

BIO-ECOLOGY AND MANAGEMENT OF KEY PESTS OF SAFFLOWER

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M. Sc. (Agri)

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THESIS
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2000

AFFENCTIONATELY DEDICATED

TO MY BELOVED PARENTS

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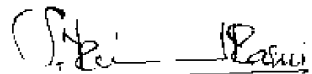

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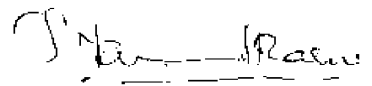

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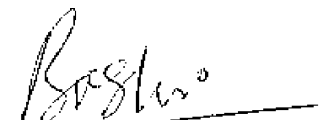

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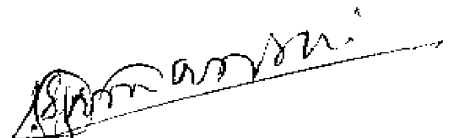
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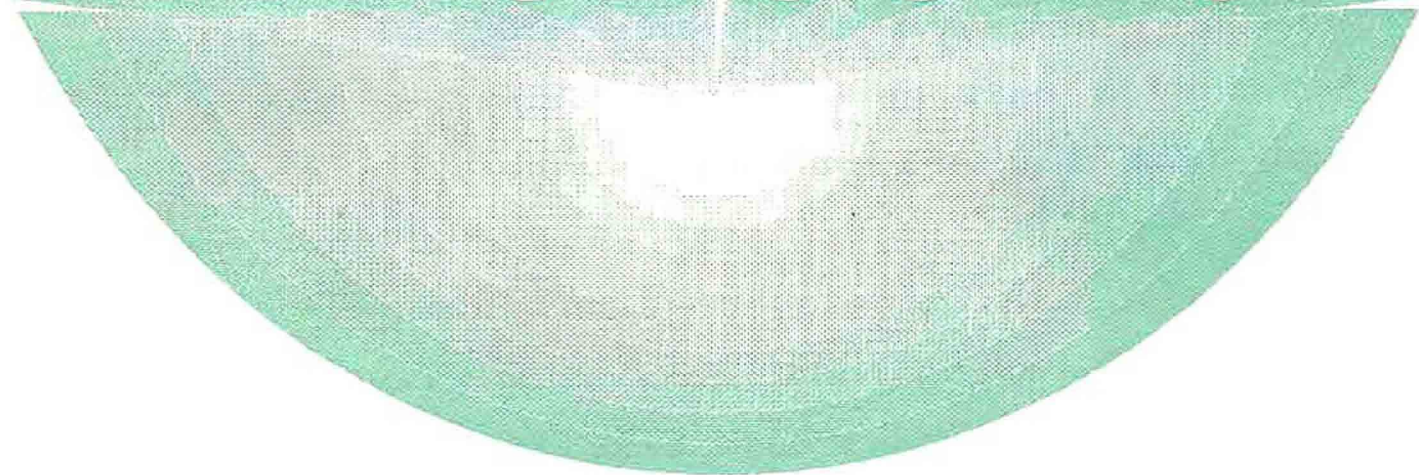
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ABBREVIATIONS

Av.	average
C.D.	critical difference
cm	centimeter
et al.	and others
Fig.	figure
ha	hectare
hr	hour
i.e.	that is
kg	kilogram
km	kilometer
lit.	litre
m	meter
mm	millimeter
ml	millilitre
No.	number
%	per cent
ppm	parts per million
RH	relative humidity
S.E.	standard error
Temp.	temperature
Viz.	namely

INTRODUCTION



Chapter-I

INTRODUCTION

Safflower, *Carthamus tinctorius* Linn. is one of the important oilseed crops cultivated in India in rabi season on an area of 7.93 lakh hectares occupying about 75 per cent of the world acreage with an annual production of 5.21 lakh tonnes (Anonymous, 1995).

Maharashtra is one of the most important safflower growing states in India followed by Karnataka and Andhra Pradesh. In Maharashtra, Safflower is cultivated as a major rabi oilseed crop over an area of about 5.84 lakh hectares with annual production of 3.98 lakh tonnes (Anonymous, 1995).

Though, India occupies first position in area in the world under this crop, the per hectare yield of 421 kg is very low as compared with those of USA (1485 kg/ha) and Mexico (1026 kg/ha) (FAO, 1992). Among the various factors, the insect pests are the major one responsible for the lower yield of safflower crop. The crop is attacked by about 25 insect pests in India. Important ones are viz., safflower fly, *Melanagromyza* spp. safflower Caterpillar *Perigoea capensis* (G.), gram pod borer, *Helicoverpa armigera* (Hub.) and safflower aphid, *Uroleucon sonchi* (Linn.)

Extensive damage by aphids has been reported from all safflower growing areas. Both nymph and adult stages cause heavy losses. In case of severe infestation, the plants are completely covered with aphids and give blackish appearance. Both the stages viz., the nymph and adult suck the cell sap from young shoot, leaves and flowers of the plants resulting in stunted growth causing considerable reduction in the yield of safflower seed and also oil content of seed. Besides, aphids excrete honeydew like substance on the leaves, which promotes the growth of sooty mold and thus hampers the photosynthetic activity of the plant.

The losses to the extent of 36.05 per cent in the seed yield of safflower have been reported by Bhumannavar and Thontadarya (1977). Affected plants do not bear flowers in several cases which cause yield loss to the extent of 60 to 80 per cent (Narayana, 1961). Suryawanshi and Pawar (1980) have reported 57.49 per cent loss in seed yield of safflower in Marathwada region. Foliar sprays of insecticides have been reported to protect the crop against the aphids (Bindra and Rathore, 1967; Sachan, 1967 and Puri and Garshin, 1978).

Recently, the emphasis is being laid on ecological basis of control based on suitable integrated pest management strategies. Studies on population dynamics

helps in planning need based application of insecticides as it clearly reveals the insect peak activity as well as insect free periods during crop growth. The climatic factors such as temperature, rainfall and humidity, usually act in a density independent manner influencing insects to a greater or lesser extent depending on the situation (Kisimoto and Dyck, 1976).

Many insecticides have been recommended for the control of safflower aphid. The commonly used insecticides are carbaryl 50 WP as dust formulation and diamethoate 30 EC, endosulphan 35 EC, thiometon 25 EC and acephate 75 SP as spray formulation against this pest (Anonymous, 1992). But injudicious and indiscriminate use of pesticides has created the problems like environmental pollution, insecticidal resistance, pesticidal hazards, resurgence owing to the destruction of natural enemies besides their objectionable residues in commodities. Therefore, there is growing awareness to search upon the effective, environmentally safe and eco-friendly alternative to insecticides. In this context the plant origin insecticides find a wide scope and safe use in agriculture. They have little or no toxic effect on livestock and hazards of body fat. Further more development of resistance by insect to such bioproducts has not so far been reported. It is therefore, evident even in this age of advancing chemical industries that such botanicals

deserve attention. Hence the plant originated insecticides have been used in the present investigation for the control of safflower pest complex.

Screening of various varieties of safflower is essential for multiple resistance to insect pests and diseases. Incidence of *Uroleucon sonchi* Linn. on 51 varieties showed that in general aphids preferred those varieties without spines on their branches, most susceptible to infestation was T-65 and least susceptible was JL 28-1 (Jagtap et al., 1985). Studies on understanding the sources and mechanism of pest resistance helps to develop resistant varieties, which will not need costly insecticides. In safflower, economic returns are less and marginal farmers cannot offer to spend on pesticides.

The information on bioecology and management of key pests of safflower is negligible . Keeping this view in mind, the present investigations were undertaken with the following objectives.

- i) To study the influence of weather parameters on the population fluctuation of safflower pest complex.
- ii) To assess the losses in the yield of safflower due to safflower pest complex
- iii) To manage safflower pest complex through botanical insecticides.
- iv) To screen the various varieties of safflower for aphid resistance.

REVIEW OF LITERATURE



Chapter-II

REVIEW OF LITERATURE

The literature pertaining to the present investigations has been reviewed and is presented in this chapter under the following heads.

- 2.1 Population dynamics of pests of safflower.
- 2.2 Assessment of losses due to safflower pest complex.
- 2.3 Management of safflower pest complex through botanical insecticides.
- 2.4 Screening of various varieties of safflower for resistance to aphid.
- 2.1 Population dynamics of pests of safflower
- 2.1.1 Aphids

Trehan and Hallepanawar (1949) noticed that during the early stages of the safflower in November, the pest aphid, *Macrosiphum jaceace* appears and later on increases considerably reaching to a peak about a week or two before the plants develop flower buds which commence during the last week of December or the first week of January when the average temperature in 1946-47 were 79.0°C maximum and 66.5°C minimum with 68.2 per cent relative humidity.

Chavan (1960) noted that the aphids were serious on safflower during December to February.

Narayanan (1961) reported during the early stage of crop growth. The pest, *Uroleucon compositae* appeared and later on incidence increased considerably reaching a peak about a week or two before the plants develop flower buds which commenced during the last week of December or the first week of January, when the average temperature was 26.0°C with 68.2 per cent relative humidity.

Wu and Kao (1964) observed that the infestation of *Macrosiphum gobonis* (*Dactynotus compositae* Theo.) on safflower lasted from 10th June to 10th September. The average temperatures in the beginning and at the end were 19°C and 16°C respectively. Population density was maximum from 20th July to 10th August when the temperature ranged from 22°C to 26°C. They also observed that the aphids left the plants when the average temperature fell below 15°C.

Bindra and Rathore (1967) stated that in Madhya Pradesh, *Dactynotus compositae* Theo. was active on safflower from early December to the end of April. Both, apterous and alate forms were present throughout the period.

Dorge and Ajri (1967) reported that the pest *Uroleucon compositae* was active on safflower from November-December in Maharashtra State and revealed that the incidence of the aphids was very low on the safflower crops sown from the first September to the 15th October.

Bishop (1974) reported that the various components of environment act not only in determining the number of individuals in a population but also as the agents of natural selection to cause evolutionary change in the individuals. He thought that models should be based more on ecological data.

Klomp (1974) studied the population dynamics, a key to the understanding of integrated control. The population dynamics is thought to aim at providing an understanding of the causation of fluctuation in population density and of the determination of population level by feed back mechanism.

Lanjewar (1976) recorded that the population of aphids, *Dactynotus compositae* on safflower developed rapidly and reached to its peak before the plants developed flower buds. The population had come down as summer approaches with high temperatures. Sudden decline in the population of aphids was recorded when maximum and minimum temperatures were 37°C and 18.7°C respectively with 61 per cent relative humidity during the first week of April.

Bhumannawar and Thontadarya (1979) reported that the aphid, *Dactynotus compositae* occurred throughout the year on safflower when the crop was made available. Heavy population build up on the October sown crop as high as 7827 aphids per plant were noticed on nine weeks old crop in 1974-75 and 5605 aphids per plant on 11 weeks old crop

in 1975-76. This peak population reached during the months of December and January and gradually reduced thereafter

Firke (1980) noticed that the aphids made their first appearance on the safflower crop in the first week of December. Further build up in the population took place depending upon the stage of the crop. The highest incidence was found in the month of January, when the minimum and maximum temperatures were 9.9 to 13.5°C and 27.4 to 29.0°C respectively and relative humidity 70 to 83 per cent. With increase in temperature coupled with decrease in humidity and by the middle of February, no aphids were found on the crop.

