole, which resulted in both qualitative and quantitative losses.

4.3.1 Quantitative losses

The data presented in Table 4.4 revealed that the infestation of seed midge damage and seed yield of fennel crop during *rabi* 2011-12 in treated plots was 1.95 per cent and 15.15 q h⁻¹ respectively, whereas, in untreated plots these figure were 15.62 per cent and 10.10 q h⁻¹ respectively.

The data revealed a similar trend of seed midge damage and seed yield of fennel crop during 2012-13 as observed in 2011-12. The seed midge damage and seed yield in treated plots were 2.00 per cent and 15.00 q h⁻¹ respectively, while in untreated plots these figures were 17.75 per cent and 10.05 q h⁻¹ respectively.

Table 4.4 The quantitative losses in fennel crop caused by *S. albipennis*

| Year | Seed midge damage (%) | | Seed yield (q h ⁻¹) | |
|---------|-----------------------|-----------------|---------------------------------|-----------------|
| | Treated plots | Untreated plots | Treated plots | Untreated plots |
| 2011-12 | 1.95 | 15.62 | 15.15 | 10.20 |
| 2012-13 | 2.00 | 17.75 | 15.00 | 10.05 |
| Pooled | 1.98 | 16.69 | 15.08 | 10.13 |

The pooled analysis of data of both the years revealed that the infestation of seed midge damage and seed yield of fennel crop in treated plots were 1.98 per cent and 15.08 q h⁻¹ respectively, while in untreated plots such figure were 16.69 per cent and 10.13 q h⁻¹ respectively.

4.3.2 Qualitative losses

4.3.2.1 Effect on oil content

It was evident from the data presented in Table 4.5 and Fig. 4.4 that the oil content in fennel seeds decreased due to the infestation of *S. albipennis*. The oil content recorded in healthy seeds was 2.70 per cent and in damaged seeds, it was 1.65 per cent. As a result of the infestation of *S. albipennis*, a reduction (38.88%) in oil content of fennel seeds was recorded.

Table 4.5 The qualitative losses in fennel crop caused by *S. albipennis*

| Oil content (%) | | | Carbohydrate (%) | | | Protein (%) | | | Germination (%) | | |
|-----------------|----------|----------|------------------|----------|----------|-------------|----------|----------|-----------------|----------|----------|
| Healthy | Infested | Decrease | Healthy | Infested | Decrease | Healthy | Infested | Increase | Healthy | Infested | Decrease |
| 2.70 | 1.65 | 38.88 | 42.25 | 35.75 | 15.38 | 9.45 | 10.10 | 5.82 | 92.25 | 67.50 | 26.83 |

4.3.2.2 Effect on carbohydrate content

Findings of the present investigations enunciated a negative effect of *S. albipennis* infestation on the carbohydrate content of fennel. The carbohydrate content recorded in healthy and damage seeds were 42.25 and 35.75 per cent respectively. A reduction of 15.38 per cent in carbohydrate content of fennel seeds was observed (Table 4.5 and Fig. 4.4).

4.3.2.3 Effect on protein content

The data revealed that protein content in fennel seeds was increased due to infestation of *S. albipennis*. The protein content recorded in healthy seeds was 9.45 per cent as compared to damaged seeds (10.10%). However, protein content of fennel seeds increased upto 5.82 per cent (Table 4.5 and Fig. 4.4).

4.3.2.4 Effect on germination of the seeds

The data revealed that germination percentage of fennel seeds was decreased as a result of the infestation of *S. albipennis*. The germination recorded in healthy seeds was 92.25 per cent, while it was 67.50 per cent in damaged seeds. Germination of fennel seeds decreased upto 26.83 per cent due to the infestation of *S. albipennis* (Table 4.5 and Fig. 4.4).

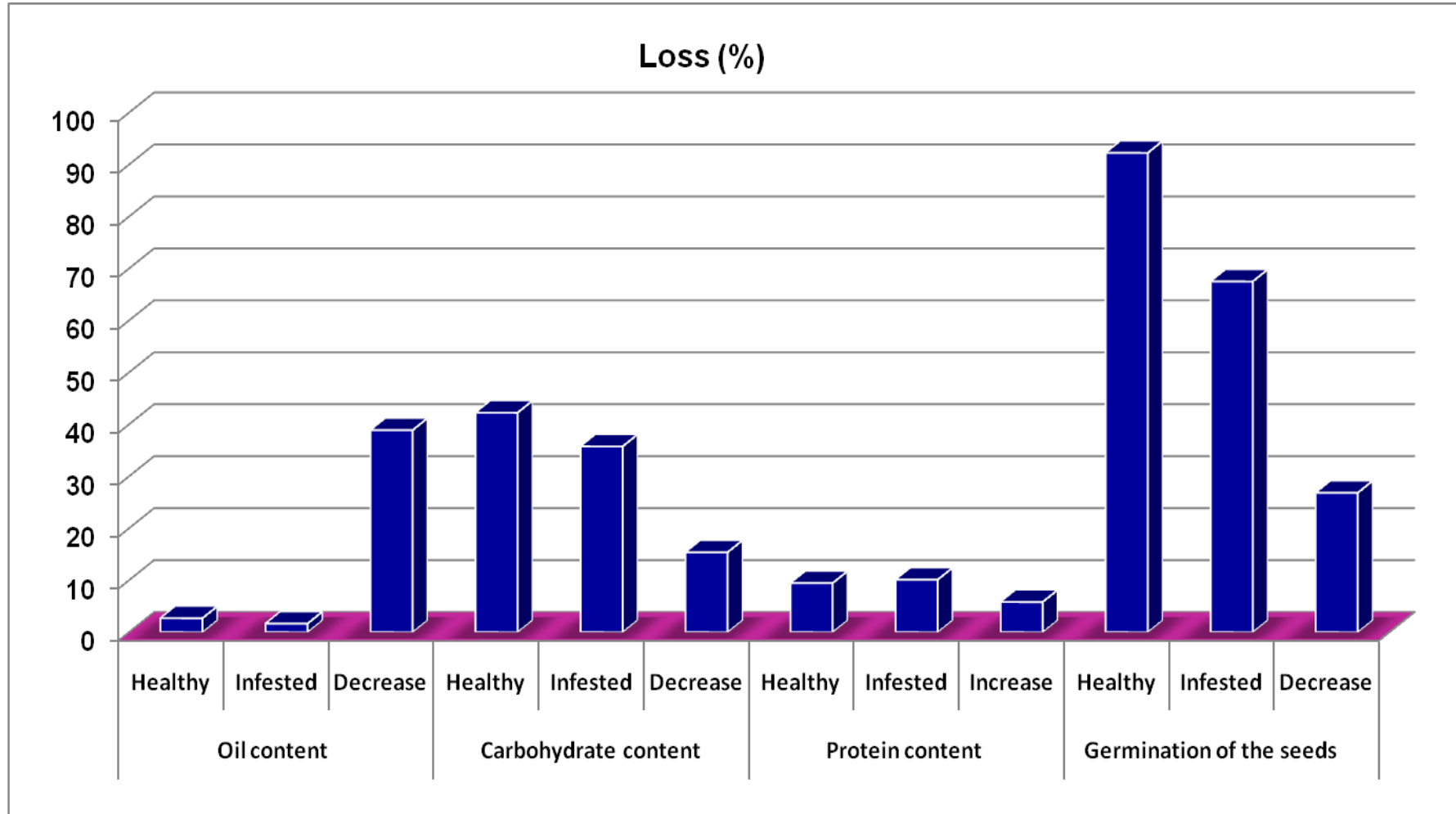


Fig. 4.4 The qualitative losses in fennel crop caused by *S. albipennis*

4.4 Management of *S. albipennis* using IPM tools

4.4.1 Impact of sowing dates on the incidence

To develop economically and ecologically feasible management strategies of the pest, a study was conducted with the aim to see the effect of different dates of sowing on the seed midge infestation and seed yield of fennel.

The data presented in Table 4.6 and Fig. 4.5 revealed that the infestation of seed midge increased with the delay in sowing time. During *rabi* 2011-12, the crop sown on 6th October exhibited 6.12 per cent seed damage which was at par with 13th October sown crop which recorded a seed damage of 8.08 per cent. The crops sown on 20th and 27th October exhibited 12.43 and 15.16 per cent seed damage respectively and were statistically comparable to each other. The maximum seed damage of 20.93 per cent was recorded on the crop sown on 3rd November and differed significantly from the rest of the sowing dates.

Perusal to the data reported in Table 4.6 and Fig 4.5, the maximum seed yield of 10.25 q h⁻¹ was recorded from 20th October sown crop and stood at par with the crop sown on 13th and 27th October as resulted in 9.50 and 9.70 q h⁻¹ seed yields respectively. The seed yield recorded on 6th October sown crop was 8.67 q h⁻¹ and stood at par with the crop sown on 13th October. The minimum seed yield (7.67 q h⁻¹) was recorded from crop sown on 3rd November and remained significantly lower to rest of the sowing dates.

Likewise, in *rabi* 2012-13 a similar trend of seed midge damage and seed yield as observed in the first year was noticed. The crop sown on 6th October exhibited 6.45 per cent seed damage and was comparable with 13th October sown crop which exhibited 9.25 per cent seed damage. The crops sown on 20th and 27th October exhibited 14.75 and 17.67 per cent seed damage respectively, however, did not differ significantly with each other. The maximum seed damage of 23.91 per cent was recorded on the crop sown on 3rd November and differed significantly from rest of the sowing dates.

The maximum seed yield of 11.70 q h⁻¹ was recorded from 20th October sown crop and differed significantly from rest of the sowing dates. The seed

yield recorded in 13th and 27th October sown crop were 10.27 and 10.33 q h⁻¹ respectively and both were comparable to each other. The seed yield was 9.20 q h⁻¹ in 6th October sown crop and stood at par with 13th October sown crop. The minimum seed yield (8.10 q h⁻¹) was recorded from crop sown on 3rd November and remained significantly lower to rest of the sowing dates.

The pooled data revealed that the minimum seed midge damage 6.29 per cent was recorded from crop sown on 6th October followed by crop sown on 13th October (8.67%) and did not differ statistically. The crops sown on 20th and 27th October exhibited 13.59 and 16.42 per cent seed damage respectively, however, did not differ significantly. The maximum seed damage of 22.42 per cent was recorded in the crop sown on 3rd November and significantly comparable to rest of the sowing dates.

The maximum seed yield (10.98 q h⁻¹) was recorded from 20th October sown crop followed by the crop sown on 27th October which resulted in a seed yield of 10.02 q h⁻¹ and both differed non-significantly with each other. The seed yields recorded on 6th and 13th October sown crop were 8.94 and 9.89 q h⁻¹ respectively and remained statistically at par with each other. The minimum seed yield (7.89 q h⁻¹) was recorded from crop sown on 3rd November but proved significantly lower to rest of the sowing dates.

During *rabi* 2011-12, a positive correlation ($r = 0.994$) was depicted between sowing dates and seed midge damage with explained variation of 98.80 per cent (Table 4.7). The relationship between the sowing dates and seed yield revealed a negative correlation ($r = -0.283$) with explained variation of 8.01 per cent. Similarly negative correlation ($r = -0.334$) was also recorded with seed midge damage and seed yield with explained variation of 11.16 per cent.

Perusal of data (Table 4.7) indicated a positive correlation ($r = 0.995$) between sowing dates and seed damage with explained variation of 99.00 per cent during *rabi* 2012-13. The relationship between the sowing dates and seed yield exhibited a negative correlation ($r = -0.251$) with explained variation of 6.30 per cent. A negative correlation ($r = -0.233$) was also observed with seed midge damage and seed yield with explained variation of 5.43 per cent.

The pooled data indicated a positive correlation ($r = 0.995$) between sowing dates and seed midge damage with explained variation of 99.00 per cent. The relationship between the sowing dates and seed yield revealed a negative correlation ($r = -0.265$) with explained variation of 7.02 per cent. A negative correlation ($r = -0.280$) was also noticed with seed midge damage and seed yield with explained variation of 7.84 per cent.

Table 4.6 Impact of sowing dates on the incidence of *S. albipennis* and yield of fennel crop

| S. No. | Dates of sowing | Per cent seed damage* | | | Mean seed yield (q h ⁻¹)* | | |
|--------|--------------------------|-----------------------|------------------|------------------|---------------------------------------|---------|--------|
| | | 2011-12 | 2012-13 | Pooled | 2011-12 | 2012-13 | Pooled |
| 1. | 6 th October | 6.12 (14.32) | 6.45 (14.71) | 6.29 (14.52) | 8.67 | 9.20 | 8.94 |
| 2. | 13 th October | 8.08 (16.51) | 9.25 (17.71) | 8.67 (17.12) | 9.50 | 10.27 | 9.89 |
| 3. | 20 th October | 12.43 (20.64) | 14.75 (22.59) | 13.59 (21.63) | 10.25 | 11.70 | 10.98 |
| 4. | 27 th October | 15.16 (22.91) | 17.67 (24.86) | 16.42 (23.90) | 9.70 | 10.33 | 10.02 |
| 5. | 3 rd November | 20.93 (27.23) | 23.91 (29.27) | 22.42 (28.26) | 7.67 | 8.10 | 7.89 |
| | S. Em± | 1.06 | 1.14 | 1.05 | 0.28 | 0.35 | 0.32 |
| | C.D. at 5% | 3.28 | 3.51 | 3.23 | 0.85 | 1.08 | 0.98 |

* Mean of four replications

Figures in parentheses are angular transformed values

Table 4.7 Relationship between different sowing dates, seed midge damage and seed yield of fennel

| S. No. | Particulars | Correlation coefficient (r) | | | Coefficient of determination (%) | | |
|--------|------------------------------------|--------------------------------|---------|--------|-------------------------------------|---------|--------|
| | | 2011-12 | 2012-13 | Pooled | 2011-12 | 2012-13 | Pooled |
| 1. | Sowing dates v/s Seed midge damage | 0.994 | 0.995 | 0.995 | 98.80 | 99.00 | 99.00 |
| 2. | Sowing dates v/s Seed yield | -0.283 | -0.251 | -0.265 | 8.01 | 6.30 | 7.02 |
| 3. | Seed midge damage v/s Seed yield | -0.334 | -0.233 | -0.280 | 11.16 | 5.43 | 7.84 |