Upadhyay et al. (1980) investigated the seasonal occurrence of safflower aphids, *Uroleucon carthami* (HRL) in relation to the weather conditions in Rajasthan. The aphids were first noticed in leaf whorls during the first week of December after which their number increased reaching a peak between mid January and mid February. Aphid population declined and the pest disappeared by the end of March. The maximum aphid population was observed at temperature of 17°C and a relative humidity of 66.67 per cent. The population showed a sharp decline with an increase in temperature and fall in relative humidity. Thus, the increase in aphid population was negatively correlated with temperature and positively correlated with relative humidity.

Rathore (1983) reported that the aphid remains active on safflower crop generally from December-January to March-April (Crop maturity). The decrease in temperature and increase in humidity from December to February provide a long period of congenial cool humid weather for the pest multiplication. The aphid reached the peak density during December-January at Phaltan (M.S.), mid January to mid February at Udaipur (Rajasthan) and mid March at Jabalpur (M.P.). The most favourable maximum and minimum temperatures and relative humidity being about 33.5°C, 15.3°C and 44.2 per cent respectively at the last locality. The pest population declined with the rise in temperature and fall in humidity and ultimately disappeared with the crop maturity i.e. in the IIIrd week of April when the maximum temperature of 40.8°C, minimum temperature of 22.1°C and relative humidity of 24.9 per cent were observed at Jabalpur. The aphid population (particularly the alate forms) was more during the drought year.

Upadhyay et al. (1983) observed the seasonal incidence of *Uroleucon compositae* and its coccinellid predators on safflower. They found that populations of *Uroleucon compositae* rose to a high level in January and February when temperatures fell and relative humidities increased and underwent a sharp decline when temperatures rose and relative humidities fell in March. Populations of the *Predacious coccinellids*, *Coccinella septempunctata* and

Fabr.

Menochilus sexmaculatus ↓ appeared in the last week of December, reached a peak on 15th February, then gradually declined.

Bankar (1984) reported that in Maharashtra, the incidence of the aphids on safflower was maximum on the crop sown on 12th November at 70 days after sowing. The aphids made their first appearance on the crop in the first week of December. Further build up in the population took place depending on the stage of the crop. The incidence was found to be maximum in the month of January. The cold (average minimum and maximum temperatures of 12.6°C to 14.9°C and 26.8°C and 28.6°C, respectively) and moderately humid climate (relative humidity 69.3 to 70.5 per cent) prevailing in the months of December and January were congenial for the activity of the pest. With increase in temperature coupled with decrease in humidity and also with advanced age of the crop, the incidence started declining and by the middle of February, no aphids were found on the crop.

Jagtap et al. (1986) noted that *Uroleucon carthami* preferred the top succulent part of the main stem and branches of safflower plant in Maharashtra as compared to other parts.

Bhat et al. (1989) sampled the aphid *Uroleucon compositae* Theobald on safflower. The central shoot was the most suitable followed by the leaves and head to the aphid.

El-Shaikh et al. (1990) studied twenty one species of insect pests belonging to 20 families and 10 orders on safflower. Of the harmful species, aphids, thrips and leaf hoppers were found to be the most abundant. The population densities of the major pests and their host plants are given in the findings.

Pote (1992) reported that the population of aphids reached a maximum peak on fourteen and thirteen weeks old safflower crop in the month of January 1988-89 and 1989-90, respectively. Negatively significant correlations of aphid population with maximum and minimum temperatures were observed, while the relation of aphid population with morning and evening humidity was positively non significant.

Bade and Kadam (1993) investigated the effect of sowing dates and abiotic factors on incidence of safflower aphid, *Uroleucon compositae*. Low incidence of *Uroleucon compositae* was found in September sown safflower while moderate and severe infestation occurred in crops sown between Mid-September to Mid-October. Infestation began in the last week of November 1989, reached a peak in January 1990 and then declined. Average maximum and minimum temperatures during the period of this study were 20.9 and 11.2°C respectively, while morning and evening relative humidities were 73 and 30 per cent respectively. There was a negative significant correlation between aphid population

and minimum temperature. Correlations were negative but non-significant for maximum temperature and morning and evening humidities.

Dubey and Thorat (1994) studied the infestation of aphid on safflower at Akola (Maharashtra) in relation with meteorological factors and found that temperature and relative humidities during earlier two weeks before pest appearance were having negative correlations. The lower temperature and humidities were found congenial for aphid attack.

Akashe *et al.* (1995) reported that the aphid population on safflower was negatively correlated with a number of weather parameters (Maximum and minimum temperature, morning and evening humidity and rainfall). Population build up started at the end of October and reached a peak in the first week of January, when maximum and minimum temperature and morning and evening relative humidity were 31.1°C, 12.9°C, 67 per cent and 39 per cent, respectively.

Gautam *et al.* (1995) reported population dynamics of aphids on safflower Cv. A-300, Nag-7 and No. 7-13-3. Population of *Uroleucon species*, which was first apparent in February, peaked in mid March.

Arya *et al.*, (1996) observed that a safflower crop planted on 13th October, 1990 was infested with a peak population of *Uroleucon compositae* (372 aphids/plant) in

the 12th week of crop growth, when the maximum temperature was 29.4°C and the minimum temperature 16.4°C. Thereafter, the population declined with increasing maximum temperature and decreasing minimum temperature and relative humidity.

2.1.2 Thrips

Weiss and Beshear (1987) sampled the thrips in 1984 and 1985 on safflower plants that had been planted in Montana on 3 dates in April-May. In 1984 *Thrips tabaci* accounted for 57 per cent of the adults collected and *Frankliniella tritici* 42 per cent; the corresponding percentages in 1985 were 52 and 44. Four other species were recorded. Regardless of planting date, *T. tabaci* was the first species detected. Population peaked on 12th and 15th July in the two years, respectively. Populations of *F. tritici* peaked on 2nd and 8th August. It is suggested that *T. tabaci* overwinters in the area, where as *F. tritici* does not.

2.2 Assessment of losses due to safflower pest complex

2.2.1 Techniques and methods in general for assessing crop losses

Several workers have listed various techniques and methods for the assessment of crop losses as listed below (Pradhan, 1964; Judenko, 1965, 1972; Smith, 1967; Strickland and Bardner, 1967 and Veeresh, 1980).

2.2.1.1 Comparison of yields from a mechanically protected pest free crop with a naturally pest infested crop

The ideal method for estimating crop loss would be to compare yields under pest infested and pest free conditions. Attempts were made by several workers to get pest free plots by different methods as indicated below.

a) Cage studies

Cages of great varieties either used to exclude or contain pest infestation (Judenko, 1965), to cover a portion of field or a plant (Smith, 1967), to prevent the oviposition (Raw and Loety, 1957) or to cover the soil to prevent the entrance of insects in to soil (Bardner and Griffiths, 1967).

b) Artificial removal of pests

Hand picking is usually employed to remove the pests from small areas (Judenko, 1938 and Judenko *et al.*, 1952). Prasad (1963) used this method for assessing the loss in cabbage plants by imported cabbage worms *Pieris rapae* L. The same method was adopted by Seshu Reddy (1973) as he estimated the loss in red gram due to *Helicoverpa armigera*.

c) Chemical treatments

Voluminous literature in economic entomology contains many examples of comparisons of treated and untreated insect populations and the effect on crop yield. Indeed, popular techniques of crop loss assessment is by

using pesticides. In this, an effort is made to protect the experimental crop by pest control schedule known for a particular pest and the yield of such crop is compared with the one which has been exposed to normal insect infestation. Though pesticides cannot give true estimates of losses from specific pests, this method has been adopted by several investigators.

Rawat and Deshpande (1970) estimated losses due to *Dactynotus compositae* Theobald in safflower by this method.

Le Clerg (1971) suggested paired plot experiments and multiple treatments experiments to know the increment of loss per unit increase in pest intensity and the competitive or interaction effects of more than one pest on yield loss.

2.2.1.2 Evaluation of damage before and after introduction of a pest into an area

Hunter (1924) and Smith (1959) have used this method for bollweevil and spotted alfalfa aphids, respectively.

2.2.1.3 Comparison of yields from artificially infested crops with pest free crops

Artificial infestation can be established at the different points on a plant (Chiang and Holdaway, 1959), on different dates (Deay et al., 1949; Prasad, 1963) on different sizes of the plant (Deay et al., 1949) and for different length of the time (Ortman and Painter, 1960).

This method was adopted for estimating the losses due to *H. armigera* in sorghum (Buckley and Burkhardt, 1962), *Spodoptera frugiperda* (Smith) on maize (Morril and Greene, 1974), *H. armigera* on red gram (Seshu Reddy, 1973), *Empoasca fabae* on soybean (Ogunlana and Pedigo, 1974) and *Dactynotus compositae* (Theobald) on safflower (Bhumannavar, 1976).

2.2.1.4 Comparison of naturally infested plants with naturally uninfested plants

Pradhan (1964) described that, in this technique, the plants from the same field are examined for the degree of infestation and their individual yields are determined.

Judenko (1972) suggested an analytical method of calculating loss based on comparison of yield from two sets of plants that are precisely identical in all respects except that one is unattacked and the other is attacked by specific pest. The economic loss was computed by the following procedure.

$$\begin{aligned}
 ACT &= \text{Actual yield} \\
 a &= \text{Mean Yield per uninfested plant} \\
 b &= \text{Mean yield per infested plant} \\
 p &= \text{Percentage of plants infested} \\
 c &= \text{coefficient of harmfulness.} \\
 &\quad (a-b) \times 100 \\
 C &= \frac{\quad}{a}
 \end{aligned}$$

The per cent economic loss (L) = $CP/100$

The expected yield in the absence of pest

$$W = \frac{100 (ACT)}{100-L}$$

Economic loss (L) = W-ACT

2.2.1.5 Manipulation of natural enemies

The feasibility of this method is limited by many potential secondary interactions (Smith, 1967).

2.2.1.6 Average amount of damage caused by individual insect

This method is utilised by Pradhan and Peswani (1961) to assess the losses caused by *Hieroglyphus nigrorepletus* (Boliver) in maize and *Plusia orichalcea* F. in cauliflower by Basu and Chatterjee (1969).

2.2.1.7 Subjective estimates of yield loss

Estimation of losses over a large areas are often made from the opinions of farmers and extension workers. This method is useful when damage is heavy.

Although, none of the foregoing methods and techniques of assessing losses gives unequivocal results, estimates of losses can be obtained that are of practical value and that show the benefits of controlling pests.

2.2.2 Assessment of losses due to safflower pest complex

2.2.2.1 Losses due to aphids

Narayana (1961) reported that the plants affected by aphid, (*Dactynotus carthami* HRL) do not bear flowers and in severe cases which cause loss in yield to the tune of 60 to 80 per cent.

Carlson (1972) found that the green peach aphid, *Myzus persicae* (Sulzer); the bean aphid, *Aphis fabae* (Scopoli) and *Aphis helichrysi* (Kaltenbach) occasionally cause economic damage to safflower plants in the Sacramento Valley of California. *M. persicae* and *A. helichrysi* feed primarily on and cause damage to seedling, terminals, developing buds and young seed heads in the spring. These plant parts develop a spotty or mottled yellow coloration (resembling a yellow virus) and can become shrivelled and distorted and loss of seed results. Seed losses upto 32 per cent can occur when *M. persicae* increase to about 20 or more per head for an extended period. Approximately 200 *A. helichrysi* per seed may affect seed production severely. *A. fabae* feeds primarily on the leaves and stems and causes leaf curling and stem distortion in spring and summer. Moderate infestations of 10 or more aphids per leaf or about 500 per plant, can cause enough plant stunting to result in a 69 per cent seed loss. Heavier infestations of about 1500 aphids per plant can destroy the plants.

Karve et al. (1978) reported the losses due to aphids, *Dactynotus carthami* in seed yield in untreated crop of safflower to the tune of 55 per cent as compared to fully protected crop.

Bhumannavar and Thontadarya (1979) took a trial to estimate the loss in safflower due to the aphid, *Dactynotus compositae*. They observed that the extent of reduction in

the seed yield was 36.05 per cent as compared to fully protected crop.

Goud (1980) analysed the damage to safflower crop due to the aphid, *Dactynotus compositae* Theobald at the agriculture college campus, Dharwad and agricultural research station, Annegiri, Karnataka State during rabi 1978. He investigated that feeding by the aphid throughout the crop period was found to result in yield loss of 67.72 per cent; 55.93 per cent and 46.72 per cent in the untreated control over the chemical control, mechanical removal of aphids and cage method respectively.

Suryawanshi and Pawar (1980) reported considerable loss due to safflower aphid in yield contributing characters. They estimated the percentage losses in untreated plots viz., in primary branches 29.26 per cent, secondary branches 28 per cent, plant height 3.17 per cent, number of capitula per plant 32.71 per cent, capitulum diameter 33.64 per cent, seeds per capitulum 26.35 and hundred seed weight 31.42 per cent.

Basavanagoud *et al.* (1981) assessed the losses in safflower due to the aphid, *Uroleucon compositae* at Dharwad during the rabi season of 1978. They recorded that grain losses in untreated plots were 67.72 per cent greater than in plots from which aphids were removed with a brush and 66.72 per cent greater than in plots where the plants were protected by caging. The most reliable of these methods

for estimating yield loss was the mechanical removal of aphids.

Mulavekar (1982) observed significant losses caused indirectly by reduction of number of branches per plant (51.18 per cent), average plant height (23.03 per cent), average number of capitula per plant (55.95 per cent), test weight of 1000 seeds (4.26 per cent) and oil content (14.01 per cent) due to *Uroleucon sonchi* in safflower.

Rathore (1983) estimated the loss in safflower due to aphids and found that the aphid caused the yield loss of about 16, 20 to 25, 35, 55 and 52 to 60 per cent respectively at Kanpur (U.P.), Hyderabad (A.P.), Jabalpur (M.P.), Parbhani (M.S.) and Udaipur (Rajasthan), the all India average being about 37 per cent.

Suryawanshi and Pawar (1983) took a trial in Marathwada to analyse the damage to safflower by *Uroleucon sonchi* in 1977-78 and 1978-79. The pest was controlled with 0.03 per cent diamethoate in plots of safflower and the effects of treatment on the plants and their yields were assessed to determine the losses in untreated plots. They investigated that the number of aphids per leaf in untreated plots averaged 19.3 in the 1st season and 12.12 in the 2nd as compared with 0.0 and 0.7 in treated plots. The corresponding yields of seeds in (kg/ha) were 244 and 325 as compared with 617 and 715.

Ghule et al. (1986) reported the lowest cumulative number of aphids (10.05/plant) in plots applied with fertilizers and full protection and full protection without fertilizer application against the pest with 0.05 per cent diamethoate at weekly interval. They found that the highest seed yield (1441 kg/ha) was obtained when the crop was protected from aphids and was applied with recommended dose of fertilizers. It was 287 kg, 230 kg and 493 kg/ha more than the plots receiving fertilizers only.

Shetgar et al. (1986) reported that the highest yields were obtained from plots treated with diamethoate 0.05 per cent for controlling aphids which represented a 24.20 per cent increase in yield compared with the untreated control.

Narangalkar and Shivapuje (1990) investigated that the percentage losses due to *Uroleucon compositae* in untreated plots in the yield contributing characters viz., primary and secondary branches/plant, plant height, number of capitula/plant, capitulum diameter, seed capitulum and hundred seed weight were 21.13, 23.98, 3.30, 18.06 41.77, 21.02 and 1.98, respectively. The per cent loss in seed yield due to aphid infestation was 30.19 per cent. They also found that due to aphid infestation on safflower, about 389 kg/ha of seed yield was reduced and can be avoided by application of a suitable insecticide.

2.2.2.2 Losses due to thrips

Carlson (1964) investigated that most bronzing and blasting of developing safflower buds are caused by Western flower thrips, *Frankliniella occidentalis* (Pergande) rather than by lygus bugs. Lygus bugs appeared to cause economic damage only when their populations attained levels equivalent to 40 bugs per sweep. Bud loss attributed to these two pests reached a magnitude of 36 to 43 per cent before reduction of seed became of economic importance.

Carlson (1966) revealed that the safflower buds are able to tolerate fairly large numbers of nymphal thrips (*Frankliniella occidentalis*) before the seed yield is reduced significantly. Adult thrips were introduced into small cages covering selected buds (1/4th inch in diameter or less on plants growing in the field. An indirect method of sampling was used to estimate the subsequent build up of the population of nymphs. The tests were set up with initial thrips densities adjusted to an average 5, 10, 20 and 40 adults per head. He recorded that the density of nymphs averaged as high as 75 per bud when 10 adults per bud were introduced into the cages and there was no consequent drop in seed production. Approximately twice as many nymphs per bud developed when initial introductions averaged 20 adults per bud decreased significantly the number of good seed heads produced, the number of seeds per head and the total yield.

2.2.2.3 Losses due to capsule fly

^a
Vishampayan et al. (1970) recorded safflower capsule fly (*Acanthiophilus helianthi* Rossi) as a serious pest of safflower (*Carthamus tinctorius* L.) around Jabalpur, Madhya Pradesh. Detailed investigations during 1967-68 showed that this pest damaged on an average 37.5 per cent $\pm$ 6.20 capsules. The net loss in the yield of seeds was 26.13 per cent taking into consideration the 30.33 per cent recovery of good marketable seeds from the damaged capsules.

Singh et al. (1972) estimated the extent of infestation and damage done by the pest, *Acanthiophilus helianthi* on three safflower varieties. They reported that towards the end of April, when the crop was nearing maturity, the fruits were observed to be heavily attacked by the safflower fly. There was not much difference among the three safflower varieties as far as percentage infestation of fruits by this tephritid fly is concerned. However, the number of infested fruits which contained unattacked safflower seeds was more (110 out of 150) in selection 144 than the varieties 12-1- P2-3 (85) and 7-13-3 (74), resulting there by in higher number of unattacked seeds obtained in the latter two varieties than in selection-144.

Jakhmola and Yadav (1980) studied the incidence of and losses caused by safflower capsule fly, *Acanthiophilus*

helianthi in 12 varieties in 1971-72 and 13 varieties in 1972-73. They reported that the incidence on capsule basis ranged from 62.1 per cent in variety No. 7 to 87.7 per cent in variety No. 25 in 1971-72 and 89.6 per cent in variety No. 6503 to 100 per cent in variety No. 80 in 1972-73. The incidence on grain basis (both partially and completely damaged) ranged from 20.3 per cent in S.F. 5 to 66.4 per cent in No. 80 in 1971-72, out of which 11.1 per cent and 54.2 per cent grains were completely damaged by the pest. In 1972-73, incidence on grains ranged from 38.6 per cent in No. 6503 to 93.2 per cent in No. 80 of which 32.6 per cent and 80.1 per cent grains were completely destroyed respectively. They also investigated that the loss in weight due to both, partial and complete destruction of grains was low in SF-5 in 1971-72 and in No. 6503 in 1972-73. A more accurate estimate of incidence was made on the basis of grains damaged than on the basis of capsules damaged.

2.2.2.4 Losses due to stem fly

Reddy (1957) reported that more damage is done by the maggot of stem fly of safflower to the young crop by killing the entire plants. The loss caused to mature crop is only partial. The activity of fly is more intense from the second week of October to the third week of November declining gradually. Random counting of attacked plants revealed the damage upto 5 per cent.

2.3 Management of safflower pest complex through botanical insecticides

2.3.1 Management with insecticides

2.3.1.1 Management of safflower aphids

Khan and Hussain (1958) tested different organophosphorus insecticides and stated that the control of safflower aphid, *Macrosiphum sonchi* by nicotine sulphate, DDT, and BHC was not complete and new aphids that survived gradually multiply and reinfest the crop necessitating further treatment. Among the insecticides tried, parathion 0.02 per cent, systox 0.021 per cent, metasystox 0.03 per cent and Basudin 0.013 per cent gave 100 per cent kill of distage aphid of safflower within 24 hours. Aphid infestation in case of systox, metasystox and Basudin started a week early than in parathion sprayed plots. It was also observed that the rate of reinfestation and multiplication of aphid was more in Basudin treated plots.

Sarup et al. (1964) tested 20 pesticides against viviparous females of safflower aphid (*Dactynotus carthami*) and determined their relative toxicity. Phorate, phosphamidon, parathion, rotenone, endosulfan, meviphos, carbophenothion, malathion, diazinon, carbaryl and pyrethrin were found to be more toxic than gamma BHC.

Bindra and Rathore (1967) reported that single application of 0.025 per cent phosphamidon, diamethoate or

methyl demeton at the end of January or beginning of February or two sprays of malathion 0.05 per cent at an interval of 10 days during same period reduced the population of *U. sonchi* on safflower.

Sachan (1967) tested parathion 0.02 per cent and 0.03 per cent, metasystox 0.05 per cent and 0.1 per cent, endrin 0.05 per cent and 0.1 per cent and tobacco decoction against safflower aphid (*D. carthami*) and found that parathion, metasystox and endrin were more effective at all concentrations when compared with tobacco decoction.

Carlson (1969) reported that seed yield of safflower increased from 1517 to 2059 lbs per acre by applying 0.5 lbs kg GS 1305 and 1 lbs endosulfan per acre.

Nachane (1971) stated that diamethoate 0.05 per cent was the most effective to control safflower aphid population followed by phosphamidon 0.02 per cent, malathion 0.02 per cent, endosulfan 0.05 per cent and endrin 0.02 per cent.

Bagle (1972) tested relative toxicity of various insecticides and found that phorate, phosphamidon endosulfan, methyl parathion, malathion, carbaryl, lindane, endrin, p'p' DDT and chlordane were effective against safflower aphid (*Dactynotus carthami* HRL).

Carlson (1972) reported that the aphid, *Myzus persicae*, *Aphis fabae* Scop. and *Aphis helichrysi* occasionally caused economic damage to safflower. Studies

were carried out for the control of aphid. Spraying of demeton at the rate of 4 oz. per acre gave fair control of *M. persicae*, spray of oxydemeton methyl at the rate of 8 oz., parathion at 8 oz., demeton 4 to 6 oz., diamethoate at 8 oz. per acre applied when at least 20 per cent plants were moderately infested, gave satisfactory control of *A. fabae*.

Kukade (1972) reported that endosulfan, parathion, malathion and carbaryl were effective in controlling safflower aphid population.

Pande et al. (1974) observed that parathion, endrin, endosulfan, chlordane and BHC were more toxic than DDT. The toxicity of endosulfan, DDT, BHC and parathion as found to be similar in controlling safflower aphid (*Dactynotus carthami*).