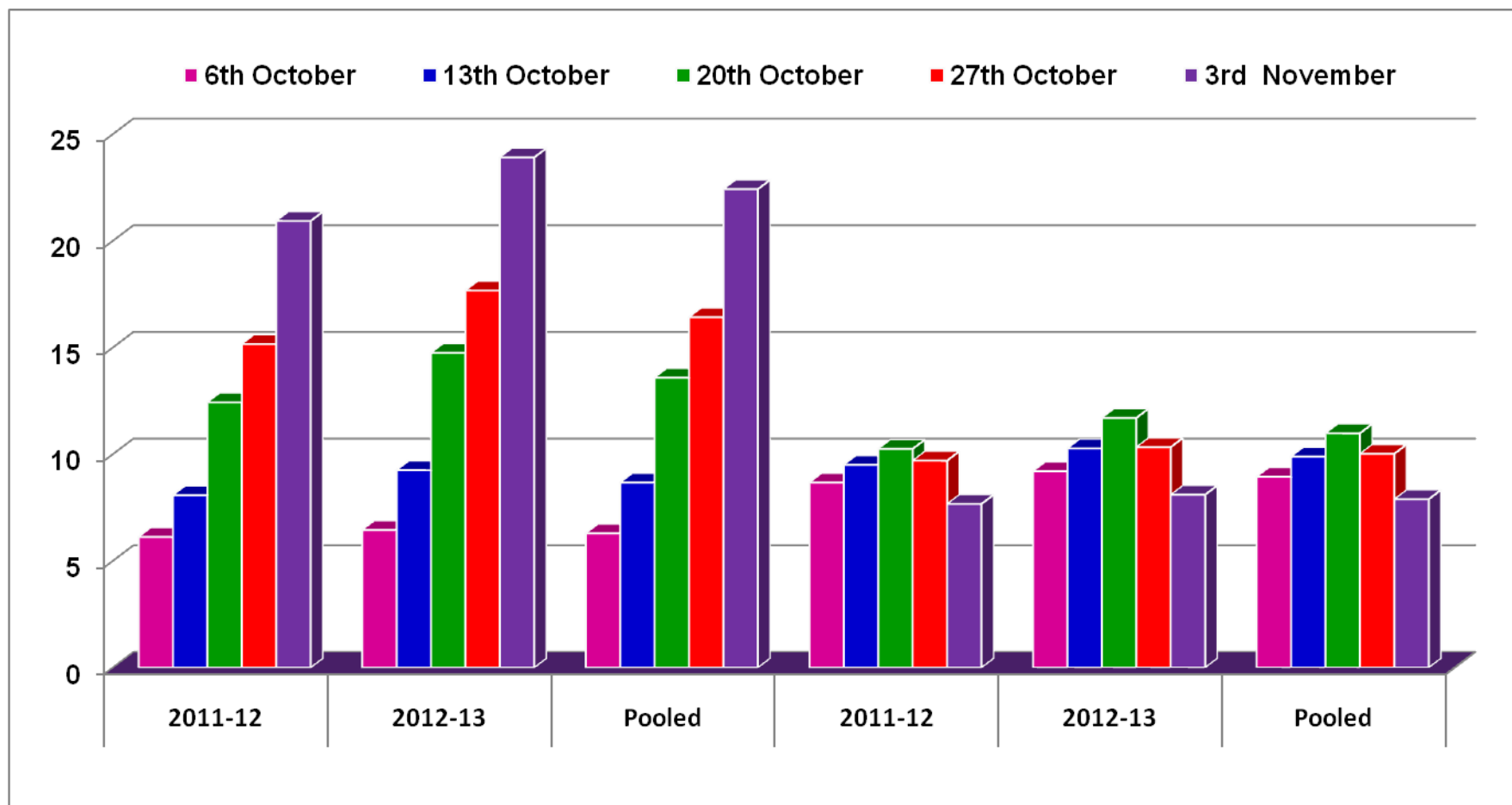


Fig. 4.5 Impact of sowing dates on the incidence of *S. albipennis* and yield of fennel crop

4.4.2 Varietal screening of fennel against seed midge, *S. albipennis*

4.4.2.1 Effect of fennel varieties on the infestation of seed midge

Seven fennel varieties were screened for their relative susceptibility against *S. albipennis* for two consecutive *rabi* seasons (2011-12 and 2012-13). The observations on seed midge damage were recorded from five randomly selected plants just before harvesting of the crop.

The observations recorded during *rabi* 2011-12 indicated that none of the fennel varieties was found immune from the attack of *S. albipennis*. The seed midge damage ranged from 12.31 to 17.70 per cent (Table 4.8 and Fig. 4.6). The maximum infestation of seed midge damage was recorded on RF-101 (17.70%) followed by RF-125 (15.62%) and found to be non-significant. The minimum seed midge damage was recorded in RF-145 (12.31%). Varieties RF-178 (13.55%), RF-205 (13.97%), RF-143 (14.20%) and local cultivar (14.65%) had moderate damage and remained statistically at par. The variability of resistance in fennel genotypes was in the order : RF-101 > RF-125 > local cultivar > RF-143 > RF-205 > RF-178 > RF-145.

The data presented in Table 4.8 and Fig. 4.6 revealed a similar trend of seed midge damage in second year as observed in the first year. The highest infestation of seed midge damage was recorded on RF-101 (18.53%) followed by RF-125 (17.62%). The minimum seed midge damage was recorded from RF-145 (13.84%) followed by RF-178 (14.86%), RF-205 (15.00%), RF-143 (15.50%) and local cultivar (16.14%) all these were proved to have non-significant difference. However, varieties RF-101, RF-125, local cultivar and RF-143; RF-125, RF-143, RF-178, RF-205 and local cultivar were statistically comparable. The variability of resistance in fennel genotypes was in the order : RF-101 > RF-125 > local cultivar > RF-143 > RF-205 > RF-178 > RF-145.

The pooled data showed that the minimum seed midge damage of 13.08 per cent was recorded in RF-145 followed by RF-178, RF-205, RF-143 and local cultivar which exhibited 14.21, 14.49, 14.85 and 15.39 per cent seed midge damage, respectively and did not differ statistically. The maximum seed midge damage of 18.12 per cent was observed in RF-101

followed by RF-125 (16.62%) and had non-significant difference. Similarly a non-significant difference existed among varieties RF- 125, RF- 143, RF- 178, RF- 205 and local cultivar. The variability of resistance in fennel varieties was in the order : RF-101 > RF-125 > local cultivar > RF-143 > RF-205 > RF-178 > RF-145.

The pooled per cent seed midge damage on fennel varieties were categorized on the basis of following formula:

$$\bar{X} \pm \sigma$$

Where, \bar{X} = mean of cumulative per cent seed midge damage (15.25),

σ = Standard deviation (1.67)

The varieties with per cent seed midge damage below 13.58, 13.58 to 16.92 and above 16.92 per cent were regarded as less susceptible, moderately susceptible and highly susceptible. Taking the above criterion into consideration, the variety RF-145 was considered as less susceptible, varieties RF-125, RF-143, RF-178, RF-205 and local cultivar as moderately susceptible and the variety RF-101 as highly susceptible.

Table 4.8 Screening of fennel varieties against *S. albipennis*

| S. No. | Varieties | Per cent seed damage* | | |
|--------|------------|-----------------------|------------------|------------------|
| | | 2011-12 | 2012-13 | Pooled |
| 1. | RF-101 | 17.70 (24.88) | 18.53 (25.49) | 18.12 (25.19) |
| 2. | RF-125 | 15.62 (23.28) | 17.62 (24.82) | 16.62 (24.06) |
| 3. | RF-143 | 14.20 (22.14) | 15.50 (23.18) | 14.85 (22.67) |
| 4. | RF-145 | 12.31 (20.54) | 13.84 (21.84) | 13.08 (21.20) |
| 5. | RF-178 | 13.55 (21.59) | 14.86 (22.67) | 14.21 (22.15) |
| 6. | RF-205 | 13.97 (21.95) | 15.00 (22.79) | 14.49 (22.37) |
| 7. | Local | 14.65 (22.50) | 16.14 (23.69) | 15.39 (23.09) |
| | S. Em± | 0.64 | 0.76 | 0.68 |
| | C.D. at 5% | 1.97 | 2.33 | 2.08 |

* Mean of three replications

Figures in parentheses are angular transformed values

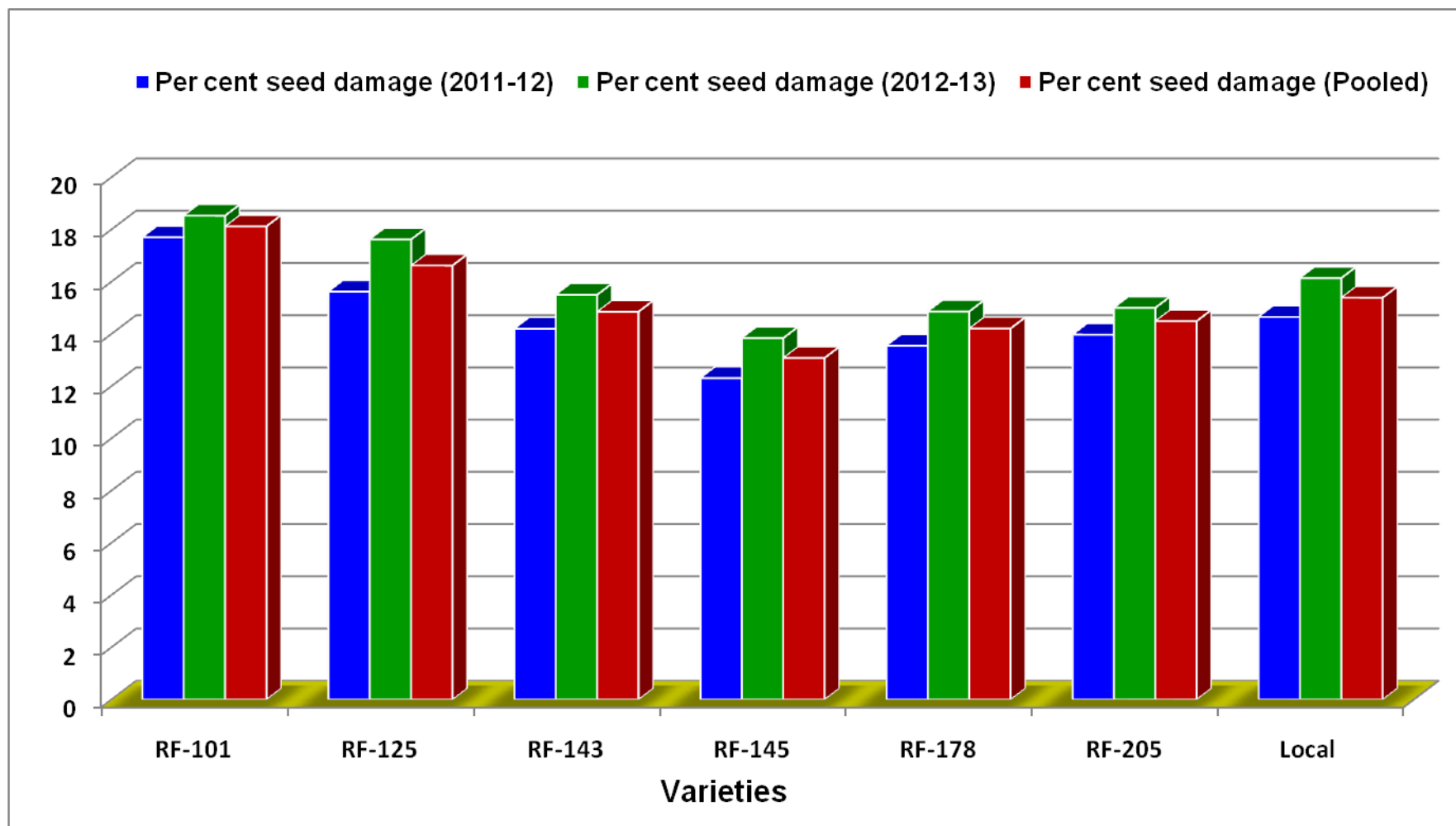


Fig. 4.6 Screening of fennel varieties against *S. albipennis*

4.4.2.2 Incidence of seed midge *vis - a - vis* morphological characters and oil content in different fennel varieties

4.4.2.2.1 Morphological characters

The morphological characters (Table 4.9) of different fennel varieties *viz.*, days to 50 per cent flowering, plant height, colour of flowers and seeds per umbel were recorded to find out their relationship with seed midge damage. The time taken for 50 per cent flowering ($r = 0.068$) was positively correlated with seed midge damage. The minimum seed midge damage (12.31%) was harboured by variety RF-145 and took 111.20 days for 50 per cent flowering, whereas, RF-101 took 115.26 days for 50 per cent flowering and registered maximum 17.70 per cent seed midge damage.

The plant height ($r = -0.278$) was negatively correlated with seed midge damage, and the mean plant height of different fennel varieties varied from 106.26 to 143.20 cm. The variety RF-145 had highest plant height (143.20 cm) and registered lowest seed midge damage (12.31%) whereas, RF-101 had a plant height of 130.10 cm with maximum seed midge damage (17.70%).

The colour of flowers of different fennel varieties varied from yellow, light yellow and lemon yellow. The maximum seed midge damage was recorded in variety with yellow colour flowers *i.e.* RF-101 and least damage in light yellow coloured flowers variety RF-145.

The seeds per umbel varied from 205.20 to 485.33 seeds and were negatively correlated ($r = -0.513$) with seed midge damage. The highest number of seeds per umbel was recorded in variety RF-145 but had lowest damage. The lowest number of seeds per umbel was recorded in local cultivar with 14.65 per cent seed midge damage.

4.4.2.2.2 Oil content

The oil content varied from 1.65 to 2.90 per cent and was significant negatively correlated ($r = -0.758$) with seed midge damage (Table 4.9). The highest oil content (2.90%) was recorded in variety RF-145 having lowest seed midge damage (12.31%). The lowest oil content (1.65%) was recorded in variety RF-101 with highest seed midge damage (17.70%). The result showed an inverse relationship between oil content and seed midge infestation.