Bhagat (1976) studied the efficacy of some important insecticidal dust formulations against safflower aphid (*Dactynotus carthami* HRL) and observed that all treatments were significantly superior over control in bringing down aphid population. The treatment with parathion 2 per cent dust proved best followed by metacid combination (2 per cent methyl parathion + 7.5 per cent DDT), malathion 5 per cent, endosulfan 4 per cent and carbaryl 10 per cent dust in controlling safflower aphid.

Bhumannawar and Thontadarya (1976) tested phosphamidon, dicrotophos, chlorofenviphos, endosulfan

sprays, malathion 5 per cent and endosulfan 4 per cent dust against safflower aphid (*Dactynotus compositae* Theobald). Sprays with phosphamidon 100 EC at 0.25 kg a.i./ha or dicrotophos 24 EC 0.5 kg a.i./ha or dusting with malathion 5 per cent at the rate of 1 kg a.i./ha two times at 20 days interval starting after 60 days of sowing were found significantly superior to other insecticides in reducing the aphid population.

Lanjewar (1976) observed that malathion 0.05 per cent proved to be the most effective in reducing the population of aphid, *Dactynotus carthami* during first application of different insecticides followed by phosphamidon 0.05 per cent, methyl demeton 0.03 per cent, quinalphos 0.05 per cent, endosulfan 0.03 per cent, monocrotophos 0.05 per cent, endrin 0.04 per cent, carbaryl 10 per cent and endosulfan 4 per cent. In general, dust formulations were less effective, however, there were no significant differences amongst spray formulations.

Sarode and Taley (1976) found that the mixture of BHC + carbaryl (10:3), phosalone + malathion (6:10) and BHC + endosulphan + malathion (26:4:5) had indicated synergistic action; the synergism being relatively much higher in the later followed by the first and second. Mixtures of endosulphan + phosphamidon (2:3), endrin + phosphamidon (6:10); quinalphos + malathion (5:6) and phosalone + BHC (1:9) gave independent type of joint

action. Malathion + carbaryl (4:5) and endrin + phosphamidon + carbaryl (4:7:10) mixtures showed antagonistic action and exhibited significantly less toxicity than the component insecticides to the safflower aphid.

Bhumannawar and Thontadarya (1977) tested phosphamidon, dicrotophos, chlorofenvinphos, endosulphan sprays, malathion 5 per cent and endosulphan 4 per cent dust against safflower aphid, *Dactynotus compositae* Theobald. Sprays with phosphamidon 100 EC at 0.25 kg a.i. per hectare or dicrotophos 24 EC at 0.5 kg a.i. per hectare or dusting with malathion 5 per cent at the rate of 1 kg a.i./ha two times at 20 days interval starting after 60 days of sowing were found significantly superior to other insecticides in reducing the aphid population.

Sharma (1979) studied comparative efficacy of endosulfan, phosphamidon, methyl demeton and diamethoate against safflower aphid by aerial spray. Phosphamidon 312.5 ml/ha proved better for controlling the safflower aphid. The other insecticides in their order of decreasing efficacy were endosulfan, diamethoate and methyl demeton.

Deshmukh et al. (1980) reported that the treatment with thiometon 0.05 per cent was found to be most effective and significantly superior to leptophos 0.05 per cent, endosulfan 0.05 per cent, phosalone 0.05 per cent, formothion 0.05 per cent, phenthoate 0.05 per cent and

diamethoate 0.02 per cent in reducing population of safflower aphid (*Dactynotus carthami* HRL). However, carbaryl 0.02 per cent and quinalphos 0.05 per cent was also effective in descending order, and found to be at par with thiometon.

Deshmukh *et al.* (1981) reported that treatment with thiometon 0.05 per cent was found to be most effective and significantly superior to endosulfan 0.05 per cent, diamethoate 0.03 per cent, phosalone 0.05 per cent formothion 0.05 per cent and phenthoate 0.05 per cent in reducing population of *Dactynotus carthami* on safflower. However, carbaryl 0.2 per cent, phosphamidon 0.02 per cent and quinalphos 0.05 per cent were also effective in descending order and were found to be at par with thiometon.

Hasabe and Moholkar (1981) tried to judge the relative efficacy of six systemic insecticides viz., methyl demeton, thiometon, diamethoate, phosphamidon, monocrotophos and menazon as seed dressers against sucking pests of safflower both under laboratory as well as field conditions. They observed that seed treatments with menazon WP, monocrotophos WSC and phosphamidon WSC at all doses proved to be safe as no adverse effect on germination was recorded. However, under field conditions, menazon, monocrotophos and phosphamidon proved to be ineffective in controlling aphids on safflower.



Goud et al. (1982) reported that sprays were relatively more effective than dusts. Sprays retained effectiveness with no or negligible aphids population build up on safflower even 15 days after application, but the effect of dust being more or less ephemeral with aphid population in treated plots reaching almost the same proportion as pre-treatment numbers. Considering the cost of insecticides per hectare, carbaryl 0.5 per cent was found to be best followed by fenitrothion 0.5 per cent, endosulfan 0.5 per cent and phosalone 0.05 per cent sprays.

Rathore and Pathak (1982) took a field trial to determine the effectiveness of sprays containing 0.025 per cent demeton-methyl, 0.04 per cent monocrotophos, 0.03 per cent diamethoate, 0.035 per cent phosalone and 0.025 per cent quinalphos against *Uroleucon compositae* on safflower. They reported that demeton-methyl at 250 ml a.i./ha was the most effective compound followed by monocrotophos at 400 ml a.i./ha and diamethoate at 300 ml a.i./ha. Treatment with demeton-methyl also resulted in the highest seed yield and appeared to be selective to the coccinellid predators, *Menochilus sekmaculatus*, *Coccinella septempunctata* and *Brumus suturalis*.

Chaudhary et al. (1983) studied various insecticides viz., quinalphos 0.03 per cent, endosulfan 0.065 per cent, monocrotophos 0.04 per cent, diamethoate 0.03 per cent, formothion 0.03 per cent and phosalone 0.04

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per cent and found that all the insecticides were equally effective against *Uroleucon compositae* upto 20 days after treatment.

Kushwala (1983) reported that aphid, *Uroleucon compositae* Theobald is a major pest of safflower and effectively controlled by methyl demeton, diamethoate, monocrotophos and quinalphos at the rate of 500 ml (0.05 per cent) per hectare.

Adsul (1985) studied the efficacy of some new carbamate insecticides against safflower aphid, *Dactynotus sonchi* (L.) and observed that oncol 0.07 per cent was the most effective followed by endosulfan 0.05 per cent, diamethoate 0.03 per cent, etrofolan 0.07 per cent and butacarboxim 0.07 per cent.

Budhraj et al. (1985) observed that BPMC, MIPC, metasystox, UC-51762 and 3 formulations of carbaryl were highly toxic to *Dactynotus sonchi* on safflower. The mortality observed with these insecticides was 70 to 100 per cent.

Dhoble et al. (1985) reported that dust formulations containing 4 % malathion, 1.5 % quinalphos or 5 % carbaryl or endosulfan (all at 20 kg/ha) significantly reduced aphid populations on safflower. Insecticides are less beneficial if applied in dust rather than spray formulations.

Gargav and Verma (1985) studied the efficacy of methyl demeton (demeton-S-methyl) at 0.025 per cent, monocrotophos at 0.04 per cent, phosalone at 0.035 per cent, phosphamidon at 0.030 per cent and cabaryl at 0.150 per cent a.i./ha against the aphid, *Uroleucon compositae* (Theob.) on safflower and found that the aphid population on the treated plots was significantly lower than the control for the whole of the experimental period. Within 24 hours of treatment, demeton-S-methyl, monocrotophos and phosphamidon were more effective than carbaryl and phosalone, but after 72 hours all the treatments were comparable. Treatments of demeton-S-methyl and phosphamidon gave the highest yields in 1977-78 and 1978-79, respectively.

Jagdale et al. (1985) studied the efficacy of some insecticides against safflower aphid, *Macrosiphum compositae* (*Uroleucon compositae*) and found that all the sprays gave significant reduction of the aphid with 0.5 per cent thiometon or endosulfan being slightly but not significantly superior to the rest 24 and 48 hours after application.

Lokare et al. (1985b) observed that phosphamidon 85 WSC at the rate of 102 g a.i./ha was superior over all other treatments in reducing safflower aphids, but was at par with the treatments butocarboxim 250 and 350 g a.i./ha. Regarding yields also, phosphamidon was superior over the

remaining treatments, but at par with butocarboxim 350 g a.i./ha and endosulfan 245 g a.i./ha.

Rathore and Pathak (1985) studied the effectiveness of sprays containing 0.025 per cent demeton-methyl, 0.04 per cent monocrotophos, 0.03 per cent diamethoate, 0.035 per cent phosphone and 0.025 per cent quinalphos against *Uroleucon compositae* on safflower and found that demeton-methyl at 250 ml a.i./ha was the most effective compound, followed by monocrotophos at 400 ml a.i./ha and diamethoate at 300 ml a.i./ha. Treatment with demeton-methyl also resulted in the highest seed yield and appeared to be selective to the coccinellid predator.

Pawar et al. (1987b) studied the bio-efficacy of cypermethrin at 0.0003, 0.0005 and 0.01 per cent against *Dactynotus sonchi* (*Uroleucon sonchi* Theob.) on safflower and compared with endosulfan at 0.05 per cent and phosphamidon at 0.02 per cent. Cypermethrin at 0.01 per cent was the most effective treatment, with the highest incremental cost-benefit ratio of 1:28.

Singh and Dhamdhare (1987) studied the persistence and toxicity of 9 insecticides viz., 0.015 per cent permethrin, 0.09 per cent cypermethrin, 0.02 per cent fenvalerate, 0.0025 per cent deltamethrin, 0.36 per cent monocrotophos, 0.04 per cent phosphamidon 0.04 per cent thiometon, 0.04 per cent diamethoate and 0.03 per cent methyl demeton (demeton-S-methyl) for the control of the

aphid, *D. carthami* (*U. carhtami*) on safflower and found that all treatments significantly reduced the aphid population. Phosphmidon was the most effective followed by demeton-S-methyl, diamethoate, monocrotophos and permethrin, while thiometon was the least effective.

Singh et al. (1988) evaluated the efficacy of endosulfan 35 EC, diamethoate 30 EC, phosphamidon 85 WSC and neem seed powder against *Uroleucon carthami* on safflower and found that two sprays of endosulfan at the rate of 800 ml or diamethoate at the rate of 750 ml/ha at fortnightly interval gave the most effective control.

Chandrakar and Gupta (1989) evaluated 9 insecticides for their efficacy against safflower aphid (*Uroleucon compositae* Theobald) and found that methyl demeton spray applied at the rate of 1000 ml/ha proved to be the best in reducing the aphid incidence followed by monocrotophos, diamethoate and phosphamidon which were at par. Highest yield was recorded in the methyl demeton treatment (14.43 q/ha) followed by phosphamidon (11.77 q/ha) and monocrotophos (11.50 q/ha). The benefit cost ratio was also the highest in methyl demeton (9.9) followed by phosphamidon (7.4) and diamethoate (5.7).

Dhurve et al. (1993) studied the comparative efficacy of some modern insecticides against aphids (*Dactynotus carthami*) on safflower. They found that carbaryl was the most effective treatment against the same

on safflower, followed by 0.3 per cent diamethoate, 0.05 per cent endosulfan, 0.05 per cent quinalphos, 0.05 per cent thiometon, 0.03 per cent monocrotophos, 0.05 per cent formothion, 0.05 per cent phenthoate and 0.05 per cent phosalone.

Singh and Sircar (1995) studied the susceptibility of safflower aphid, *Dactynotus carthami* to some commonly used insecticides. They tested seven insecticides as contact Poison against the viviparous adult of safflower aphid, *Dactynotus carthami* HRL; out of which five insecticides viz., phosphamidon, endosulphan, malathion, carbaryl and pyrethrins proved to be more toxic and p'p' DDT less toxic than gamma BHC. The order of toxicity of these insecticides was also determined against three other species of aphids viz., *Aphis craccivora*, *Aphis gossypii* and *Lipaphis erysimi*. They observed that phosphamidon proved to be most effective followed by endosulfan, malathion and lindane respectively against the above pests. Relative resistance was highest for *D. carthami* vis-a-vis *L. erysimi* with majority of the insecticides tested except endosulphan. Endosulphan was found to be most effective against safflower aphid, *D. carthami* as well as safest against the aphid predator, *Coccinella septempunctata* and honey bee, *Apis cerana*.

Dange et al. (1996) evaluated 9 insecticides for their relative efficacy against safflower aphid, *U.*

compositae Theobald. These insecticides were diamethoate (0.03 %), phosphamidon (0.02 %), monocrotophos (0.04 %), neemark (0.5 %), indiara (1.00 %), chinmix (0.003 %), fluvalinate (0.003 %), lambda-cyhalothrin (0.003 %), quinalphos (0.05 %) and carbaryl (0.1 %). All the insecticidal treatments were found to be significantly superior over untreated control. The average population of aphids was significantly low in the plots treated with monocrotophos 0.04 per cent followed by phosphamidon 0.02 per cent, lambda-cyhalothrin 0.003 per cent, quinalphos 0.05 per cent and diamethoate 0.03 per cent. These insecticides were at par with each other. Considering the overall efficacy of insecticides, it was observed that monocrotophos 0.04 per cent and phosphamidon 0.02 per cent were found to be superior both in reducing aphid infestation and increasing the yield.

Charati and Pawar (1998) evaluated the efficacy of different insecticides against safflower aphids. They found that all insecticidal treatments were significantly superior to untreated control and at par with each other. MIPC 50 % WP @ 0.07 % proved to be the most effective treatment in controlling the safflower aphids followed by chinimix 5 % EC @ 0.01 % and endosulphan 35 EC @ 0.05 %. As regards yield, MIPC 50 % WP @ 0.07 % recorded the highest yield (405 kg/ha) as compared to other treatments.

2.3.1.2 Management of safflower thrips

Carlson and Witt (1977) observed that methidathion and oxydemeton-methyl effectively reduced bud damage from feeding by the Western flower thrips, *Frankliniella occidentalis* (Pergande) and *Lygus hesperus* (Knight) on safflower. Both insecticides at 0.56 kg a.i./ha effectively controlled thrips damage and 2 applications (at prebloom and onset of bloom) were superior to one. Methidathion applied at 0.56 kg and 1.12 kg a.i./ha by aircraft, was more effective in controlling populations of *L. hesperus* than oxydemeton methyl and seed yields were significantly better than in the controls for both dosages. They also reported that residues of methidathion at 0.56 kg a.i./ha after 3 hand or aircraft applications were low and residues of oxydemeton-methyl after 3 hand applications also were low.

2.3.1.3 Management of safflower capsule fly

Jakhmola and Yadav (1983) evaluated the efficacy of insecticides against safflower capsule fly, *Acanthiophilus helianthi* rossi. They investigated that phosphamidon, endosulphan, monocrotophos, dicrotophos, dursban, diamethoate, parathion, vamidothion, methyl demeton, malathion and fenitrothion with 2 applications in 1971-72 and phosphamidon, monocrotophos, dicrotophos, dursban, endosulphan, sevimol and phosvel with 2, 3 and 4 applications in 1972-73 proved significantly better in

reducing the incidence of the fly, *Acanthiophilus helianthi* and increased the grain yield of safflower.

2.3.1.4 Management of *Helicoverpa armigera* and safflower caterpillar, *Perigoea capensis*

Jha et al. (1997) studied the effects of sowing date and treatment with 0.025 % methyl-demeton on *Trichoplusia urichalcea*, *Perigoea capensis* and *Helicoverpa armigera* on safflower during 1989-90. Plants were sown on 1st and 15th November and 1st and 15th December. They reported that treatment with demeton-s-methyl significantly reduced the population of larvae of *T. orichalcea* but populations of *C. capensis* and *H. armigera* were slightly greater in insecticide treated plots. The greatest mean population of *C. capensis* and *H. armigera* was obtained from plants sown on the 4th date.

2.3.2 Management with botanical insecticides

2.3.2.1 Management of safflower aphids

Devkumar et al. (1986) evaluated hexane extracted oil, deterpenated pure oil, lipid associated limonoids, all derived from fresh neem seeds, limonoidal residues from expeller grade neem oil and groundnut oil in the laboratory against safflower aphid, *Dactynotus carthami* and found that only those compounds containing limonoids were aphicidal. Azadirachtin were found to be highly toxic to *D. carthami*.

Singh et al. (1988a) studied the relative toxicity of the botanical insecticides, pyrethrins, rotenone and

nicotine sulphate to a number of important insect pests in the laboratory and several conventional insecticides were used for comparison. The botanical insecticides were found to be particularly effective against number of insects including larvae of *Euproctis lunata* and the aphid, *Myzus persicae*, *Brevicoryne brassicae*, *Dactynotus carthami* (*Uroleucon carthami*) and *Lipaphis erysimi* and were relatively harmless to the predator, *Coccinella septempunctata*. Rotenone and pyrethrins were found to be 12.288 and 1.908 times respectively more toxic than lindane against safflower aphid, *Dactynotus carthami*.

2.4 Screening of safflower varieties for resistance to aphid

Bhumannavar (1976) found that all the 25 safflower varieties screened were found susceptible. However, all India varieties had less number of aphids per unit area.

Novvab-Gojrati and Zare (1978) screened several varieties of safflower for the relative tolerance to *Tetranychus turkestanii* Ugarov and Nikolski. They found that all the varieties of safflower were lightly infested with mites but did not reach damaging levels during the growing season.

Bhumannavar and Thontadarya (1979) screened 25 varieties of safflower at regional research station, University of agricultural sciences, Dharwad to know the resistance to aphid, if any. They reported that spineless

variety G-1156 recorded the least number of aphids (2990) per plant, while G-929 A, a heavy spiny variety recorded the maximum number of aphids (13225) per plant which was significantly higher than any of the varieties tested. There was no significant difference in the number of aphids per main leaf in varieties G-1286 and G-1266. The mean number of aphids per main leaf in all the indigenous varieties was less (127.74) as compared to the exotic varieties (212.95). They investigated that the aphid density was maximum on most of the spineless varieties as compared to spiny varieties which may be due to the fact that the spineless varieties were more succulent and spiny varieties were more hardy type.

Basavangoud et al. (1980) evaluated the resistance of 232 varieties of safflower to attack by *Uroleucon compositae* in field-plot tests in Annegiri, India in 1978. They found that CTS-7403, a non-spiny variety was the least susceptible and CTS-7205, a heavy spiny variety was the most susceptible, CTS-7403 had higher levels of reducing sugar, total sugars and total phenols and lower levels of amino acid than CTS-7205.

Goud (1980) screened twenty two varieties of safflower for their reaction to the aphid. He recorded that the mean number of aphids per plant ranged from 1527.67 to 9138.50 in all the varieties. Non-spiny variety, CTS-7403 was found to be resistant recording least

number of aphids per plant (1527.67), where as heavy spiny variety CTS-7205 was found to be susceptible recording maximum number of aphids per plant (9138.50).

Rathore and Pathak (1982) evaluated 20 varieties of safflower for aphid resistance. They investigated that only 2 varieties were identified as highly resistant, 12 as moderately resistant, 4 moderately susceptible and 2 highly susceptible to aphid, *Uroleucon compositae*. On an average, all the varieties had 1.64 times more aphid population and 11.12 times less yield due to severe drought and late sowing. Use of highly resistant varieties like JL-35-5 and moderately resistant high yielding ones like N-62-8 and JSF-1 was a suitable component of Integrated aphid management.

Rathore and Pathak (1983) observed that earlier the crop sown, longer the duration of it's escape from aphid, lesser the pest incidence and more was it grown up to tolerate the pest damage. They found that JSF-1 was significantly the least while JSF-2 was the most susceptible variety to aphid (1.88 times less population in former than later). Relatively resistant varieties JL 35-5 and JSF-1 did not need aphicide when sown upto November 6 and 21 respectively, while the most susceptible JSF-2 required pesticidal umbrella even when sown earlier.

Samelo (1983) evaluated the responses of 9 varieties of safflower to infestation by *Dactynotus*

carthami in relation to several characteristics of the plants. He observed that S-144 suffered the lowest infestation and gave the highest yield. The second best yield was obtained from the susceptible variety V-83.

Deokar et al. (1984) tested 450 cultivars of safflower grown with or without normal plant protection treatments showed that untreated plots became infested by *Macrosiphum carthami* (*Uroleucon carthami*) in 50-90 days, with 5 grades of infestation (upto 10, 11-20, 21-40, 41-60 and 61-90 aphids/2.5 cm stem) that were reflected in yield reduction. Comparison of these results in varieties with non-spiny, moderately spiny and very spiny stems showed that aphid incidence was negatively and yield positively correlated with plant spininess. It was therefore suggested that selection should be made for a more spiny character in safflower varieties, susceptible to *U. carthami*.

Jagtap et al. (1985b) observed the incidence of *Uroleucon carthami* on 51 varieties of safflower. They recorded that in general aphids preferred those varieties without spines on their branches. Most susceptible to infestation was T-65, while JL-28-1 was the least susceptible (28.89 per cent).

Naik (1987) screened 17 promising safflower varieties under irrigated conditions and reported that none of the varieties was resistant to aphids. However, variety

WA-300 and Tara showed the lowest aphid population as compared to standard check N-62-8.

Akashe *et al.* (1993a) screened safflower gemrplasm accessions against reaction to aphids. They investigated that the GMU Nos. 181, 300, 421, 589, 632, 1183, 1406 and 5-14-2B had consistantly 2 grades for drying of foliage with comparatively higher grain yield levels. They also found that the entries GMU-138 and 174 had 1 grade for drying of foliage in 1989-90, however, it was 3 in 1988-89 which indicated inconsistancy in drying of foliage due to aphids. Apart from the number of aphids / 10 cm apical twig and drying of foliage, all these entries yielded comparatively high grain yield which needs agronomic experimentation and exploitation of tolerance in the high yielding released varieties.

Akashe *et al.* (1993b) studied the qualitative and quantitative characters of many entries of safflower and revealed that the most of the spiny and white flowered entries were more resistant to aphids which may be due to non-preference mechanism whereas all non-spiny entries were susceptible because of their more succulent nature of plant type.