Table 4.9 Morphological characters and oil content of different fennel varieties and their correlation with seed midge damage

| S. No. | Varieties | Morphological characters | | | | Oil content (%) | Per cent seed damage |
|--|-----------|--------------------------|-------------------|-------------------|-------------|-----------------|----------------------|
| | | Days of 50% flowering | Plant height (cm) | Colour of flowers | Seeds/umbel | | |
| 1 | RF-101 | 115.26 | 130.10 | Yellow | 280.33 | 1.65 | 17.70 |
| 2. | RF-125 | 106.40 | 110.40 | Lemon yellow | 384.00 | 2.60 | 15.62 |
| 3. | RF-143 | 116.50 | 106.26 | Lemon Yellow | 283.53 | 2.21 | 14.20 |
| 4. | RF-145 | 111.20 | 143.20 | Light yellow | 485.33 | 2.90 | 12.31 |
| 5. | RF-178 | 115.00 | 131.13 | Light yellow | 334.80 | 2.19 | 13.55 |
| 6. | RF-205 | 110.33 | 123.80 | Light Yellow | 383.46 | 2.52 | 13.97 |
| 7. | Local | 118.00 | 136.00 | Lemon yellow | 205.20 | 2.30 | 14.65 |
| Correlation coefficient (r) with seed midge damage | | 0.068 | -0.278 | - | -0.513 | -0.758* | - |

* Significant at 5% level

4.4.3 Efficacy of the insecticides/biopesticides against *S. albipennis*

The relative efficacy of seven insecticides/biopesticides namely, NSKE (5.0%), ahook (1ml/l), karanj seed extract (5.0%), spinosad (0.01%), malathion (0.05%), abamectin (0.5 ml/l) and cartap hydrochloride (0.05%) were evaluated against the infestation of seed midge, *S. albipennis* under field conditions for two consecutive *rabi* seasons (2011-12 and 2012-13). Two foliar sprays of all the insecticides/biopesticides were applied. The first spray was made after initiation of fruit set and second spray was repeated after 15 days of the first.

4.4.3.1 Per cent seed midge damage

The observations recorded during *rabi* 2011-12 revealed that all the pesticidal treatments reduced seed midge damage significantly in comparison to untreated check (Table 4.10 and Fig. 4.7). The minimum seed midge damage (2.04%) was recorded in the treatment of NSKE followed by abamectin (2.35%) and ahook (3.16%) and did not differ significantly from each other however, proved superior over rest of the treatments. Similarly the treatments of spinosad and karanj seed extract were also comparable to ahook resulting in 4.23 and 4.25 per cent seed midge damage respectively. The maximum seed midge damage was recorded in the treatment of malathion (8.33%) followed by cartap hydrochloride (7.00%), however, stood at par with each other and proved inferior to rest of the treatments. The ascending order of effectiveness of pesticides was: malathion, cartap hydrochloride, karanj seed extract, spinosad, ahook, abamectin and NSKE.

During the second year *i.e.* *rabi*, 2012-13 all the pesticidal treatments proved superior as compared to untreated check. The minimum seed midge damage (2.65%) was observed in the treatment of NSKE followed by

abamectin (3.25%) and ahook (3.75%) and proved highly effective with non-significant difference. The moderately effective treatments were spinosad (4.80%) and karanj seed extract (4.85%). However, non-significant difference existed between the treatments of abamectin, ahook, spinosad and karanj seed extract. The maximum seed midge damage was recorded in the treatments of malathion (8.84%) followed by cartap hydrochloride (7.39%) and proved least effective with non significant difference. The efficacy of pesticides in ascending order was: malathion, cartap hydrochloride, karanj seed extract, spinosad, ahook, abamectin and NSKE.

The pooled analysis of data indicated that all the pesticidal treatments minimized the seed midge damage significantly over untreated check. The minimum seed midge damage (2.35%) was recorded from the treatment of NSKE followed by abamectin and ahook which exhibited 2.80 and 3.46 per cent seed midge damage respectively and remained statistically comparable to each other however, proved superior over rest of the treatments. The next best treatments were spinosad (4.52%) and karanj seed extract (4.55%) and remained moderately effective. However, the treatments of ahook, spinosad and karanj seed extract stood at par with each other. The maximum seed midge damage was recorded in the treatments of malathion (8.59%) followed by cartap hydrochloride (7.19%) and proved least effective but did not differ to each other. The efficacy of pesticides in ascending order was: malathion, cartap hydrochloride, karanj seed extract, spinosad, ahook, abamectin and NSKE.

Table 4.10 Efficacy of insecticides/biopesticides against *S. albipennis*

| S.No | Pesticides | Conc. (%) / dosage | Per cent seed damage* | | |
|------|----------------------------|--------------------------|-----------------------|------------------|------------------|
| | | | 2011-12 | 2012-13 | Pooled |
| 1 | NSKE | 5.00 | 2.04 (8.21) | 2.65 (9.37) | 2.35 (8.82) |
| 2. | Achook | 1 ml/l | 3.16 (10.24) | 3.75 (11.17) | 3.46 (10.72) |
| 3. | Karanj seed extract | 5.00 | 4.25 (11.89) | 4.85 (12.72) | 4.55 (12.32) |
| 4. | Spinosad 2.5 SC | 0.01 | 4.23 (11.87) | 4.80 (12.66) | 4.52 (12.27) |
| 5. | Malathion 50 EC | 0.05 | 8.33 (16.78) | 8.84 (17.29) | 8.59 (17.04) |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 2.35 (8.82) | 3.25 (10.39) | 2.80 (9.63) |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 7.00 (15.34) | 7.39 (15.77) | 7.19 (15.55) |
| 8. | Untreated check | - | 14.35 (22.26) | 17.82 (24.97) | 16.09 (23.65) |
| | S. Em± | | 0.77 | 0.78 | 0.71 |
| | C.D. at 5% | | 2.34 | 2.39 | 2.16 |

* Mean of three replications

Figures in parentheses are angular transformed values

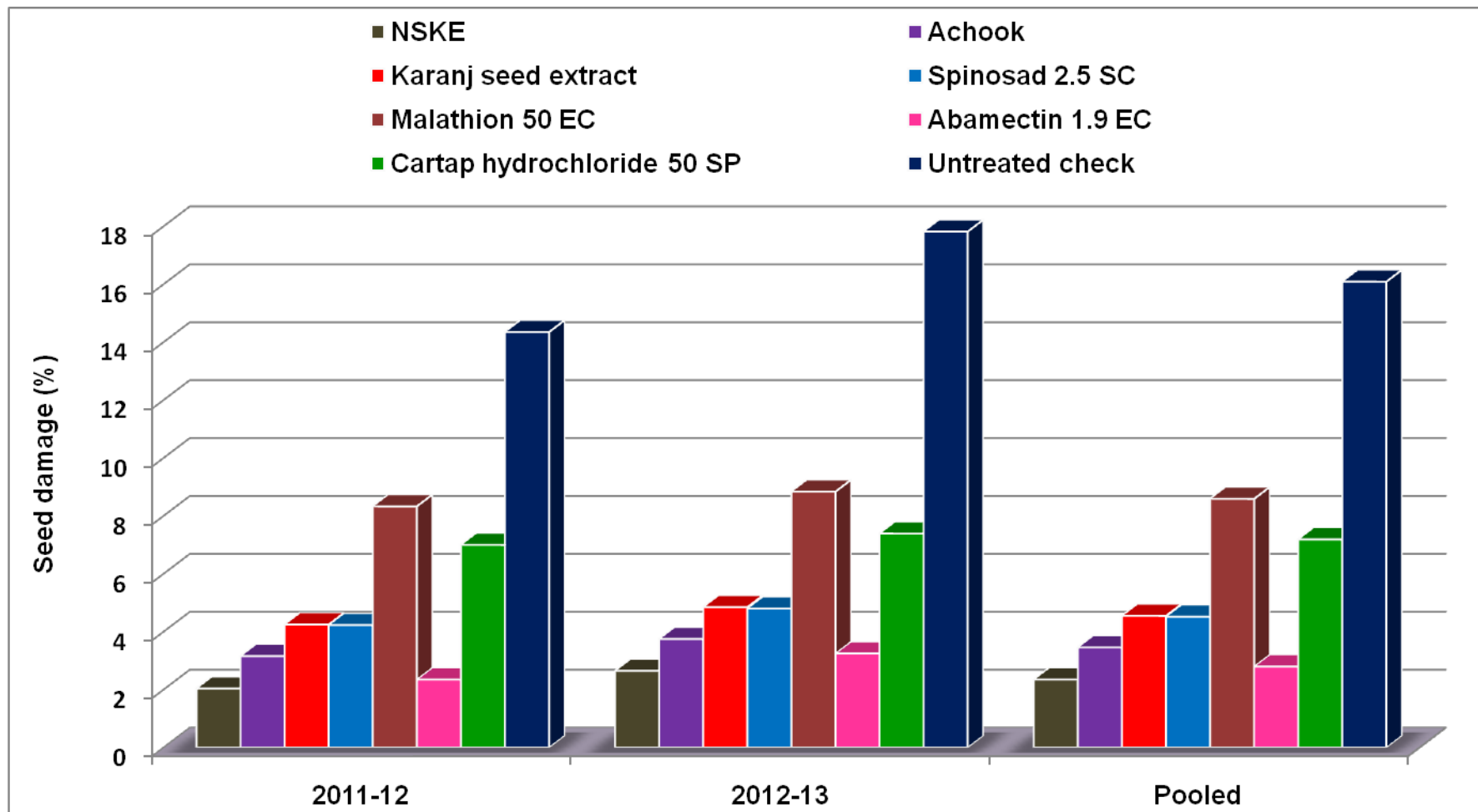


Fig. 4.7 Efficacy of insecticides/biopesticides against *S. albipennis* infesting fennel

4.4.3.2 Effect of insecticides/biopesticides on the seed yield of fennel

The data presented in Table 4.11 and Fig. 4.8 revealed that the plots treated with insecticides gave significantly higher seed yield of fennel over untreated check in both the years. During first year *i.e.* *rabi* 2011-12, the maximum seed yield (15.10 q ha⁻¹) was obtained from the plots treated with NSKE followed by abamectin (14.50 q ha⁻¹) and ahook (14.15 q ha⁻¹) and remained statistically at par with each other and proved significantly superior over rest of the treatments. The moderately effective treatments were spinosad (13.90 q ha⁻¹) and karanj seed extract (13.67 q ha⁻¹). However, they were comparable to abamectin and ahook. The minimum seed yield (12.15 q ha⁻¹) was recorded in plots treated with malathion followed by cartap hydrochloride (12.40 q ha⁻¹) and proved least effective with non significant difference.

During 2012-13 similar trend of seed yield was observed. The maximum (15.75 q ha⁻¹) seed yield was obtained from the plots treated with NSKE followed by abamectin which gave a yield of 14.75 q ha⁻¹, however minimum seed yield (12.40 q ha⁻¹) was recorded in the plots treated with malathion.

The pooled data revealed that all the plots treated with insecticides gave significantly higher seed yield over untreated check (10.38 q ha⁻¹). The maximum seed yield of 15.43 q ha⁻¹ was recorded in the plots treated with NSKE followed by abamectin (14.63 q ha⁻¹) and ahook (14.27 q ha⁻¹) and stood at par to each other and proved significantly superior over rest of the treatments. The moderately effective treatments were spinosad (14.00 q ha⁻¹)

and karanj seed extract (13.79 q ha⁻¹). However, non-significant difference existed between them and both were also comparable with abamectin and achook. The minimum seed yield (12.45 q ha⁻¹) was obtained in plots treated with malathion followed by cartap hydrochloride (12.28 q ha⁻¹) and remained least effective with non significant difference.

The order of effectiveness of insecticides on the basis of seed yield was: NSKE > abamectin > achook > spinosad > karanj seed extract > cartap hydrochloride > malathion.

Table 4.11 Effect of insecticides/biopesticides on the seed yield of fennel

| S. No. | Pesticides | Conc. (%) / dosage | Mean seed yield (q h ⁻¹)* | | |
|--------|----------------------------|--------------------|---------------------------------------|---------|--------|
| | | | 2011-12 | 2012-13 | Pooled |
| 1 | NSKE | 5.00 | 15.10 | 15.75 | 15.43 |
| 2. | Achook | 1 ml/l | 14.15 | 14.39 | 14.27 |
| 3. | Karanj seed extract | 5.00 | 13.67 | 13.92 | 13.79 |
| 4. | Spinosad 2.5 SC | 0.01 | 13.90 | 14.10 | 14.00 |
| 5. | Malathion 50 EC | 0.05 | 12.15 | 12.40 | 12.28 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 14.50 | 14.75 | 14.63 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 12.40 | 12.50 | 12.45 |
| 8. | Untreated check | - | 10.25 | 10.50 | 10.38 |
| | S. Em± | | 0.32 | 0.45 | 0.38 |
| | C.D. at 5% | | 0.96 | 1.37 | 1.17 |

* Mean of three replications

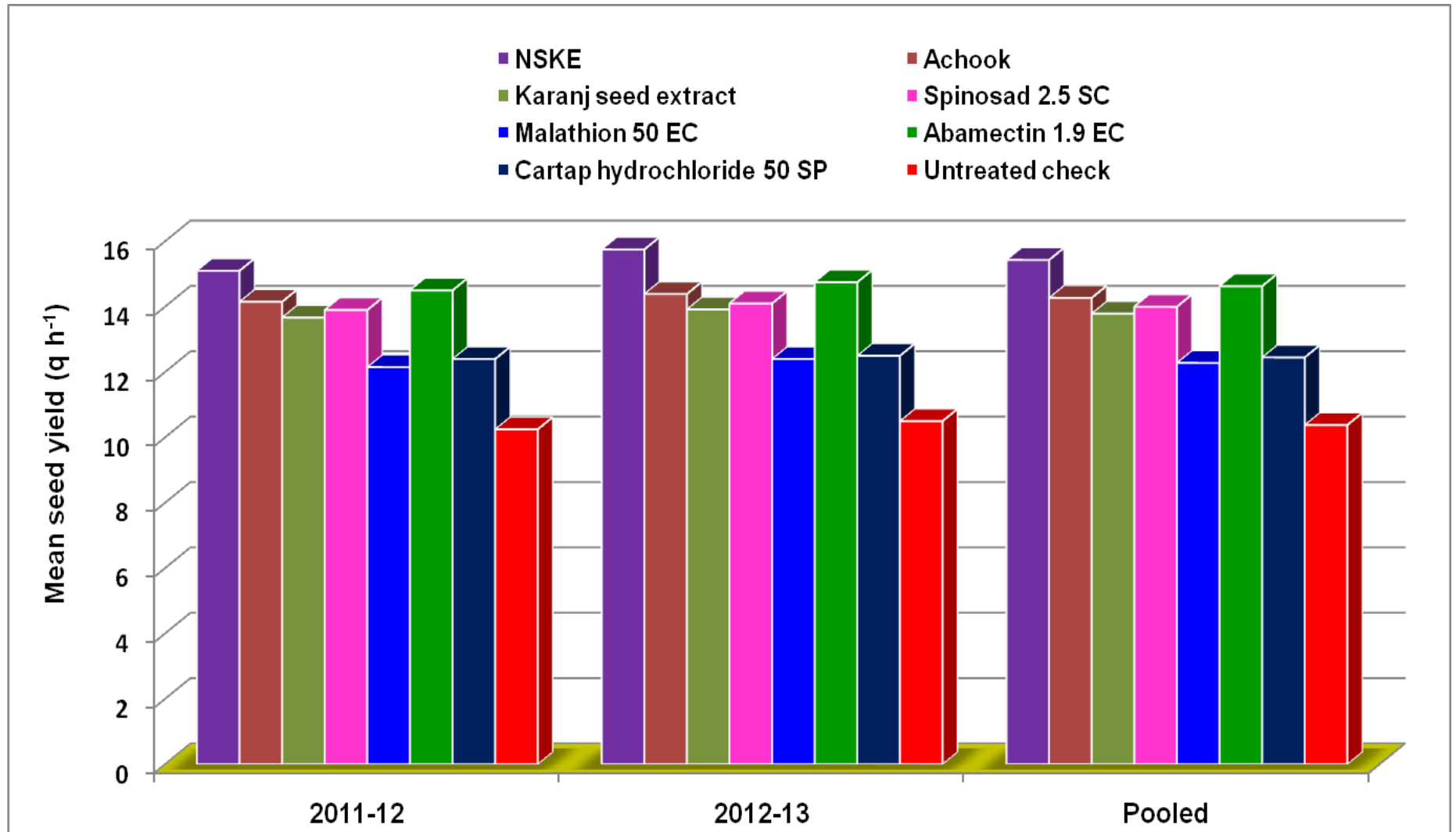


Fig. 4.8 Effect of insecticides/biopesticides on the seed yield of fennel

4.4.3.3 Assessment of losses and increase in yield

During the first year *i.e. rabi*, 2011-12 the total avoidable losses and percent avoidable losses were zero in the plots treated with NSKE (Table 4.12) followed by abamectin and achook with corresponding figures serially as 0.60 and 0.95 q ha⁻¹ and 3.97 and 6.29 per cent respectively. The maximum total avoidable losses (4.85 q ha⁻¹) and percent avoidable loss (32.12%) were recorded from untreated check, followed by malathion and cartap hydrochloride where such losses were 2.95 and 2.70 q ha⁻¹ with 19.54 and 17.89 per cent percent avoidable losses respectively. Whereas, in the treatments of spinosad and karanj seed extract the total avoidable losses were 1.20 and 1.43 q ha⁻¹ with 7.95 and 9.47 per cent percent avoidable losses respectively.