Akashe *et al.* (1994) evaluated promising safflower entries for multiple resistance to insect pests and diseases under three different sowing dates and found that general higher yields were produced by early and normal

sowing as compared to late sowing. Comparatively lower aphid population intensity was observed on early and normal sowing date crops than on late sowing date crops. They also observed that, the aphid population was high as compared to standard control Bhima in all the entries except NS-1021-1 in early sowing and SSFF-145 and PI-306983 in normal sowing. The aphid tolerant entries were less affected by foliage drying than the *Alternaria carthami* tolerant group indicating susceptibility of disease tolerant entries against aphid due to their non-spiny plant type. Four aphid tolerant entries (PK 306983, PK 307077, SSF-40 and GMU-1251) and two *A. carthami* tolerant entries (GMU-822 and GMU-1824) were tolerant of both, aphids and alternaria.

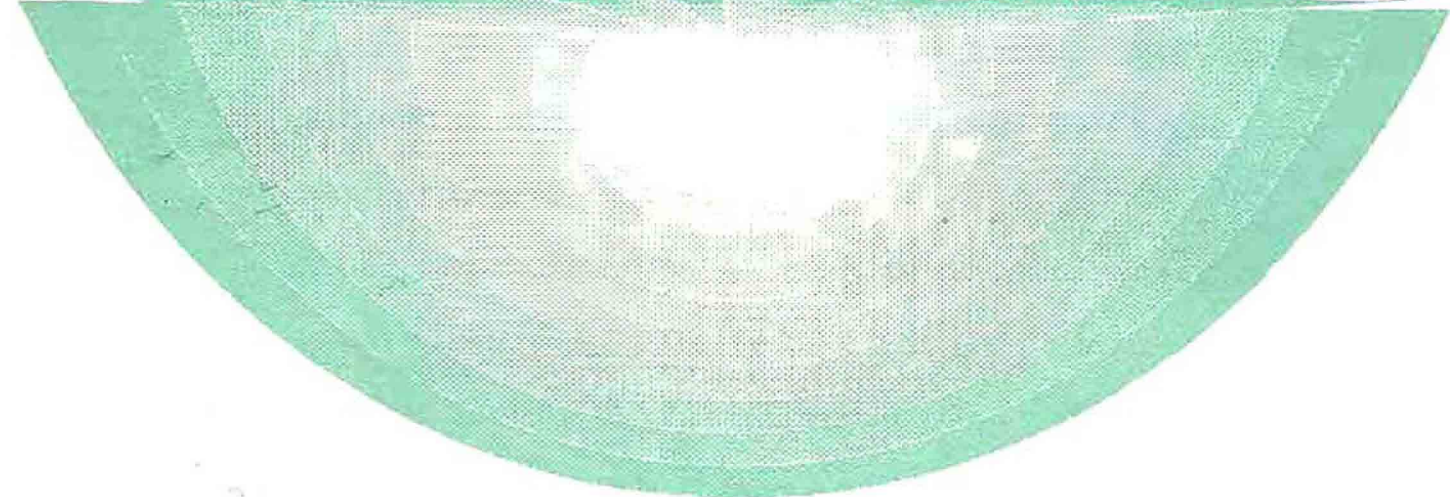
Balakrishnan and Venkateswara Rao (1994) evaluated gemrplasm collections of safflower for morphological characters and its association with reaction to aphid infestation and found that bushy and cone shaped plant types were showing more degree of tolerance than appressed and erect plant types. Plant types with many or intermediate number of spines on upper stem leaves and outer involucral bracts (OIB) showed better tolerance to aphids than those with no spines or only a few spines. Long and moderate length of spines on OIB were associated with better tolerance and aphid infestation than those of short spines or no spines on OIB. They also observed that

plant types with fleshy upper leaves were more susceptible than those with normal and leathery leaves. Susceptible reaction to infestation of aphids resulted in reduction in number of capitula per plant and yield per plant. Early physiological maturity was closely associated with tolerance to aphid infestation.

Akashe et al. (1996) reassessed 16 promising safflower entries against aphids including Tara and Sharda and reported that out of these cultivars, GMU-174, 178, 1630, 5130, 5133, 5142 and PPI 307077 were promising aphid tolerant sources, which can be exploited in breeding programme to develop high yielding varieties with tolerance to aphids.

Dhembare (1998) evaluated the performance of 23 safflower entries against aphids. Out of these varieties tested, the entries 16-4, NS-5, NS-1021-1 and PI 199915 were found to be tolerant sources against safflower aphid.

MATERIALS AND METHODS



Chapter III

MATERIALS AND METHODS

Field experiments were conducted to study the population dynamics of different pests of safflower, to assess the losses caused to safflower crop due to pest complex, to evaluate the efficacy of botanical insecticides against the pest complex of safflower and to screen the various varieties of safflower for aphid resistance during rabi seasons of 1998-99 and 1999-2000. The materials used and the methods adopted are described in this chapter.

3.1 Experimental site

The experiments were conducted in rabi seasons of 1998-99 and 1999-2000, at the Horticultural Research Scheme, Marathwada Agricultural University, Parbhani. The site was uniform with typical black cotton soil having medium fertility and drainage.

3.2 Weather condition

Parbhani is situated at 408.50 meters above the mean sea level and has subtropical climate. It lies between 19°-20° North latitude and 76° East longitude. The meteorological data viz., temperature, humidity, rainfall etc. during entire crop growth were collected at the meteorological observatory of Marathwada Agricultural .pn48

University, Parbhani are presented in Appendix-I and Appendix-II which was used for statistical analysis.

3.3. Experimental design

3.3.1 Population dynamics of pests of safflower

The experiment was laid out on an area of 10 m x 5 m plot which was kept unprotected throughout. The variety PBNS-10 was sown on 4th November in 1998 and 27th October in 1999.

3.3.2 Assessment of losses due to safflower pest complex

The experiment was conducted in a factorial randomised block design with two safflower varieties and four treatments under rainfed conditions. Thus, the experiment had eight treatment combinations replicated four times. The factors under study were

1. Two safflower varieties

V₁ CO-1 (Aphid susceptible)

V₂ Lats₁ (Aphid tolerant)

2. Four spray treatments

T₁ Protected during vegetative stage.

T₂ Protected during reproductive stage.

T₃ Protected throughout growth period.

T₄ Unprotected throughout growth period.

The gross plot size was 2.5 x 5 m and net plot size was 2.05 x 4.55 m. Spacing adopted was 45 x 20 cm. The experiment was sown on 4th November in 1998 and on 27th October in 1999.

3.3.2.1 Technique adopted for assessment of crop losses

Popular technique of crop loss assessment by using pesticides as per Le Clerg (1971) was followed with modification in design to suit the requirements of the present experiment. He adopted a paired plot technique which involves a comparison of yields of the plots in each of several replications where the plants of one plot are protected from pest by an appropriate pesticide, whereas the plants of the other plot are allowed to damage by naturally occurring population of the same pest. The same method is used in present investigations with some modification i.e. Instead of adopting paired plot, factorial randomised block design was used to calculate the losses due to safflower pest complex in two safflower varieties.

3.3.2.2 Application of treatments.

In this experiment, insecticides were applied as per the plant protection schedule. In the treatment T_1 , the crop was protected during vegetative stage by treating the crop with systemic insecticide i.e. methyl demeton (0.05 per cent). In the treatment T_2 , the crop was protected during reproductive stage by using contact insecticide i.e. Endosulphan (0.05 per cent). In T_3 , the crop was kept unsprayed throughout growth period to assess the losses due to sucking pest complex. In T_4 , the crop was

protected throughout growth stage by using recommended plant protection schedule i.e. methyl demeton (0.05 per cent) (Anonymous, 1998).

3.3.3 Management of safflower pest complex through botanical insecticides

The experiment was laid out in randomised block design with ten treatments each replicated thrice. The gross plot size was 2.25 x 5.0 m and net plot size was 2.05 x 4.55 m. Row to row and plant to plant distance was 45 cm and 20 cm respectively. The 'PBNS-10' variety of safflower was used. In order to avoid the pesticidal drift, a distance of one meter between two replications and 0.75 m. between adjacent treatments was maintained. The experiment was sown on 4th November in 1998 and 27th October in 1999. The experiment consisted of following treatments.

T ₁	Nimbicidin	0.5 per cent	(05 ml/lit.)
T ₂	Bioneem	0.3 Per cent	(03 ml/lit.)
T ₃	Neem oil	3.0 per cent	(30 ml/lit.)
T ₄	Castor oil	1.0 per cent	(10 ml/lit.)
T ₅	Neemark	1.0 per cent	(10 ml/lit.)
T ₆	Neemgold	0.5 per cent	(05 ml/lit.)
T ₇	Methyl demeton	0.05 per cent	(1.5 ml/lit.)
T ₈	Thiamethoxam	0.01 per cent	(0.63 gm/lit.)
T ₉	Endosulphan	0.05 per cent	(1.5 ml/lit.)
T ₁₀	Untreated control		

3.3.3.1 Application of treatments

The first treatment spray against safflower pest complex was given at 40th day after sowing and the subsequent sprays were administered at 10 days interval. In all four sprays were given. While spraying, tarpolin screen was used between each plot to avoid the drift of chemicals from one treatment to another. The sprayings were given by using Marut foot sprayer. The detail information regarding insecticides viz., Names of the insecticides, concentration used and source of supply is given in Table 1.

3.3.4 Screening of various varieties of safflower for aphid resistance

Entries, PBNS-51, PBNS-10, CTV₃₀ X Lats₁, A₁ X 19-185, CO-1, HUS-305, S₄ x Lats₂, A₁, Lats₂, PSF₁₄, Sel-4, Set-48, Sharda, GMU-7868, PBNS-12, PBNS-11, GMU-7047, F₄F₅ NO. 62, LASF-29 and GMU-1787 were tested for their reaction to aphid. Each variety was grown in 10m independent line. The experiment was sown on 4th November in 1998 and 27th October in 1999.

3.4 Cultural operations

The selected field was kept fallow during the kharif season. It was ploughed once and harrowed twice before sowing. One weeding was done to keep the plots free from wseeds. The fertilizer dose was applied @ 60 kg N, 40 kg P₂O₅ and 40 kg K₂O per hectare. Half dose of Nitrogen

and full dose of phosphorus and potash was applied as a basal dose. Remaining half dose of 'N' was applied one month after sowing as top dressing. In all, two irrigations were given. The first irrigation was given as presowing irrigation and the second was given after one month of sowing.

3.5 Relationship between weather parameters and aphid population

Meteorological data on weekly basis were collected from Department of Meteorology, Marathwada Agricultural University, Parbhani. Correlation and multiple regression between aphid incidence and weather parameters were worked out. In addition, path coefficient analysis was performed to understand the direct and indirect contributions of environmental correlation with aphid population.

3.6 Methods of recording observations

3.6.1 Population dynamics of pests of safflower

The population of aphids and thrips was recorded at weekly interval on 5 cm terminal shoot length throughout the crop season. The number of *Helicoverpa armigera* and safflower caterpillar was recorded on the leaves till capsule formation and then *Helicoverpa* larvae were counted on capsule. The pest population was counted on twenty randomly selected plants.

3.6.2 Assessment of losses due to safflower pest complex

The observations were recorded one month after sowing till the harvesting stage of the crop at an interval of seven days. Observations were recorded on number of aphids, thrips, *Helicoverpa armigera* and safflower caterpillar on twenty randomly selected plants in each replication. In case of aphids, observations were made on 5 cm terminal length of the shoot throughout the crop season.