The maximum increase in yield over untreated check was recorded in the treatment of NSKE in which total increase in yield over untreated check was 4.85 q ha⁻¹ and percent increase in yield over untreated check was 47.32 percent followed by abamectin and achook where these were 4.25 and 3.90 q ha⁻¹ and 41.46 and 38.05 per cent respectively. The minimum total increase in yield over untreated check (1.90 q ha⁻¹) and percent increase in yield over untreated check (18.54%) was found in the plots treated with malathion followed by cartap hydrochloride treatments with a figures of 2.15 q ha⁻¹ and 20.98 per cent respectively. The total increase and percent increase in yield over untreated check were found as 3.65 and 3.42 q ha⁻¹ and 35.61 and 33.37 per cent in the treatments of spinosad and karanj seed extract respectively.

Table 4.12 Assessment of losses caused by *S. albipennis* on fennel during *rabi*, 2011-12

| S. No. | Pesticides | Conc. (%) / doses | Yield (q ha⁻¹) | Total avoidable losses (q ha⁻¹) | Per cent avoidable losses | Total increase in yield over untreated check (q ha⁻¹) | Per cent increase in yield over untreated check |
|---------------|----------------------------|--------------------------|----------------------------------|---|----------------------------------|---|--|
| 1. | NSKE | 5.00 | 15.10 | 0.00 | 0.00 | 4.85 | 47.32 |
| 2. | Achook | 1 ml/l | 14.15 | 0.95 | 6.29 | 3.90 | 38.05 |
| 3. | Karanj seed extract | 5.00 | 13.67 | 1.43 | 9.47 | 3.42 | 33.37 |
| 4. | Spinosad 2.5 SC | 0.01 | 13.90 | 1.20 | 7.95 | 3.65 | 35.61 |
| 5. | Malathion 50 EC | 0.05 | 12.15 | 2.95 | 19.54 | 1.90 | 18.54 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 14.50 | 0.60 | 3.97 | 4.25 | 41.46 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 12.40 | 2.70 | 17.89 | 2.15 | 20.98 |
| 8. | Untreated check | - | 10.25 | 4.85 | 32.12 | - | - |

Similarly, during the second year (*i.e.* 2012-13) the total avoidable losses and percent avoidable losses were zero in the plots treated with NSKE followed by abamectin and achook with the total avoidable losses of 1.00 and 1.36 q ha⁻¹ and percent avoidable losses of 6.35 and 8.63 per cent respectively (Table 4.13). The maximum total avoidable losses (5.25 q ha⁻¹) and percent avoidable loss (33.33%) were recorded from untreated check followed by malathion and cartap hydrochloride in which total avoidable losses were 3.35 and 3.25 q ha⁻¹ with 21.27 and 20.63 per cent percent avoidable losses respectively. Whereas, in the treatments of spinosad and karanj seed extract, the total avoidable losses were 1.65 and 1.83 q ha⁻¹ and the percent avoidable losses were 10.48 and 11.62 per cent respectively.

The maximum increase in yield over untreated check was recorded in the plots treated with NSKE in which total increase in yield over untreated check was 5.25 q ha⁻¹ with percent increase in yield over untreated check as 50.00 percent followed by abamectin and achook where total increase in yield over untreated check were 4.25 and 3.89 q ha⁻¹ and percent increase in yield over untreated check were 40.48 and 37.05 per cent respectively. The minimum total increase in yield over untreated check (1.90 q ha⁻¹) and percent increase in yield over untreated check (18.09%) was found in the plots treated with malathion followed by cartap hydrochloride treatments with a figures of 2.00 q ha⁻¹ and 19.05 per cent respectively. The total increase and percent increase in yield over untreated check were observed to be 3.60 and 3.42 q ha⁻¹ and 34.29 and 32.57 per cent in the treatments of spinosad and karanj seed extract respectively.

Table 4.13 Assessment of losses caused by *S. albipennis* on fennel during *rabi*, 2012-13

| S. No. | Pesticides | Conc. (%) / doses | Yield (q ha⁻¹) | Total avoidable losses (q ha⁻¹) | Per cent avoidable losses | Total increase in yield over Untreated check (q ha⁻¹) | Per cent increase in yield over Untreated check |
|---------------|----------------------------|--------------------------|----------------------------------|---|----------------------------------|---|--|
| 1. | NSKE | 5.00 | 15.75 | 0.00 | 0.00 | 5.25 | 50.00 |
| 2. | Achook | 1 ml/l | 14.39 | 1.36 | 8.63 | 3.89 | 37.05 |
| 3. | Karanj seed extract | 5.00 | 13.92 | 1.83 | 11.62 | 3.42 | 32.57 |
| 4. | Spinosad 2.5 SC | 0.01 | 14.10 | 1.65 | 10.48 | 3.60 | 34.29 |
| 5. | Malathion 50 EC | 0.05 | 12.40 | 3.35 | 21.27 | 1.90 | 18.09 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 14.75 | 1.00 | 6.35 | 4.25 | 40.48 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 12.50 | 3.25 | 20.63 | 2.00 | 19.05 |
| 8. | Untreated check | - | 10.50 | 5.25 | 33.33 | - | - |

The pooled data presented in Table 4.14 indicated that treatment of NSKE recorded zero total avoidable losses and per cent avoidable losses over untreated check. It was followed by abamectin and achool where total avoidable losses were 0.8 and 1.16 q ha⁻¹ with per cent avoidable losses over untreated check as 5.18 and 7.52 per cent respectively. The treatments of spinosad and karanj seed extract resulted into a total avoidable losses of 1.43 and 1.64 q ha⁻¹ with per cent avoidable losses of 9.27 and 10.63 per cent respectively, whereas the maximum avoidable loss (5.05 q ha⁻¹) and per cent avoidable loss (32.73%) was recorded in untreated check followed by cartap hydrochloride and malathion with corresponding figures of 2.98 and 3.15 q ha⁻¹ and 19.31 and 20.14 per cent respectively.

The maximum total increase in yield over untreated check (5.05 q ha⁻¹) was also recorded in the plots treated with NSKE with 48.65 per cent increase in yield over untreated check. It was followed by the treatments of abamectin and achool with total increase in yield as 4.25 and 3.89 q ha⁻¹ and 40.94 and 37.48 per cent respectively. The minimum total increase in yield over untreated check (1.90 q ha⁻¹) and per cent increase in yield over untreated check (18.30%) were recorded in the treatment of malathion followed by cartap hydrochloride where such figures were 2.07 q ha⁻¹ and 19.94 per cent respectively. The treatments of spinosad and karanj seed extract recorded a total increase in yield as 3.62 and 3.41 q ha⁻¹ and per cent increase in yield as 34.87 and 32.85 per cent respectively.

Table 4.14 Assessment of losses caused by *S. albipennis* on fennel during *rabi*, 2011-12 and 2012-13 (pooled)

| S. No. | Pesticides | Conc. (%) / doses | Yield (q ha⁻¹) | Total avoidable losses (q ha⁻¹) | Per cent avoidable losses | Total increase in yield over untreated check (q ha⁻¹) | Per cent increase in yield over untreated check |
|---------------|----------------------------|--------------------------|----------------------------------|---|----------------------------------|---|--|
| 1. | NSKE | 5.00 | 15.43 | 0.00 | 0.00 | 5.05 | 48.65 |
| 2. | Achook | 1 ml/l | 14.27 | 1.16 | 7.52 | 3.89 | 37.48 |
| 3. | Karanj seed extract | 5.00 | 13.79 | 1.64 | 10.63 | 3.41 | 32.85 |
| 4. | Spinosad 2.5 SC | 0.01 | 14.00 | 1.43 | 9.27 | 3.62 | 34.87 |
| 5. | Malathion 50 EC | 0.05 | 12.28 | 3.15 | 20.41 | 1.90 | 18.30 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 14.63 | 0.80 | 5.18 | 4.25 | 40.94 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 12.45 | 2.98 | 19.31 | 2.07 | 19.94 |
| 8. | Untreated check | - | 10.38 | 5.05 | 32.73 | - | - |

4.4.3.4 Economics of insecticidal treatments

4.4.3.4.1 Net profit

During 2011-12 the net profit (Rs.19505.00) was maximum in the treatment of NSKE followed by ahook, abamectin and karanj seed extract where a net profit of Rs. 16350.00, Rs. 14988.20 and Rs. 12670.00 was obtained respectively. On the contrary a loss of Rs. -54455.00 was incurred in the plots treated with spinosad. However, the treatments of malathion and cartap hydrochloride recorded the net profit of Rs. 7510.00 and Rs. 7214.20 respectively (Table 4.15).

The data presented in Table 4.16 for the year 2012-13 indicated that the NSKE had the maximum net profit of Rs. 31565.00 followed by a net profit of Rs. 23925.00 and Rs. 23328.20 in the treatments of ahook and abamectin respectively. On the contrary a loss of Rs. -47640.00 was incurred in the plots treated with spinosad. The other treatments *viz.*, karanj seed extract, malathion and cartap hydrochloride resulted into a net profit of Rs. 19270.00, Rs. 11150.00 and Rs. 10379.20.

The pooled data (Table 4.17) revealed that the maximum net profit (Rs. 25335.00) was recorded in the treatment of NSKE followed by the treatments of ahook and abamectin with corresponding figures of Rs. 20115.00 and Rs. 19158.20 respectively. The other treatments *viz.*, karanj seed extract, malathion and cartap hydrochloride recorded a net profit of Rs. 15915.00, Rs. 9328.00 and Rs. 8844.20. On the contrary a loss of Rs. 51050.00 was incurred in the plots treated with spinosad.

4.4.3.4.2 Benefit- cost ratio

The data presented in Table 4.15 revealed that during first year (2011-12), the treatment of ahook obtained the maximum benefit cost ratio (13.63) followed by the treatments of NSKE, malathion and karanj seed extract where such ratio were 8.41, 7.22 and 4.66 respectively. On the other hand a rupee invested remained into a loss of Re. -0.77 in the treatment of spinosad. The

benefit cost ratio was minimum (2.93) in the treatment of cartap hydrochloride followed by abamectin (3.63).

Similarly during 2012-13 (Table 4.16), the minimum benefit cost ratio (3.96) was recorded in the treatment of cartap hydrochloride followed by abamectin (5.43), while gains could not be attained in spinosad (B:C ratio = -0.67). The maximum benefit cost ratio (17.59) was obtained in the treatment of ahook followed by the treatments of NSKE, malathion and karanj seed extract which had the ratio as 12.33, 9.29 and 6.51 respectively.

Perusal of pooled data shown in Table 4.17 indicated that maximum benefit cost ratio (15.71) was recorded in the treatment of ahook followed by the treatments of NSKE, malathion and karanj seed extract where corresponding figures were 10.38, 8.31 and 5.60 respectively. The minimum benefit cost ratio (3.48) was observed in the treatment of cartap hydrochloride followed by abamectin (4.54), while gains could not be attained in spinosad (B:C ratio = -0.71).

4.5 Residue analysis

No residue estimation of seeds of fennel was done as NSKE remained most effective and being plant product, it was not required to estimate.

Table 4.15 Comparative economics of pesticidal treatments on fennel during *rabi*, 2011-12

| S. No. | Pesticides | Conc. (%) / doses | Yield (q ha ⁻¹) | Increase in yield over untreated check (q ha ⁻¹) | Return of increased yield (q ha ⁻¹)* | Total cost of expenditure (Rs)** | Net profit (Rs ha ⁻¹) | B : C ratio |
|--------|----------------------------|-------------------|-----------------------------|--|--|----------------------------------|-----------------------------------|-------------|
| 1. | NSKE | 5.00 | 15.10 | 4.85 | 21825 | 2320.00 | 19505.00 | 8.41 |
| 2. | Achook | 1 ml/l | 14.15 | 3.90 | 17550 | 1200.00 | 16350.00 | 13.63 |
| 3. | Karanj seed extract | 5.00 | 13.67 | 3.42 | 15390 | 2720.00 | 12670.00 | 4.66 |
| 4. | Spinosad 2.5 SC | 0.01 | 13.90 | 3.65 | 16425 | 70880.00 | -54455.00 | -0.77 |
| 5. | Malathion 50 EC | 0.05 | 12.15 | 1.90 | 8550 | 1040.00 | 7510.00 | 7.22 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 14.50 | 4.25 | 19125 | 4136.80 | 14988.20 | 3.63 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 12.40 | 2.15 | 9675 | 2460.80 | 7214.20 | 2.93 |

* Cost of fennel seed at current season was Rs 4500/- per q.

** It includes cost of insecticides and labour charges.

Table 4.16 Comparative economics of pesticidal treatments on fennel during *rabi*, 2012-13

| S. No. | Pesticides | Conc. (%) / doses | Yield (q ha ⁻¹) | Increase in yield over untreated check (q ha ⁻¹) | Return of increased yield (q ha ⁻¹)* | Total cost of expenditure (Rs)** | Net profit (Rs ha ⁻¹) | B : C ratio |
|--------|----------------------------|-------------------|-----------------------------|--|--|----------------------------------|-----------------------------------|-------------|
| 1. | NSKE | 5.00 | 15.75 | 5.25 | 34125 | 2560.00 | 31565.00 | 12.33 |
| 2. | Achook | 1 ml/l | 14.39 | 3.89 | 25285 | 1360.00 | 23925.00 | 17.59 |
| 3. | Karanj seed extract | 5.00 | 13.92 | 3.42 | 22230 | 2960.00 | 19270.00 | 6.51 |
| 4. | Spinosad 2.5 SC | 0.01 | 14.10 | 3.60 | 23400 | 71040.00 | -47640.00 | -0.67 |
| 5. | Malathion 50 EC | 0.05 | 12.40 | 1.90 | 12350 | 1200.00 | 11150.00 | 9.29 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 14.75 | 4.25 | 27625 | 4296.80 | 23328.20 | 5.43 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 12.50 | 2.00 | 13000 | 2620.80 | 10379.20 | 3.96 |

* Cost of fennel seed at current season was Rs 6500/- per q.

** It includes cost of insecticides and labour charges.

Table 4.17 Comparative economics of pesticidal treatments on fennel during *rabi*, 2011-12 and 2012-13 (pooled)

| S. No. | Pesticides | Conc. (%) / doses | Yield (q ha ⁻¹) | Increase in yield over untreated check (q ha ⁻¹) | Return of increased yield (q ha ⁻¹)* | Total cost of expenditure (Rs)** | Net profit (Rs ha ⁻¹) | B : C ratio |
|--------|----------------------------|-------------------|-----------------------------|--|--|----------------------------------|-----------------------------------|-------------|
| 1. | NSKE | 5.00 | 15.43 | 5.05 | 27775 | 2440.00 | 25335.00 | 10.38 |
| 2. | Achook | 1 ml/l | 14.27 | 3.89 | 21395 | 1280.00 | 20115.00 | 15.71 |
| 3. | Karanj seed extract | 5.00 | 13.79 | 3.41 | 18755 | 2840.00 | 15915.00 | 5.60 |
| 4. | Spinosad 2.5 SC | 0.01 | 14.00 | 3.62 | 19910 | 70960.00 | -51050.00 | -0.71 |
| 5. | Malathion 50 EC | 0.05 | 12.28 | 1.90 | 10450 | 1122.00 | 9328.00 | 8.31 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 14.63 | 4.25 | 23375 | 4216.80 | 19158.20 | 4.54 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 12.45 | 2.07 | 11385 | 2540.80 | 8844.20 | 3.48 |

* Cost of fennel seed at current season was Rs 5500/- per q.

** It includes cost of insecticides and labour charges.

5. Discussion

The results of present investigations “Management of seed midge, *Systole albipennis* Walker infesting fennel, *Foeniculum vulgare* Miller” have been presented in preceding chapter. The findings of the investigations have been discussed in the light of previously available information and important conclusions have been drawn.

5.1 Survey for the infestation level of seed midge, *Systole albipennis* Walker infesting fennel

Almost no field surveys have been conducted on fennel crop in the state of Rajasthan to know the infestation level caused by seed midge. One possible reason for this could be that seed midge has only become serious pest in recent years and has been proving to be a limiting factor in fennel production. As such, programme on field surveys were carried out on farmers fields in Sirohi, Nagaur and Dausa districts of Rajasthan for estimating the per cent infestation caused by seed midge, *S. albipennis* in fennel for two consecutive year *i.e.* during *rabi* 2011-12 and 2012-13.

During the present investigations, the maximum infestation of seed midge was recorded in Degana tehsil followed by Nagaur tehsil of Nagaur district. The minimum infestation of seed midge was observed in Reodar tehsil of Sirohi district followed by Lalsot tehsil of Dausa district during both the years. The variation in damage intensity among localities may be due to growing of different varieties/cultivars as well as growing of the same seeds already infested by the pest species in the same field in ensuing years. Present study get support from the observations of Bamborot *et al.* (1993), who observed infestation of *S. albipennis* in seeds of coriander at various locations in Chile and reported that the damage varied from locality to locality and year to year. They further found that the cultivation of coriander crop in the same field for two consecutive years led to increased the damage level. In the present findings the damage ranged from 12.23 to 19.04 per cent get partial support from the observations recorded by Agrawal *et al.* (2004) where they noticed the damage

caused by *S. albipennis* in fennel crop as high as 50 per cent during a field survey in 2003. Similarly Patil (2009) carried out surveys at farmer field in four major coriander growing districts of Rajasthan for the infestation of *S. albipennis* and reported varied per cent damage in different districts of Rajasthan fully support the present results.

5.2 The seasonal incidence of *S. albipennis* on fennel in relation to weather parameters

For developing effective management programme of pest, there is a need to have studies on ecological aspects for better understanding of insect-pests in relation to a crop and environment. With this view to provide a sound base for the management of insect pests of fennel, studies were carried out on the quantitative estimation of seed midge infestation in relation to key abiotic factors, like maximum and minimum temperatures, relative humidity and rainfall under the prevailing agroclimatic conditions.

The present results indicated that the infestation of seed midge, *S. albipennis* initially appeared in the last week of March (13 SMW) during *rabi*, 2011-12 and in the first week of April (14 SMW) during *rabi*, 2012-13. The maximum seed midge damage (15.50%) was recorded in the first week of May (18 SMW) at 38.7 °C maximum, 19.8 °C minimum temperature and 31.5 per cent relative humidity during 2011-12 and similarly in the first week of May (17.50 %) at 39.1 °C maximum, 20.0 °C minimum temperature and 30.0 per cent relative humidity during 2012-13. The results are in close conformity with the findings of Patel and Patel (2003) who carried out studies in Gujarat to observe the intensity of seed midge in fennel crop during 1997-98 and found that the seed midge infestation commenced with the initiation of seed setting in the umbel and continued up to harvest fully support the present findings. The damage (0.50 – 17.50%) caused by *S. albipennis* are more or less close with the findings of Patel *et al.* (2009) who also reported that the damage of *S. albipennis* in fennel ranged from 5.4 to 20.7 per cent but with regards to the data on the incidence, the present finding do not match with the observations reported earlier by the same authors because minimum and maximum incidence was in April and May respectively, as compared to earlier report

where these were in January and March respectively. On the other hand, the present findings in respect to the incidence do not match with the observations of Patel *et al.* (1986) who observed that infestation of *S. albipennis* in fennel crop was maximum in January and minimum in March. The probable reason for the variation in damage intensity among different localities of country might be due to the difference in crop husbandry.

The maximum and minimum temperatures had non-significant correlation with seed midge damage during 2011-12, while such correlation was positively significant during 2012-13. The average relative humidity had non-significant correlation with seed midge infestation during 2011-12, whereas a negatively significant correlation existed during 2012-13. Total rainfall had non-significant correlation with seed midge damage during both the years.

A parasitic wasp, *Tetrastichus* sp. was reported to parasitized seed midge, *S. albipennis* under field conditions. The incidence of *Tetrastichus* sp. commenced in the third week of April and continued upto crop harvest during both the years. The parasitic wasp laid egg (generally one or two) in the seeds already infested by *S. albipennis* and developed into adult which emerged out of the seed by boring a hole in the seed wall. The present findings fully corroborate with the earlier findings of Batra *et al.* (1959) and Sehgal (1966) who reported that *S. albipennis* was found to be parasitized by *Tetrastichus* sp.

5.3 The quantitative and qualitative losses in fennel crop

A female of *S. albipennis* laid egg in the embryo of grain and developing larva fed, pupate inside the grain and adult emerged from the grain by making hole, which resulted in both qualitative and quantitative losses.

5.3.1 Quantitative losses

The infestation of seed midge damage and seed yield of fennel crop in treated plots were 1.98 per cent and 15.08 q h⁻¹ respectively, while in untreated plots these figure were 16.69 per cent and 10.13 q h⁻¹ respectively. These results are in partial agreement with the findings of Batra *et al.* (1959) who observed 30 per cent damage in fennel crop as a result of infestation of *S. albipennis* at IARI, New Delhi. Likewise, Santis *et al.* (1989) collected seeds of

wild and cultivated umbellifers in Chile to observe emergence of *S. albipennis* and recorded 5.5 per cent damage in fennel crop partially support the present findings.

5.3.2 Qualitative losses

5.3.2.1 Effect on oil content

Perusal of data indicated that the oil content in fennel seeds decreased due to the infestation of *S. albipennis*. The oil content recorded in healthy and damage seeds were 2.70 and 1.65 per cent respectively. As a result of the infestation, a reduction of 38.88 per cent in oil content of fennel seeds was recorded. The present findings are fully corroborated with the earlier observations of Lamborot *et al.* (1995) who found that damage to 1 or 2 mericarps of coriander seed due to *Systole coriandri* resulted in a reduction in oil content by 16.7 and 42.0 % respectively as compared to undamaged seeds.

5.3.2.2 Effect on carbohydrate content

Findings of the present investigations enunciated a negative effect of *S. albipennis* infestation on the carbohydrate content of fennel. The carbohydrate content recorded in healthy and damage seeds was 42.25 and 35.75 per cent respectively. 15.38 per cent reduction in carbohydrate content of fennel seeds was observed. However, no such information on this aspect in case of fennel crop infested by *S. albipennis* is available presently in literature, hence result could not be compared with the findings of the earlier workers.

5.3.2.3 Effect on protein content

The data revealed that protein content in fennel was increased due to infestation of *S. albipennis*. The protein content recorded in healthy seeds was 9.45 per cent as compared to damaged seeds (10.10%). However, protein content of fennel seeds increased upto 5.82 per cent. Increase in the content of crude protein apparently seems illogical as larva of *S. albipennis* preferably eats on endosperm or embryo of grain, which contains protein. Hence there should have been an inverse relationship between infestation level and the protein content of the fennel grains. However, exhibited a positive relationship

between the two parameters against the hypothesis. Later studies revealed that increase in contents of crude protein in the infested grains was actually due to production of non beneficial rather harmful proteins such as cast skins, exuviate, dead insects, wings, legs and other body parts of the insects that came along with the infested grain samples. Besides the increase in protein percentage may also be due to depletion of carbohydrates that constituted major part of a fennel grain. The scanning of literature indicated no reports on this aspect, hence remained un-discussed.

5.3.2.4 Effect on germination of the seeds of fennel

The data revealed that germination percentage of fennel seeds was decreased due to infestation of *S. albipennis*. The germination recorded in healthy seeds was 92.25 per cent, while it was 67.50 per cent in damaged seeds. Germination of fennel seeds decreased upto 26.83 per cent. This information is in close conformity with the observations of Batra *et al.* (1959) who observed that egg of *S. albipennis* was laid inside the tender seed of fennel and the grub fed inside the mericarps and rendered them hollow and damaged seed did not germinate. Likewise, Lamborot *et al.* (1995) also found that infestation of coriander seed by *S. coriandri* resulted in a significant negative correlation between infestation and germination fully support the present findings.

5.4 Management of *S. albipennis* using IPM tools

5.4.1 Impact of sowing dates on the incidence

With the increasing and indiscriminate use of insecticides, insects have developed resistance against them. Moreover, insecticides cause environmental pollution, which makes life more miserable and increase the health hazards to mankind and animals. The manipulation of sowing time helps to minimize pest damage by producing asynchrony between host plant and the pest or synchronizing insect pests with their natural enemies. Hence, alteration of sowing times of fennel crop to manage the seed midge, *S. albipennis* was attempted in the present study.

The data on the impact of variation in the time of sowing on the incidence of *S. albipennis* indicated that there was a definite increasing trend in the incidence of seed midge in fennel crop with the delay in sowing times but had inverse relationship with seed yield. It was revealed from the data that minimum infestation of seed midge damage (6.29%) was recorded from crop sown on 6th October, followed by crop sown on 13th October which exhibited 8.67 per cent seed damage. The crops sown on 20th and 27th October resulted in 13.59 and 16.42 per cent seed damage respectively. However, maximum seed damage (22.42%) was observed in late sown crop *i.e.* 3rd November. It was concluded that the seed midge damage increased with the delay in sowing time. The maximum seed yield (10.98 q h⁻¹) was obtained from 20th October sown crop followed by the crop sown on 27th October. The minimum seed yield of 7.89 q h⁻¹ was recorded from crop sown on 3rd November which was significantly lower to rest of the sowing dates. The reduction in yield in late sown crop was probably due to heavy incidence of *S. albipennis*. It is well known that certain stages of crop growth are preferred by the insect pests for feeding and breeding (Kogan, 1982), the difference in sowing time resulted in availability of different stages of crop at a time resulting higher multiplication of the insect pests. These results corroborate with the results of Baswana *et al.* (1989) who reported that *S. albipennis* infestation on coriander increased significantly with a delay in sowing with the highest percentage infestation in the crop sown on 29th December, however, highest seed yields were obtained in crop sown on 30th October. Similarly, Kashyap *et al.* (1994) observed that the fennel crop sown during December-January suffered the maximum seed infestation by *S. albipennis i.e.* (up to 17%) with a minimum yield of (1.1 q/ha) as compared to October sown crops which had the lowest seed infestation (4%) with the maximum yield (32 q/ha) fully support the present findings.

The sowing dates depicted significant positive correlation ($r = 0.995$) with seed midge damage and had negative correlation ($r = -0.265$) with the seed yield. The seed midge damage was also negatively correlated ($r = -0.280$) with seed yield of fennel. Sowing dates caused 7.02 per cent variation in seed yield and seed midge damage caused 7.84 per cent variation in seed yield. Thus,

the knowledge of the seed midge damage in relation to the time of sowing may be utilized for developing the economical and effective pest management programmes. From the present findings, it can be concluded that sowing time of fennel *i.e.* 20th October in semi-arid region of Rajasthan is appropriate to minimize the infestation of seed midge, *S. albipennis*.

5.4.2 Varietal screening of fennel against seed midge, *S. albipennis*

5.4.2.1 Effect of fennel varieties on the infestation of seed midge

It is well known that certain varieties of crop are less attacked by a specific insect pest as compared to others, because of natural resistance. In the cultural practices, currently employed to minimize the losses caused by insect pests, growing of resistance varieties may be one of the most important tool in the management of pest without additional cost.