3.6.3 Management of safflower pest complex through botanical insecticides

Observations were recorded on number of aphids and the per cent infestations of aphids on shoots on five randomly selected plants from each treatment plot, seven days after each spraying. Observations were also recorded on incidence of other pests. From the above randomly selected plants, observations on other biometrical parameters such as plant height, primary branches, secondary branches and yield and yield contributing characters viz., number of capsules per plant, diameter of capsule, number of seeds per capsule and yield per plot were recorded. All the biometrical observations were recorded at weekly interval. Harvesting and threshing of each plot was done separately. The weight of safflower seed from each plot was recorded separately and from this yield in kg per hectare was calculated.

3.6.4 Screening of various varieties of safflower for resistance to aphid

Observations on number of aphids, thrips, *Helicoverpa armigera* and safflower caterpillar were recorded on five randomly selected plants at weekly interval, from the date of appearance of pest till harvest of the crop. Damage rating of aphid was worked out as suggested by All India Co-ordinated Research Project on Safflower (Anonymous, 1996). Observations were also recorded on morphological parameters of various cultivars tested for studying their reaction against aphid.

3.7 Statistical analysis

The data on the population of aphid, thrip, *Helicoverpa armigera* and safflower caterpillar were analysed statistically after transforming the value using poison formula,

$$\sqrt{X + 0.5}$$

Where 'X' = average number of insects.

The data were statistically analysed by standard analysis of variance method (Panse and Sukhatme, 1967). The null hypothesis was tested by 'F' test of significance to know whether the observed treatment effects were significant and the appropriate standard error (S.E.) and critical difference (C.D.) were calculated for comparing the means of treatments.



PLATE-I : *Coccinella septempunctata* predating on safflower aphids



PLATE-II: Lats₁ (aphid tolerant) cultivar



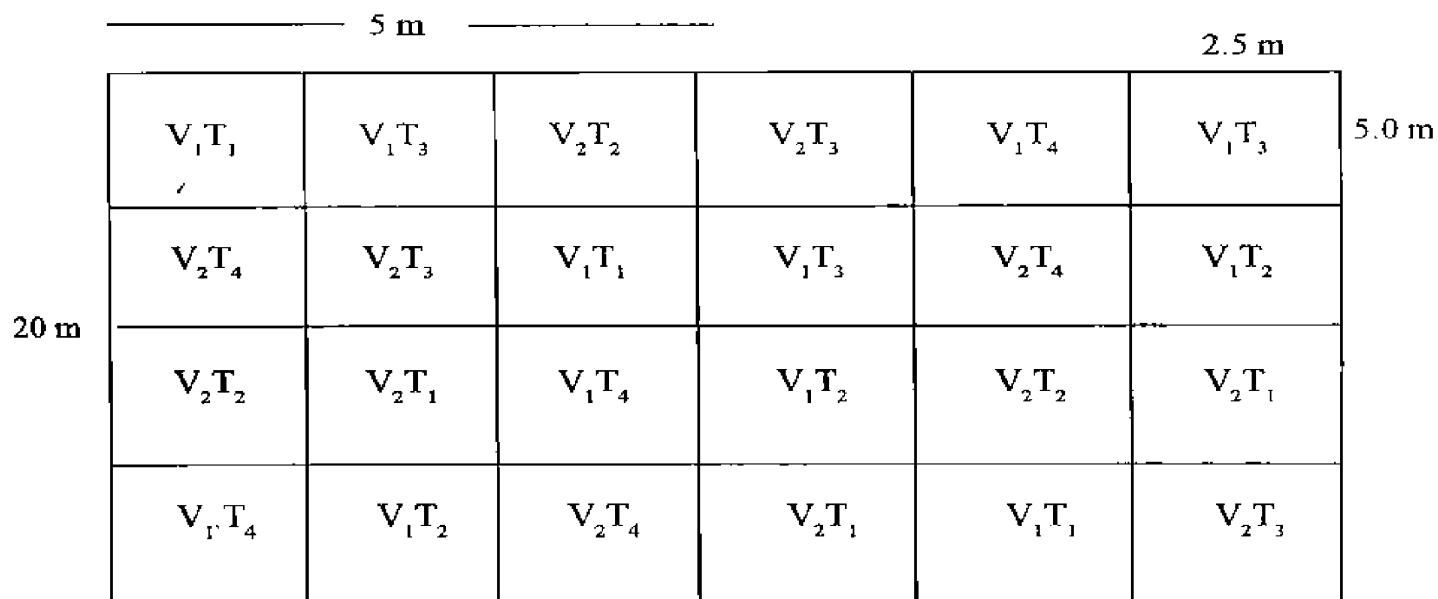
PLATE-III: Co-1 (aphid susceptible) cultivar



PLATE-IV: Plot protected throughout growth period

Table 1. Details of the insecticides used.

Sr. No.	Name of the insecticides	Conc. used (%)	Manufacturer
1	Nimbicidin	0.5	West Coast, Herbochem Pvt. Ltd., Mumbai.
2	Bioneem	0.3	Zuari Agro-chemicals Ltd., Jai Kissan Bhawan, Zuarinagar, Goa.
3	Neem oil	3.0	Local source, Parbhani.
4	Castor oil	1.0	Local source, Parbhani.
5	Neemark	1.0	West Coast, Herbochem Pvt. Ltd., Tumkur, Bangalore.
6	Neemgold	0.5	Jindal India, Agro-Tech Corporation, Jindal House, Jalna.
7	Methyl demeton	0.05	Bayer India Ltd., C/o. FMC India, Visanji Nagar, Jalgaon.
8	Thiamethoxam	0.01	Novartis India Ltd., 198, Jamshetji Tata Road, Mumbai 400 020.
9	Endosulphan	0.05	Rallies India Ltd., Rally House, 21-D, Sukhadwala Marg, Mumbai - 400 001.
10	Untreated control	--	--



1) Loss assessment

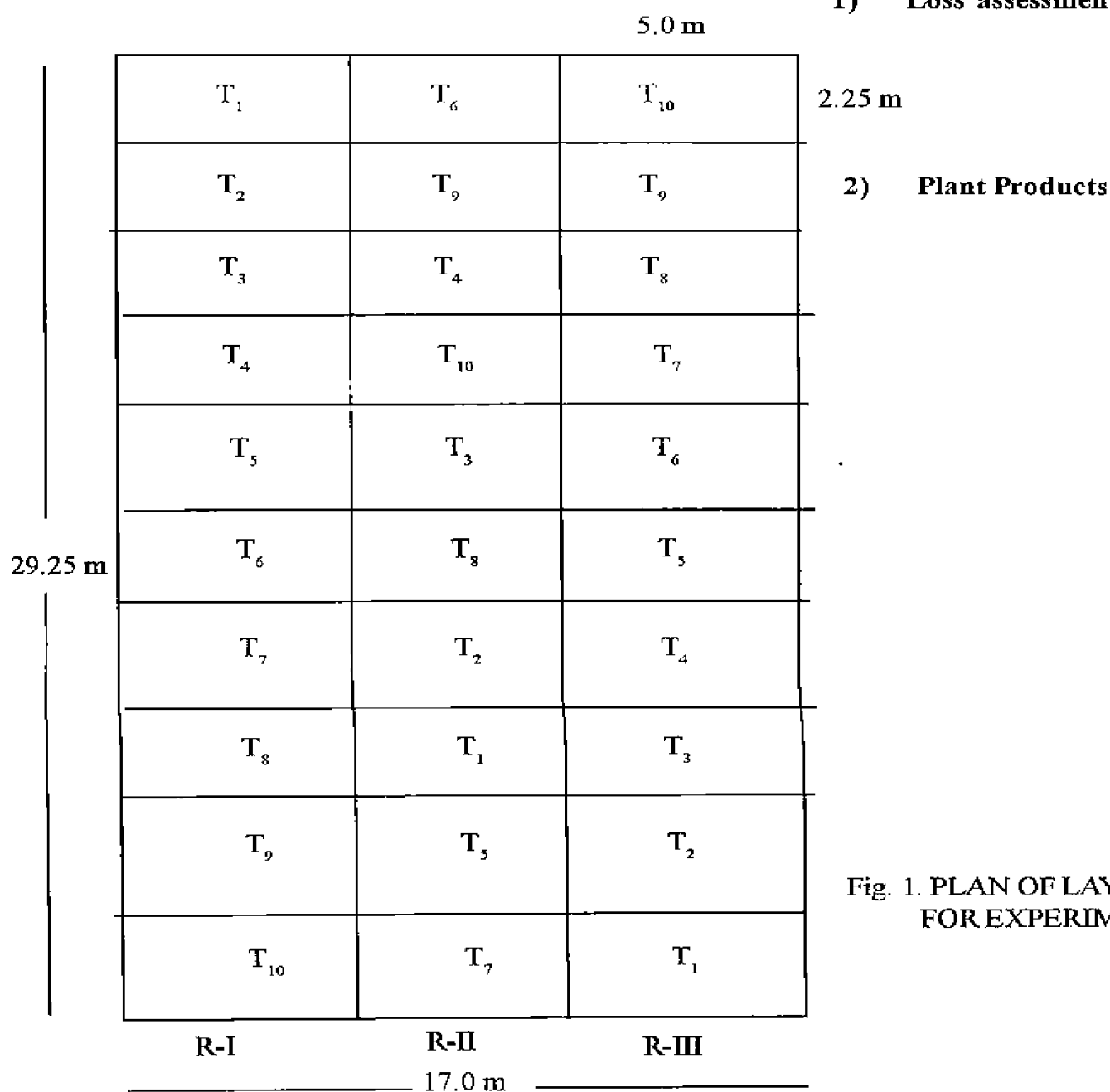
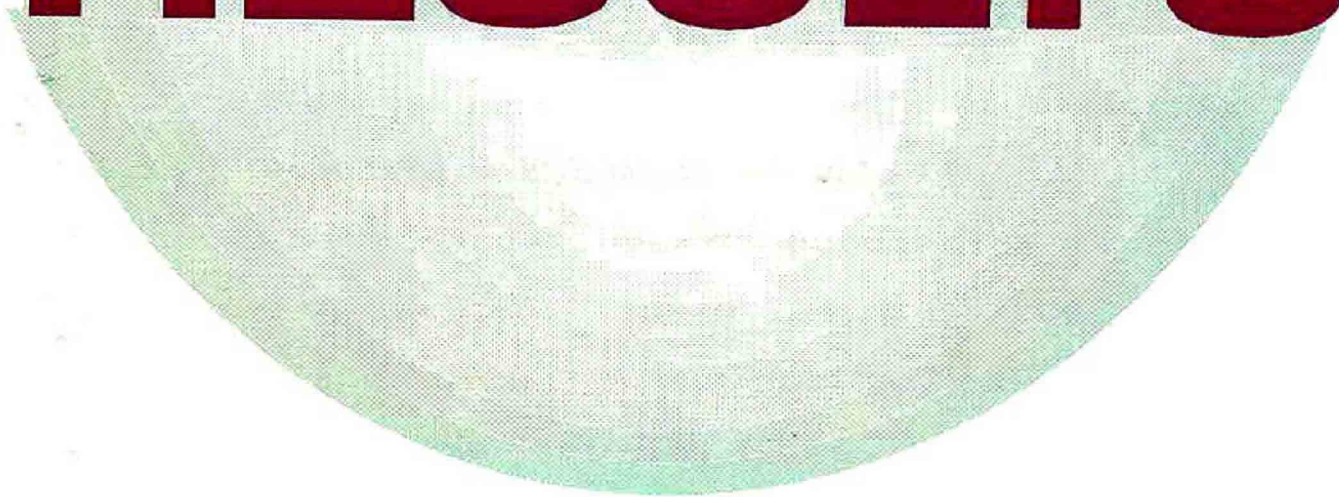


Fig. 1. PLAN OF LAYOUT FOR EXPERIMENTS

RESULTS



Chapter-IV

RESULTS

Field experiments were conducted during winter seasons to study the different components of the pest management of safflower crop viz., population dynamics, assessment of losses, effect of plant products and screening of various varieties of safflower for aphid resistance.