During the present studies, seven fennel varieties were screened for their relative susceptibility against *S. albipennis*. The results of two years data indicated that none of the fennel varieties was found completely free from seed midge infestation. The pooled analysis of data revealed that the minimum seed midge damage of 13.08 per cent was recorded from RF-145 followed by RF-178, RF-205, RF-143 and local cultivar which exhibited 14.21, 14.49, 14.85 and 15.39 per cent seed midge damage respectively and stood statistically at par. The maximum seed midge damage of 18.12 per cent was recorded from RF-101 followed by RF-125 (16.62%) and existed a non-significant difference between them. However, different varieties showed varying degree of susceptibility against *S. albipennis* infestation. The seed midge infestation during both the years on different varieties of fennel was categorized on the basis of formula $\bar{X} \pm \sigma$. The categorization of varieties indicated RF-145 as least susceptible, whereas, RF-125, RF-143, RF-178, RF-205 and local cultivar grouped as moderately susceptible. Variety RF-101 was found extremely susceptible. Singh and Baswana (1984) screened 88 different coriander varieties/cultivars against the infestation of *S. albipennis* and reported that none of the variety/cultivar was found immune. They further revealed that the incidence ranged from 5.84 to 23.75 per cent (season's average), the highest

being on JCO-32 and the minimum on DH-13 fully support the present findings. Likewise, Kalra and Sharma (2001) screened different fennel cultivars/varieties against seed midge, *S. albipennis* and reported entry JF-192 least susceptible with seven per cent seed damage. Similarly, Kalra (2003) observed fennel cultivar UF-178 as most susceptible whereas cv. HF-33 proved least susceptible. The present results are also tally with the earlier findings of Patil (2009) who screened 10 coriander variety/cultivars for their relative susceptibility against *S. albipennis* and found none of them immune.

5.4.2.2 Incidence of seed midge *vis - a - vis* morphological characters and oil content in different fennel varieties

5.4.2.2.1 Morphological characters

To establish the relationship of different fennel varieties and seed midge damage, the morphological characters *viz.*, days to 50 per cent flowering, plant height, colour of flowers and seeds per umbel were recorded. The time taken for 50 per cent flowering ($r = 0.068$) was positively correlated with seed midge damage. The minimum seed midge damage (12.31%) was harboured in variety RF-145 and took 111.20 days for 50 per cent flowering, whereas, RF-101 took 115.26 days for 50 per cent flowering and harboured maximum (17.70%) seed midge damage. The plant height ($r = -0.278$) was negatively correlated with seed midge damage and the mean plant height of different fennel varieties varied from 106.26 to 143.20 cm. The variety RF-145 had highest plant height (143.20 cm) and registered lowest seed midge damage (12.31%) whereas, RF-101 had a plant height of 130.10 cm with maximum seed midge damage (17.70%). The maximum seed midge damage was recorded in yellow coloured flowers variety *i.e.* RF-101 and least damage on light yellow coloured flowers variety RF-145. The seeds per umbel varied from 205.20 to 485.33 seeds and were negatively correlated ($r = -0.513$) with seed midge damage. The highest number of seeds per umbel (485.33) was recorded in variety RF-145 but had lowest damage (12.31%). The lowest number of seeds per umbel (205.20) was registered in local cultivar with 14.65 per cent seed midge damage. However, no such information on morphological characters of fennel crop infested by *S.*

albipennis is presently available in literature, hence result could not be compared with the findings of the earlier workers.

5.4.2.2.2 Oil content

The oil content in different fennel varieties were estimated using standard method *vide supra* 3.2.3.2.2 (A). The oil content in different fennel varieties varied from 1.65 to 2.90 per cent and was significant negatively correlated ($r = -0.758$) with seed midge damage. The oil content was highest (2.90%) in variety RF-145 with lowest seed midge damage (12.31%) and such figures were lowest (1.65%) in variety RF-101 with highest seed midge damage (17.70%). The result showed that the oil content in fennel varieties significantly decreased with increase in seed midge infestation. The results on this aspect could not be compared in want of work done by earlier workers.

5.4.3 Efficacy of the insecticides/biopesticides against *S. albipennis*

In order to evaluate the effectiveness of any insecticides for the management of insect pests on specific crop, different criterion could be used. In the present investigations, the following criteria were taken into consideration for successful evaluation of insecticides/biopesticides against seed midge, *S. albipennis* infesting fennel crop.

1. Effect of insecticides/biopesticides application on the per cent seed midge damage
2. Effect of insecticides/biopesticides application on the seed yield of fennel,
3. Assessment of losses caused by *S. albipennis* and economics of insecticides/biopesticides treatments.

5.4.3.1 Effect of insecticides/biopesticides application on the per cent seed midge damage

In the present investigations, the treatment of NSKE (5.0%) was found to be most effective against *S. albipennis* followed by abamectin (0.5 ml/l) and ahook (1ml/l). The next effective treatments in decreasing order were

spinosad (0.01%) and karanj seed extract (5.0%). The treatment of cartap hydrochloride (0.05%) and malathion (0.05%) proved to be least effective.

In the present study minimum seed midge damage of 2.35 per cent was recorded from the treatment of NSKE (5.0%) followed by abamectin (0.5ml/l) and ahook (1ml/l) which exhibited 2.80 and 3.46 per cent seed midge damage respectively. Kant *et al.* (2011) evaluated different pesticides against *S. albipennis* infesting coriander and found NSKE (5.0%) most effective resulting maximum protection against *S. albipennis* with 2.20 per cent seed damage and ranked first in order of efficacy very well support the present findings.

The data revealed that the treatment of spinosad (0.01%) and karanj seed extract (5.0%) were moderately effective against *S. albipennis* and resulted in 4.52 and 4.55 per cent seed damage respectively. The present observations are in close conformity with the findings of Patil (2009) who reported spinosad (0.01%) in medium order of effectiveness against *S. albipennis* infesting coriander crop at Jobner.

The maximum seed midge damage was recorded in the treatments of malathion (8.59%) followed by cartap hydrochloride (7.19%) and proved least effective get partial support from the findings of Mittal and Butani (1995) who observed that applications of parathion-methyl and endosulfan at the flowering stage of fennel minimized the infestation of *S. albipennis* under Gujarat conditions. On the other hand Kant *et al.* (2011) evaluated different synthetic insecticides against *S. albipennis* infesting coriander and found quinalphos least effective giving minimum protection against the pest with 10.50 per cent seed damage support the present findings as malathion recorded a damage of 8.95 per cent, however, both being contact and stomach poisons.

5.4.3.2 Effect of insecticides/biopesticides on the seed yield of fennel

The data showed that all the plots treated with insecticides/biopesticides gave significantly higher seed yield over untreated check. The maximum seed yields of 15.43 q ha⁻¹ was recorded in the plots treated with NSKE followed by abamectin (14.63 q ha⁻¹) and ahook (14.27 q ha⁻¹) and were comparable to each other and proved significantly superior over rest of the treatments. The

moderately effective treatments were spinosad (14.00 q ha⁻¹) and karanj seed extract (13.79 q ha⁻¹). However, non-significant difference existed between them and both were also comparable with abamectin and achook. The minimum seed yield was obtained in plots treated with malathion (12.45 q ha⁻¹) followed by cartap hydrochloride (12.28 q ha⁻¹) and proved least effective with non significant difference.

The present findings are more or less close to the observations of Kant *et al.* (2011) who reported that maximum yield of coriander was recorded in the treatment of NSKE (5.0%) and karanj seed powder (5.0%) against the pest *S. albipennis*.

5.4.3.3 Assessment of losses caused by *S. albipennis* and economics of insecticides/biopesticides treatments

While judging the utility of any insecticides in the pest management programme, it is not only evaluated by its relative potency against the target pest and the period for which its application provided protection to the crop, but the economics of treatments also remain a major consideration. Hence, the benefit cost ratio was also worked out in the present investigations.

The results indicated that treatment of NSKE recorded total avoidable and per cent avoidable losses as zero over untreated check. It was followed by abamectin and achook where total avoidable losses were 0.8 and 1.16 q ha⁻¹ with per cent avoidable losses over untreated check as 5.18 and 7.52 per cent. The treatments of spinosad and karanj seed extract resulted into a total avoidable losses of 1.43 and 1.64 q ha⁻¹ with per cent avoidable losses of 9.27 and 10.63 per cent respectively. The maximum avoidable loss (5.05 q ha⁻¹) and per cent avoidable loss (32.73%) was recorded in untreated check followed by cartap hydrochloride and malathion with corresponding figures of 2.98 and 3.15 q ha⁻¹ and 19.31 and 20.14 per cent respectively.

The maximum total increase in yield over untreated check (5.05 q ha⁻¹) was also recorded in the plots treated with NSKE with 48.65 per cent increase in yield over untreated check. It was followed by the treatments of abamectin and achook with total increase in yield as 4.25 and 3.89 q ha⁻¹ and 40.94 and

37.48 per cent. The minimum total increase in yield over untreated check (1.90 q ha⁻¹) and per cent increase in yield over untreated check (18.30%) were recorded in the treatment of malathion followed by cartap hydrochloride where such figures were 2.07 q ha⁻¹ and 19.94 per cent respectively. The treatments of spinosad and karanj seed extract recorded a total increase in yield as 3.62 and 3.41 q ha⁻¹ and per cent increase in yield as 34.87 and 32.85 per cent respectively.

The pooled data revealed that the maximum net profit (Rs. 25335.00) was recorded in the treatment of NSKE followed by the treatments of achook and abamectin with corresponding figures of Rs. 20115.00 and Rs. 19158.20 respectively. The other treatments *viz*, karanj seed extract, malathion and cartap hydrochloride recorded the net profit of Rs. 15915.00, Rs. 9328.00 and Rs. 8844.20 respectively. On contrary a loss of Rs. 51050.00 was incurred in the plots treated with spinosad.

Perusal of pooled data revealed maximum benefit cost ratio (15.71) in the treatment of achook followed by the treatments of NSKE, malathion and karanj seed extract where corresponding figures were 10.38, 8.31 and 5.60 respectively. The minimum benefit cost ratio (3.48) was recorded in the treatment of cartap hydrochloride followed by abamectin (4.54), while gains could not be attained in spinosad (B:C ratio = -0.71). The present observations are in conformity with the findings of Patil (2009) who recorded maximum avoidable losses in untreated check of coriander infested by *S. albipennis*. The maximum and minimum benefit : cost ratios were obtained in the treatment of endosulfan and neem oil. The negative benefit : cost ratio was obtained in spinosad due to high cost of the insecticide. However, no such information on benefit : cost ratio in case of fennel crop infested by *S. albipennis* is presently available in literature, hence result could not be compared with the findings of the earlier workers.

6. Summary and Conclusion

The present investigations entitled “Management of seed midge, *Systole albipennis* Walker infesting fennel, *Foeniculum vulgare* Miller” were conducted during 2011-12 and 2012-13 at Agronomy farm and in the laboratory, Department of Entomology, S.K.N. College of Agriculture, Jobner (Rajasthan) with the following objectives :

- (vi) To survey the infestation level of seed midge, *Systole albipennis* Walker infesting fennel.
- (vii) To study the seasonal incidence of *S. albipennis* on fennel in relation to weather parameters.
- (viii) To estimate the quantitative and qualitative losses in fennel crop.
- (ix) To manage the *S. albipennis* using IPM tools.
- (x) To estimate the residue of effective insecticides.

Surveys were conducted at farmer's fields in Sirohi, Nagaur and Dausa districts of Rajasthan for estimating the per cent infestation caused by seed midge, *S. albipennis* in fennel crop. The maximum infestation of the pest (19.04%) was recorded in Degana tehsil followed by Nagaur tehsil (16.89%) of Nagaur district. The minimum infestation (12.23%) was found in Reodar tehsil of Sirohi district followed by 15.54 per cent in Lalsot tehsil of Dausa district during both the year.

The infestation of the seed midge commenced in the last week of March (13 SMW) during 2011-12 and first week of April (14 SMW) during 2012-13 and continued upto crop harvest *i.e.* first week of May (18 SMW) during both the years. The infestation gradually increased and reached to maximum in the first week of May (15.50 and 17.50%) during 2011-12 and 2012-13 respectively. The maximum and minimum temperatures and the average relative humidity had non-significant correlation with regards to seed midge damage during 2011-12. A positively significant correlation was observed between seed midge damage and maximum and minimum temperatures but such correlation was

negatively significant with average relative humidity during 2012-13. However, total rainfall showed non-significant correlation during both the years.

A parasitic wasp, *Tetrastichus* sp. was reported to parasitized seed midge, *S. albipennis* under field conditions. The incidence of *Tetrastichus* sp. commenced in the third week of April and continued upto crop harvest during both the years. The parasitic wasp laid egg (generally one or two) in the seeds already infested by *S. albipennis* and developed into adult which emerged out of the seed by boring a hole in the seed wall. It was worthy to mention that the hole on seed wall made by *S. albipennis* was comparatively larger in size as compared to hole made by *Tetrastichus* sp.

The quantity losses *i.e.* infestation of seed midge damage and seed yield in treated plots in fennel crop were 1.98 per cent and 15.08 q h⁻¹, while in untreated plots these figure were 16.69 per cent and 10.13 q h⁻¹ respectively.

The oil content (2.70%) was recorded in healthy seeds as compared to damaged seeds (1.65%). 38.88 per cent reduction in oil content of fennel seeds was recorded as a result of the infestation of the pest.

The carbohydrate content recorded in healthy and damage seeds were 42.25 and 35.75 per cent respectively. A reduction of 15.38 per cent in carbohydrate content of fennel seeds was observed. The protein content recorded in healthy seeds was 9.45 per cent as compared to damaged seeds (10.10%). However, protein content of fennel seeds increased upto 5.82 per cent.

The germination percentage in healthy seeds was recorded to be 92.25 per cent, while it was 67.50 per cent in damaged seeds. Germination of fennel seeds decreased upto 26.83 per cent due to the infestation of *S. albipennis*.

The data on the impact of variations in the time of sowing indicated a definite increasing trend on the incidence of seed midge in fennel crop with the delay in sowing times but had inverse relationship with seed yield during both the years. The minimum seed midge damage (6.29%) was recorded from crop sown on 6th October followed by crop sown on 13th October. The maximum seed damage (22.42%) was observed in the crop sown on 3rd November during

both the years. The maximum seed yield (10.98 q ha⁻¹) was recorded from 20th October sown crop followed by the crop sown on 27th October. The crop sown after 20th October had drastic reduction in seed yield as a result of increased seed midge infestation.

The sowing dates depicted significant positive correlation with seed midge damage and had negative correlation with the seed yield. However, the seed midge damage was negatively correlated with seed yield of fennel. Sowing dates caused 7.02 per cent variation in seed yield and seed midge damage caused 7.84 per cent variation in seed yield. The fennel crop sown on 20th October in semi-arid region of Rajasthan may be appropriate to minimize the infestation of seed midge, *S. albipennis*.

Seven fennel varieties were screened for their relative susceptibility against *S. albipennis*. The results of two years data indicated that none of the fennel varieties was found completely free from seed midge infestation. The categorization of varieties indicated RF-145 as least susceptible (seed midge damage <13.58%), whereas, RF-125, RF-143, RF-178, RF-205 and local cultivar grouped as moderately susceptible (seed midge damage 13.58 to 16.92%) and the variety RF-101 as highly susceptible (seed midge damage >16.92%).

The morphological characters and oil content of different fennel varieties were observed to find out their relationship with seed midge damage. The time taken for 50 per cent flowering was positively correlated with seed midge damage. The minimum seed midge damage was harboured by variety RF-145 and took 111.20 days for 50 per cent flowering, whereas, RF-101 took 115.26 days for 50 per cent flowering and registered maximum seed midge damage. The plant height was negatively correlated with seed midge damage and variety RF-145 had highest plant height (143.20 cm) and registered lowest seed midge damage whereas, RF-101 had a plant height of 130.10 cm with maximum seed midge damage. The maximum seed midge damage was recorded in variety with yellow colour flowers *i.e.* RF-101 and least damage in light yellow coloured flowers variety RF-145. The seeds per umbel varied from

205.20 to 485.33 seeds and were negatively correlated with seed midge damage.

The oil content varied from 1.65 to 2.90 per cent and had a significant negatively correlation with seed midge damage. The highest oil content (2.90%) was recorded in variety RF-145 having lowest seed midge damage (12.31%). The lowest oil content (1.65%) was recorded in variety RF-101 with highest seed midge damage (17.70%).

The relative efficacy of seven insecticides/biopesticides *viz.*, NSKE (5.0%), ahook (1 ml/l), karanj seed extract (5.0%), spinosad (0.01%), malathion (0.05%), abamectin (0.5 ml/l) and cartap hydrochloride (0.05%) were evaluated against the infestation of seed midge, *S. albipennis* under field conditions. The minimum seed midge damage (2.35%) was recorded from the treatment of NSKE followed by abamectin and ahook which exhibited 2.80 and 3.46 per cent seed midge damage respectively and proved superior over rest of the treatments. The treatments of spinosad and karanj seed extract remained moderately effective. The maximum seed midge damage (8.59%) was recorded in the treatments of malathion followed by cartap hydrochloride and proved least effective.

The maximum seed yields of 15.43 q ha⁻¹ was recorded in the plots treated with NSKE followed by abamectin (14.63 q ha⁻¹) and ahook (14.27 q ha⁻¹). The minimum seed yield (12.45 q ha⁻¹) was obtained in plots treated with malathion.

The maximum avoidable loss (5.05 q ha⁻¹) and per cent avoidable loss (32.73%) was recorded in untreated check followed by cartap hydrochloride and malathion with corresponding figures of 2.98 and 3.15 q ha⁻¹ and 19.31 and 20.14 per cent respectively. The total avoidable and per cent avoidable losses were zero over untreated check in the treatment of NSKE. The maximum total increase in yield over untreated check (5.05 q ha⁻¹) was also recorded in the plots treated with NSKE with 48.65 per cent increase in yield over untreated check. It was followed by the treatments of abamectin and ahook with total increase in yield as 4.25 and 3.89 q ha⁻¹ and 40.94 and 37.48

per cent respectively. The minimum total increase in yield over untreated check (1.90 q ha^{-1}) and per cent increase in yield over untreated check (18.30%) were recorded in the treatment of malathion.

The maximum net profit (Rs. 25335.00) was recorded in the treatment of NSKE followed by the treatments of ahook and abamectin with corresponding figures of Rs. 20115.00 and Rs. 19158.20 respectively. On contrary a loss of Rs. 51050.00 was incurred in the plots treated with spinosad. The maximum benefit cost ratio (15.71) was observed in the treatment of ahook followed by the treatments of NSKE (10.38), malathion (8.31) and karanj seed extract (5.60). The minimum benefit cost ratio (3.48) was in the treatment of cartap hydrochloride, while gains could not be attained in spinosad (B:C ratio = -0.71).

CONCLUSION

- The field surveys indicated maximum infestation of seed midge, *S. albipennis* in Degana tehsil of Nagaur district and minimum in Reodar tehsil of Sirohi district.
- The infestation of the pest commenced in the last week of March during 2011-12 and first week of April during 2012-13 and continued upto the first week of May during both the years. The infestation gradually increased and reached to maximum in the first week of May. The maximum and minimum temperatures and the average relative humidity had non-significant correlation with regards to seed midge damage during 2011-12. A positively significant correlation was observed between seed midge damage and maximum and minimum temperatures but such correlation was negatively significant with average relative humidity during 2012-13. However, total rainfall showed non-significant correlation during both the years.
- A parasitic wasp, *Tetrastichus* sp. was reported to parasitized seed midge, *S. albipennis* under field conditions. The incidence of *Tetrastichus* sp. commenced in the third week of April and continued upto crop harvest during both the years.
- The quantity losses *i.e.* infestation of seed midge damage and seed yield in treated plots in fennel crop were 1.98 per cent and 15.08 q h⁻¹, while in untreated plots these figure were 16.69 per cent and 10.13 q h⁻¹ respectively.
- A reduction in oil and carbohydrate contents of fennel seeds was recorded. Protein content of fennel seeds increased upto 5.82 per cent. The germination percentage of fennel seeds decreased as a result of the infestation of *S. albipennis*.
- The minimum seed midge damage was recorded from crop sown on 6th October and maximum from 3rd November sown crop. The maximum seed yield was recorded from 20th October sown crop.

- Out of seven fennel varieties screened variety RF-145 proved as least susceptible, whereas, RF-125, RF-143, RF-178, RF-205 and local cultivar grouped as moderately susceptible and RF-101 was found extremely susceptible.
- The time taken for 50 per cent flowering was positively correlated, while plant height was negatively correlated with seed midge damage. The maximum seed midge damage was recorded in variety with yellow colour flowers and least damage in light yellow coloured flowers variety. The seeds per umbel were negatively correlated with seed midge damage. The oil content in different fennel varieties had significant negatively correlation with seed midge damage.
- NSKE (5.0%) was found to be most effective whereas cartap hydrochloride (0.05%) and malathion (0.05%) proved least effective.
- The maximum benefit cost ratio (15.71) was observed in the treatment of achook. The minimum benefit cost ratio (3.48) was recorded in the treatment of cartap hydrochloride, while gains could not be attained in spinosad (B:C ratio = -0.71).

Literature cited

- Agrawal, V. K.; Sharma, S. L.; Rajput, S. S. and Sharma, B. M. 2004. New record of seed midge fly (*Systole albipennis* Walker) on fennel from Rajasthan. *National seminar on new perspectives in commercial cultivation, processing and marketing of seed spices and medicinal plants*. Rajasthan Agricultural University, Campus – Jobner, pp. 74.
- Anonymous, 1991. Fourteen annual reports. All India Co-ordinated Spices and Cashewnut Improvement Project. University Bikaner campus- Jobner, 1990-91, pp. 6.
- Anonymous, 2011-12. Rajasthan Agriculture Statistics at a Glance. Directorate of Agriculture, Rajasthan, Jaipur, pp. 120.
- Anonymous, 2012-13. Area and production statistics of Arecanut and Spices. Directorate of Arecanut and Spices Development (Department of Agriculture and Cooperation) Ministry of Agriculture, GOI, Calicut, pp. 67.
- AOAC, 1970. "Official Methods of Analysis". Association of Official Analytical Chemist, Washington, D.C. 20044.
- *Bamborot, L.; Paredes, F.R.; Arretz, P.; Guerrero, M.A. and Araya, J.E. 1993. Distribution of *Systole coriandri* (Gussakovsky) (Hymenoptera: Eurytomidae) and evaluation of damage to the seeds of coriander, *Coriandrum sativum* L. (Umbellifera), in Chile. *Acta Entomologica Chilena*, 18: 97-99.
- Baswana, K.S.; Pandita, M.L. and Sharma, S.S. 1989. Response of coriander to dates of planting and row spacing. *Indian Journal of Agronomy*, 34 : 355-357.

- Batra, H.N.; Subba Rao, B.R. and Bhatia, S.K. 1959. A new record of phytophagous chalcidoid in fennel seed in India. *Current Science*, 28: 451-452.
- *Beltrame, R. and Salto, C. 2000. *Ammi majus* L. and *Foeniculum vulgare* Miller as host for aphids and their natural enemies. *Revista de la Facultad de Agronomia*, 20 : 395-400.
- Bliss, C.I. 1937. Angles corresponding to percentages. *Plant protection*. No. 12, Leningrad.
- Gupta, S.C. 1962. Occurrence of the exembryonate seeds in the umbelliferae. *Current Science*, pp. 203-205.
- Hedge, J.E. and Hofreiter, B.T. 1962. *Carbohydrate Chemistry* 17 (Eds Whistler, R.L. and Be Miller, J.N.) Academic Press, New York.
- Jat, B.L. 1993. Varietal susceptibility and control of insect-pests of fennel (*Foeniculum vulgare* Mill.). M. Sc. (Ag.) Thesis, Submitted to Rajasthan Agricultural University, Bikaner.
- Jhala, R.C.; Patel, B.D. and Bharpoda, T.M. 1998. Ovicidal and adulticidal efficacy of various plant extracts against red spider mite, *Tetranychus cinnabarinus* on okra. *Proceeding of the Seminar on Entomology in 21st Century*, 30th April to 2nd May, 1988. *Entomological Research Association*, RCA, Udaipur, pp.- 44-46.
- Kalra, V. K. 2003. Annual Report (2002-2003). Department of Entomology, CCSHAU, Hisar.
- Kalra, V. K. 2006. Insect pests of seed spice crops and their management, pp. 136-142. In: *Emerging Trend in Economic Entomology* (Eds.) Chhillar B. S., Saini, R. K. and Roshan Lal Center of Advanced Studies, Department of Entomology, HAU, Hisar.

- Kalra, V. K. 2007. Advances in Integrated pest management of seed spices (Coriander, Cumin, Fenugreek, Fennel), pp. 130-136. In: *Advances in the Integrated Pest Management of Horticultural, Spices and Plantation crops*, (Eds.) Chhillar B. S., Kalra, V. K., Sharma, S. S. and Singh, R., Center of Advanced Studies, Department of Entomology, HAU, Hisar.
- Kalra, V. K. and Sharma, S. S. 2001. Annual Report (2000-01). Department of Entomology, CCSHAU, Hisar.
- Kant, K.; Sharma, Y.K.; Meena, S.R.; Meena, S.S. and Mehta, R.S. 2011. Management of seed wasp, *Systole albipennis* Walker (Hymenoptera : Eurytomidae) in coriander. *International Journal of Seed Spices*, 1: 53-55.
- Kanwat, P.M. 1988. Studies on insect-pests of fennel (*Foeniculum vulgare* L.) and their control. Ph. D. Thesis, Rajasthan Agricultural University, Bikaner.
- Kashyap, R.K.; Choudhary, O.P. and Thakral, K.K. 1994. Influence of management practices on the incidence of *Systole albipennis* Walker in fennel (*Foeniculum vulgare* Mill.). *Journal of Spices and Aromatic Crops*, 3 : 124-129.
- Khare, D. and Bhale, M.S. 2000. Seed technology. Scientific publishers (India) P.O. Box. 91. Jodhpur, pp. 260.
- Kogan, K. 1982. Plant resistance in pest management. In: R.L. Metcalf and W.H. Luckmann (eds), Introduction to Insect Pest Management. John Wiley & Sons, New York, USA, pp. 93-134.
- Kumar, N. and Sagar, P. 1994. Seasonal history and host range of the coriander aphid, *Hydaphis corianderi* (Das.). *Punjab Agricultural University Research Journal*, 31 : 283-284.

- *Lamborot, L.; Paredes, F. R.; Araya, J. E.; Arretz, P. and Guerrero, M.A. 1995. Effects of infestation by *Systole coriandri* (Gussakovsky) (Hymenoptera: Eurytomidae) on the germination and oil content of coriander seeds. *Acta Entomologica Chilena*, 19 : 155-157.
- Mittal, V. P. and Butani, P. G. 1995. Chemical control of seed midge (*Systole albipennis* Walker) infesting stored fennel. *Gujarat Agricultural University Research Journal*, 21 : 189-192.
- Murty, R.A. and Sridhar, V. 2001. Seed Spices and Ayurveda. In Agarwal, S., Sastry, E.V.D. and Sharma, R.K. (Eds.) Seed Spices- Production Quality and Export. Pointer Publishers Jaipur (Rajasthan).
- Nayer, K.K.; Ananthakrishna, T.N. and David, B.V. 1982. General and Applied Entomology. Tata McGraw Hill Publishing Company Ltd., New Delhi. pp. 537.
- *Ostrovskii, N. I. 1940. A bio-chemical method for the determination of the death of the larvae of *Systole coriandri* Nik. after fumigation of seeds. *Bulletin of Plant Protection*, 4 : 53-56.
- Patel, A. J. and Patel, G. M. 2003. Infestation of seed midge (*Systole albipennis*) in fennel (*Foeniculum vulgare* Mill.). *Indian Journal of Applied Entomology*, 17 : 161-162.
- Patel, G. M.; Patel, B.R. and Patel, J.K. 2009. Management of Insect pests in Seed spices, Paper presented at: *National Seminar on Recent Advances in Seed Spices*, CRSS, Jagudan (Gujarat).
- Patel, R. C.; Yadav, D. N.; Dodia, J. F. and Patel, A. R. 1986. On occurrence of *Systole albipennis* Walker (Hymenoptera: Eurytomidae) infesting fennel in Gujarat. *Gujarat Agricultural University Research Journal*, 12: 51-52.

Patil, M.G. 2009. Damage Intensity, Varietal Susceptibility and Management of Coriander Seed Midge, *Systole albipennis* Walker (Hymenoptera: Eurytomidae). M. Sc. Thesis, S.K. Rajasthan Agricultural University, Bikaner.

*Popov, P. 1979. A new pest of fennel. *Rastitelna Zashchita*, 27 : 26.

Pradhan, S. 1964. Assessment of losses caused by insect-pests of crop and estimation of insect population. *Entomology in India*, Entomological Society of India, New Delhi, pp. 17-58.

Pruthi, H.S. 1976. Spices and Condiments. National Book Trust, India, New Delhi, pp.103.

*Ribeiro-dos-Santos, J.H.; Arcanjo-Alves, J.H.; Holanda-Pinho, J.; Pires-Mendes, S.; Farias, S.M.; Mendes-Brito, L. 1996. Revista-de-la-Facultad – de - Agronomia, Universidad – Central – de - Venezuela. 22: 113-19

*Santis, L. D.E.; Lamborot, L.; Guerrero, M. A.; Sureda, A. and Arretz, P. 1989. *Systole albipennis* Walker (Hymenoptera: Eurytomidae) a new species for Chile on wild and cultivated umbellifers. *Acta Entomologica Chilena*, 15: 281-282.

Sastry, E.V.D. and Sharma, R.K. 2001. Status of seed spices research in Rajasthan. In Agarwal, S., Sastry, E.V.D. and Sharma, R.K. (Eds.) Seed Spices- Production Quality and Export. Pointer Publishers Jaipur (Rajasthan), 19-41.

Sehgal, C.B. 1966. Studies relating to seed set and germination in umbellifers. *Proceeding of National Institute of Science, India*, 34: 60-70.

Singh, G. and Baswana, K. S. 1984. Screening of coriander germplasm against chalcid fly (*Systole albipennis* Walker). *Annals of Applied Biology*.104:114-115.

- Singh, M. P. 2008. Integrated pest management in seed spices, pp. 139-148.
In: *Production, Development, Quality and Export of Seed Spices* (Eds.)
Malhotra, S. K. and Vashishtha, B.B. National Research Center on Seed
Spices, Ajmer, Rajasthan.
- Singh, V.; Bhanot, J. P.; Kalra, V. K. 2009. Population build-up of insect-pests
of coriander (*Coriandrum sativum* Linn.) and their natural enemies.
Annals of Agri Bio Research, 14 : 129-134.
- Snell, F.B. and Snell, C.T. 1949. Colorimetric method of analysis. 3rd edition
Vole II D. Vannostrand Co. Inc. Prinction New Jerssy, pp. 814-819.

* Original not seen

**Management of seed midge, *Systole albipennis* Walker
infesting fennel, *Foeniculum vulgare* Miller**

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ABSTRACT

Investigations on “Management of seed midge, *Systole albipennis* Walker infesting fennel, *Foeniculum vulgare* Miller” were conducted at S.K.N. College of Agriculture, Jobner during 2011-12 and 2012-13. The field surveys indicated maximum infestation of seed midge (19.04%) in Degana tehsil of Nagaur district and minimum (12.23%) in Reodar tehsil of Sirohi district.

The infestation of the pest commenced in the last week of March during 2011-12 and first week of April during 2012-13 and continued upto the first week of May during both the years. The infestation gradually increased and reached to maximum in the first week of May. The maximum and minimum temperatures and the average relative humidity had non-significant correlation with regards to seed midge damage during 2011-12. A positively significant correlation was observed between seed midge damage and maximum and minimum temperatures but it was negatively significant with average relative humidity during 2012-13. Total rainfall showed non-significant correlation during both the years.

A parasitic wasp, *Tetrastichus* sp. was reported to parasitize seed midge, *S. albipennis* under field conditions. The incidence of *Tetrastichus* sp. commenced in the third week of April and continued upto crop harvest during both the years.

The quantity losses *i.e.* infestation of seed midge damage and seed yield in treated plots in fennel crop were 1.98 per cent and 15.08 q h⁻¹, while in

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untreated plots these figure were 16.69 per cent and 10.13 q h⁻¹ respectively. A reduction in oil and carbohydrate contents of fennel seeds was recorded. Protein content increased upto 5.82 per cent and the germination percentage of fennel seeds decreased as a result of the infestation of the pest species.

The minimum seed midge damage (6.29%) was recorded from crop sown on 6th October and maximum (22.42%) from 3rd November sown crop. The maximum seed yield (10.98 q ha⁻¹) was recorded from 20th October sown crop.

Out of seven fennel varieties screened variety RF-145 proved as least susceptible, whereas, RF-125, RF-143, RF-178, RF-205 and local cultivar grouped as moderately susceptible and RF-101 was found extremely susceptible. The time taken for 50 per cent flowering was positively correlated, while plant height and seeds per umbel were negatively correlated with seed midge damage. The maximum seed midge damage was recorded in variety with yellow colour flowers. The oil content in different fennel varieties depicted a significantly negative correlation with seed midge damage.

The treatment of NSKE (5.0%) was found to be most effective followed by abamectin (0.5 ml/l) and ahook (1ml/l) against *S. albipennis*. The treatment of cartap hydrochloride (0.05%) and malathion (0.05%) proved to be least effective.

The maximum seed yield (15.43 q ha⁻¹) and net profit (Rs. 25335.00) was recorded in the plots treated with NSKE. The maximum benefit cost ratio (15.71) was observed in the treatment of ahook followed by the treatments of NSKE (10.38).

सौंफ, फोइनीकुलम वलगेयर मिलर में सीड मिज, सिस्टोल अल्बेपेनिस वॉकर
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अनुक्षेपण

‘सौंफ, फोइनीकुलम वलगेयर मिलर में सीड मिज, सिस्टोल अल्बेपेनिस वॉकर का प्रबन्धन’ विषय पर अनुसंधान श्री कर्ण नरेन्द्र कृषि महाविद्यालय, जोबनेर में 2011–12 एवं 2012–13 के दौरान किया गया। प्रक्षेत्र सर्वेक्षण में सीड मिज का अधिकतम प्रकोप (19.04 प्रतिशत) नागौर जिले की डेगाना तहसील में एवं न्यूनतम (12.23 प्रतिशत) सिरोही जिले की रेवदर तहसील में पाया गया।

सीड मिज का प्रकोप 2011–12 के दौरान मार्च के अन्तिम सप्ताह में एवं 2012–13 के दौरान अप्रैल के प्रथम सप्ताह से प्रारम्भ होकर दोनों वर्षों में मई के प्रथम सप्ताह तक रहा। सीड मिज की क्षति धीरे-धीरे बढ़ती गई और मई के प्रथम सप्ताह में चरम सीमा पर पहुँच गई। अधिकतम एवं न्यूनतम तापमान और आपेक्षिक आर्द्रता का 2011–12 में सीड मिज की क्षति के साथ नगण्य सहसम्बन्ध पाया गया। सीड मिज की क्षति का 2012–13 में अधिकतम एवं न्यूनतम तापमान के साथ अर्थपूर्ण सकारात्मक सहसम्बन्ध और आपेक्षिक आर्द्रता के साथ अर्थपूर्ण नकारात्मक सहसम्बन्ध पाया गया। वर्षा के साथ दोनों वर्ष नगण्य सहसम्बन्ध पाया गया।

प्रक्षेत्र परिस्थितियों में सीड मिज पर परजीवी ततैया, *टेट्रास्टीकस* स्पी. परजीवी के रूप में पाया गया। दोनों वर्ष में *टेट्रास्टीकस* स्पी. का प्रकोप अप्रैल के तीसरे सप्ताह से शुरू होकर फसल की कटाई तक रहा।

सीड मिज की वजह से उपचारित व अनुपचारित क्यारियों में मात्रात्मक व उपज में नुकसान क्रमशः 1.98 एवं 16.69 प्रतिशत व 15.08 एवं 10.13 कु. प्रति है. रहा। सौंफ के बीज में तेल और कार्बोहाइड्रेट की मात्रा में कमी दर्ज की गई। सौंफ के बीज में

* विद्यावाचस्पति शोध छात्र, कीट विज्ञान विभाग, श्री कर्ण नरेन्द्र कृषि महाविद्यालय, जोबनेर।

** विद्यावाचस्पति (कृषि) की उपाधि प्राप्ति हेतु, आंशिक पूर्ति के लिए वर्तमान शोध कार्य डॉ. अशोक शर्मा, आचार्य कीट विज्ञान विभाग, श्री कर्ण नरेन्द्र कृषि महाविद्यालय, जोबनेर, (श्री कर्ण नरेन्द्र कृषि विश्वविद्यालय, जोबनेर) के निर्देशन में पूर्ण किया गया।

सिस्टोल अल्बेपेनिस की क्षति से प्रोटीन की मात्रा में 5.82 प्रतिशत तक वृद्धि तथा अंकुरण प्रतिशत में कमी दर्ज हुई।

सीड मिज की न्यूनतम क्षति (6.29 प्रतिशत) 6 अक्टूबर तथा अधिकतम क्षति (22.42 प्रतिशत) 3 नवम्बर को बोई गई फसल में थी। अधिकतम बीज उपज (10.98 कु. प्रति है.) 20 अक्टूबर को बोई गई फसल से अभिलेखित की गई।

सौंफ में *सिस्टोल अल्बेपेनिस* के प्रति प्रजातीय सम्बन्धित सुग्राह्यता ज्ञात करने के लिए बोई गई सात किस्मों में से आर एफ-145 प्रजाति न्यूनतम सुग्राही पाई गई, जबकी आर एफ-125, आर एफ-143, आर एफ-178, आर एफ-205 एवं स्थानीय प्रजाति मध्यम सुग्राही एवं आर एफ-101 अधिकतम सुग्राही पाई गई। सीड मिज की क्षति का पुष्पन हेतु लिए गए 50 प्रतिशत दिन के साथ धनात्मक सहसम्बन्ध जबकि पादप ऊँचाई व बीज प्रति पुष्पछत्र के साथ ऋणात्मक सहसम्बन्ध पाया गया। सीड मिज की अधिकतम क्षति पीले रंग के फूलों की किस्म में दर्ज की गई। सीड मिज की क्षति का विभिन्न सौंफ की किस्मों में तेल की मात्रा के साथ अर्थपूर्ण ऋणात्मक सहसम्बन्ध पाया गया।

एनएसकेई (5 प्रतिशत) का उपचार *सिस्टोल अल्बेपेनिस* के खिलाफ सबसे अधिक प्रभावी सिद्ध हुआ जिसका अनुसरण एबामेक्टीन (0.5 मिली प्रति ली.) एवं अचूक (1 मिली प्रति ली.) के उपचार ने किया। कर्टाप हाइड्रोक्लोराइड (0.05 प्रतिशत) एवं मैलाथियॉन (0.05 प्रतिशत) का उपचार न्यूनतम प्रभावी पाया गया।

अधिकतम बीज उपज (15.43 कु. प्रति है.) व लाभ (रु 25335.00) एनएसकेई के उपचार में पायी गई। अधिकतम लाभ लागत अनुपात (15.71) अचूक के उपचार में पाया गया जिसका अनुसरण एनएसकेई (10.38) ने किया।

Appendix I

Economics of pesticidal treatments on fennel during *rabi*, 2011-12

| S. No. | Pesticides | Conc. (%) / doses | Quantity needed ha⁻¹ in two applications (l/kg) | Rates / kg (Rs.) | Cost of insecticides (Rs) | Cost of labour (Rs)* | Total expenditure |
|---------------|----------------------------|--------------------------|---|-------------------------|----------------------------------|-----------------------------|--------------------------|
| 1. | NSKE | 5.00 | 80.00 | 20 | 1600.00 | 720** | 2320.00 |
| 2. | Achook | 1 ml/l | 1.60 | 450 | 720.00 | 480 | 1200.00 |
| 3. | Karanj seed extract | 5.00 | 80.00 | 25 | 2000.00 | 720** | 2720.00 |
| 4. | Spinosad 2.5 SC | 0.01 | 6.40 | 11000 | 70400.00 | 480 | 70880.00 |
| 5. | Malathion 50 EC | 0.05 | 1.60 | 350 | 560.00 | 480 | 1040.00 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 0.80 | 4571 | 3656.80 | 480 | 4136.80 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 1.60 | 1238 | 1980.80 | 480 | 2460.8 |

* Labour charges @ 120/- per day per labour

** It includes two extra labour for preparation of NSKE and Karanj seed extract

Appendix II

Economics of pesticidal treatments on fennel during *rabi*, 2012-13

| S. No. | Pesticides | Conc. (%) / doses | Quantity needed ha⁻¹ in two applications (l/kg) | Rates / kg (Rs.) | Cost of insecticides (Rs) | Cost of labour (Rs)* | Total expenditure |
|---------------|----------------------------|--------------------------|---|-------------------------|----------------------------------|-----------------------------|--------------------------|
| 1. | NSKE | 5.00 | 80.00 | 20 | 1600.00 | 960** | 2560.00 |
| 2. | Achook | 1 ml/l | 1.60 | 450 | 720.00 | 640 | 1360.00 |
| 3. | Karanj seed extract | 5.00 | 80.00 | 25 | 2000.00 | 960** | 2960.00 |
| 4. | Spinosad 2.5 SC | 0.01 | 6.40 | 11000 | 70400.00 | 640 | 71040.00 |
| 5. | Malathion 50 EC | 0.05 | 1.60 | 350 | 560.00 | 640 | 1200.00 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 0.80 | 4571 | 3656.80 | 640 | 4296.80 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 1.60 | 1238 | 1980.80 | 640 | 2620.80 |

* Labour charges @ 160/- per day per labour

** It includes two extra labour for preparation of NSKE and Karanj seed extract

Appendix III

Economics of pesticidal treatments on fennel during *rabi*, 2011-12 and 2012-13 (pooled)

| S. No. | Pesticides | Conc. (%) / doses | Quantity needed ha ⁻¹ in two applications (l/kg) | Rates / kg (Rs.) | Cost of insecticides (Rs) | Cost of labour (Rs)* | Total expenditure |
|--------|----------------------------|-------------------|---|------------------|---------------------------|----------------------|-------------------|
| 1. | NSKE | 5.00 | 80.00 | 20 | 1600.00 | 840** | 2440.00 |
| 2. | Achook | 1 ml/l | 1.60 | 450 | 720.00 | 560 | 1280.00 |
| 3. | Karanj seed extract | 5.00 | 80.00 | 25 | 2000.00 | 840** | 2840.00 |
| 4. | Spinosad 2.5 SC | 0.01 | 6.40 | 11000 | 70400.00 | 560 | 70960.00 |
| 5. | Malathion 50 EC | 0.05 | 1.60 | 350 | 560.00 | 560 | 1122.00 |
| 6. | Abamectin 1.9 EC | 0.5 ml/l | 0.80 | 4571 | 3656.80 | 560 | 4216.80 |
| 7. | Cartap hydrochloride 50 SP | 0.05 | 1.60 | 1238 | 1980.80 | 560 | 2540.80 |

* Labour charges @ 140/- per day per labour

** It includes two extra labour for preparation of NSKE and Karanj seed extract