The findings of various studies are presented in this chapter.

4.1 Population dynamics of pests of safflower

4.1.1. Population dynamics of aphid

The observations on population fluctuations of aphid during the year 1998-99 and 1999-2000 are presented in Table 2 and Table 3 and graphically depicted in Fig. 2. It is evident from Table 2 and 3 that the first appearance of aphid was noted in the last week of December (52nd meteorological week) in both the seasons when temperatures and relative humidity were 17.8°C and 53 per cent and 19.8°C and 52 per cent respectively. The aphid activity was subsequently increased in the month of January. The activity of aphid increased gradually and heavy incidence i.e. 190.60 aphids per plant in 1998-99 and 182.0 aphids per plant in 1999-2000 was recorded in first week of

Table 2. Population dynamics of aphid in rabi season, 1998-99.

Obs. No.	Date of obs.	Meteo. weeks	No. of aphids/ plant	Temp. °C		Humidity(%)		Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
				Max.	Min.	A.M.	P.M.			
1.	25-12-98	52	29.75 (5.50)	27.8	7.9	78	28	10.6	3.4	2.6
2.	1-1-99	1	53.90 (7.37)	28.0	7.8	80	31	10.2	3.8	2.3
3.	8-1-99	2	79.00 (8.91)	26.2	6.9	71	30	10.4	4.2	3.0
4.	15-1-99	3	102.80 (10.16)	28.7	9.0	78	29	10.4	4.4	2.8
5.	22-1-99	4	140.25 (11.86)	30.5	11.0	74	28	10.7	4.9	1.6
6.	29-1-99	5	178.65 (13.38)	30.5	11.7	74	27	10.9	4.2	2.2
7.	5-2-99	6	190.60 (13.82)	30.5	15.6	83	38	10.0	4.6	1.0
8.	12-2-99	7	141.25 (11.90)	32.0	14.7	77	36	10.7	4.8	4.5
9.	19-2-99	8	105.65 (10.30)	34.5	14.7	66	38	11.2	5.0	2.9
10.	26-2-99	9	56.90 (7.57)	35.5	15.8	69	29	11.2	6.3	3.4
11.	5-3-99	10	21.20 (4.65)	36.2	16.5	60	28	11.5	6.6	3.4
12.	12-3-99	11	4.60 (2.25)	36.7	17.8	51	24	11.3	6.0	2.5

The average population (92.04) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

Table 3. Population dynamics of aphid in rabi season, 1999-2000.

Obs. No.	Date of obs.	Meteo. weeks	No. of aphids/ plant	Temp. °C		Humidity(%)		Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
				Max.	Min.	A.M.	P.M.			
1.	27-12-99	52	17.63 (4.25)	29.0	10.7	75	29	10.4	4.0	2.6
2.	3-1-2000	1	29.00 (5.43)	28.0	8.0	76	25	10.6	3.4	3.2
3.	10-1-2000	2	52.90 (7.30)	29.7	10.0	73	30	10.7	4.2	3.3
4.	17-1-2000	3	76.60 (8.78)	31.2	13.5	75	35	10.7	4.6	3.9
5.	24-1-2000	4	112.60 (10.63)	30.6	11.4	76	27	10.8	4.5	3.5
6.	31-1-2000	5	153.95 (12.42)	31.2	10.7	74	35	10.6	4.4	3.3
7.	7-2-2000	6	182.00 (13.50)	30.5	12.6	72	33	10.5	4.5	4.1
8.	14-2-2000	7	155.05 (12.47)	31.0	14.0	68	43	9.5	5.0	5.1
9.	21-2-2000	8	119.10 (10.93)	30.7	13.2	77	51	9.3	4.8	5.2
10.	28-2-2000	9	54.05 (7.38)	31.8	13.4	72	28	8.3	4.8	3.6
11.	6-3-2000	10	21.95 (4.73)	34.5	13.2	62	25	11.1	5.2	4.0
12.	13-3-2000	11	4.95 (2.33)	35.4	12.8	58	29	11.2	5.7	4.3

The average population (81.64) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

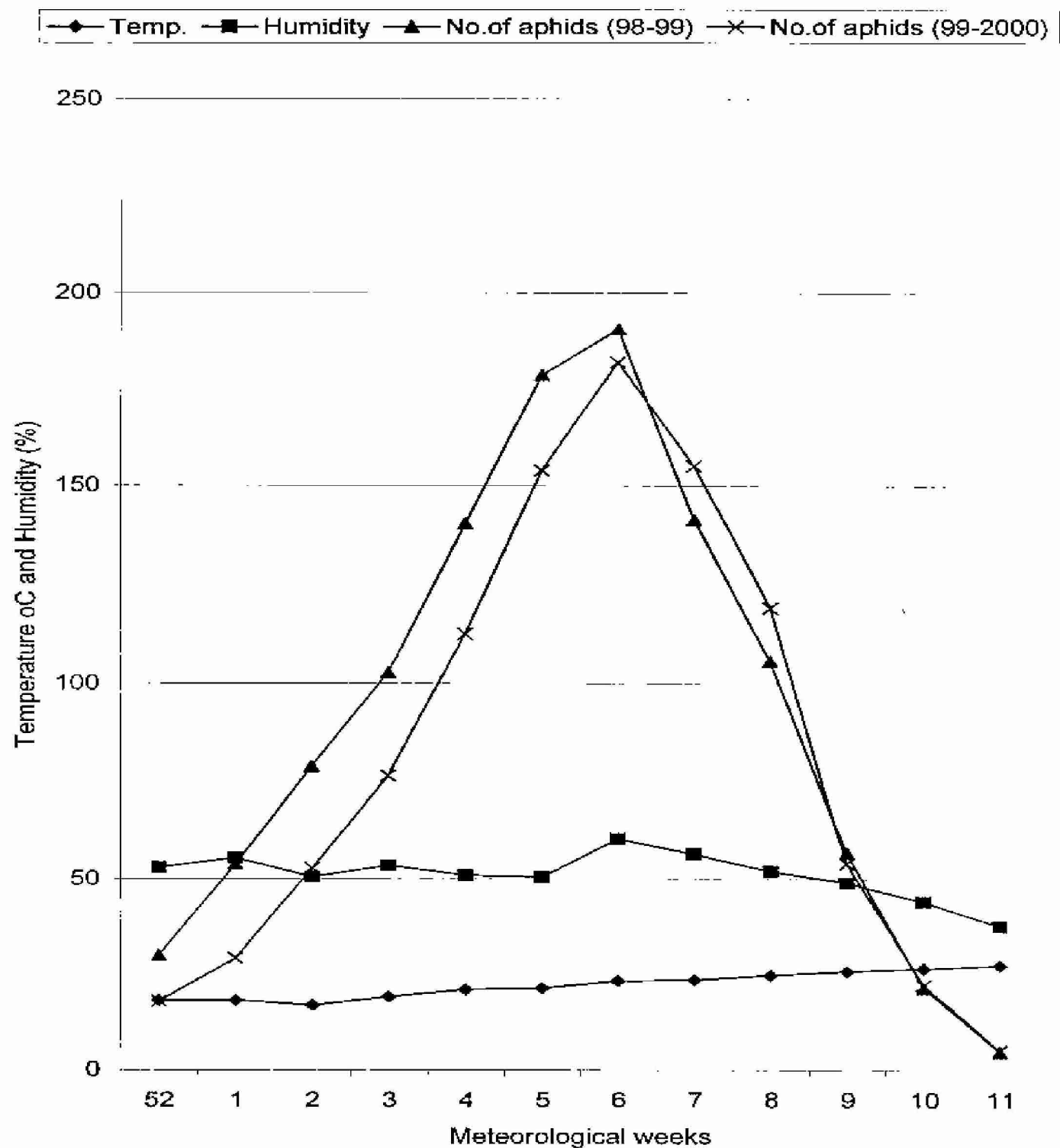


Fig. 2. Population dynamics of aphids in different meteorological weeks.

February. Again the population of aphid was decreased in both the seasons. The average populatin of aphid per plant was 92.04 during 1998-99 and 81.64 during 1999-2000.

4.1.2 Population dynamics of thrips

The observations on population fluctuations of thrips during the year 1998-99 and 1999-2000 are presented in Table 4 and Table 5 and graphically depicted in Fig. 3. It is evident from Table 4 and 5 that the first appearance of thrips was noted in the last week of December (52nd meteorological week) when temperature and relative humidity were 17.8 °C and 53 per cent during 1998-99 and 19.8 °C and 52 per cent during 1999-2000 respectively. Population of thrips was subsequently increased upto first week of February in 1998-99 and third week of January in 1999-2000. Again the pest population decreased in both the seasons. Highest population of thrips (12.25 thrips/plant) was recorded in first week of February during 1998-99 and (13.10 thrips/plant) in third week of January during 1999-2000 (6th and 4th meteorological week). The population of thrips varied from 0.55 to 12.25 per plant throughout season of 1998-99 and 1.05 to 13.10 per plant throughout season of 1999-2000.

4.1.3 Population dynamics of *Helicoverpa armigera*

The observations on population dynamics of *Helicoverpa armigera* on leaves and on capsules during the

Table 4. Population dynamics of thrips in rabi season, 1998-99.

Obs. No.	Date of obs.	Meteo. weeks	No.of thrips/plant	Temp. ^o C		Humidity(%)		Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
				Max.	Min.	A.M.	P.M.			
1.	25-12-98	52	3.85 (2.08)	27.8	7.9	78	28	10.6	3.4	2.6
2.	1-1-99	1	6.25 (2.59)	28.0	7.8	80	31	10.2	3.8	2.3
3.	8-1-99	2	8.00 (2.91)	26.2	6.9	71	30	10.4	4.2	3.0
4.	15-1-99	3	9.15 (3.10)	28.7	9.0	78	29	10.4	4.4	2.8
5.	22-1-99	4	10.10 (3.25)	30.5	11.0	74	28	10.7	4.9	1.6
6.	29-1-99	5	11.30 (3.43)	30.5	11.7	74	27	10.9	4.2	2.2
7.	5-2-99	6	12.25 (3.57)	30.5	15.6	83	38	10.0	4.6	1.0
8.	12-2-99	7	8.60 (3.01)	32.0	14.7	77	36	10.7	4.8	4.5
9.	19-2-99	8	7.20 (2.77)	34.5	14.7	66	38	11.2	5.0	2.9
10.	26-2-99	9	5.20 (2.38)	35.5	15.8	69	29	11.2	6.3	3.4
11.	5-3-99	10	3.10 (1.89)	36.2	16.5	60	28	11.5	6.6	3.4
12.	12-3-99	11	0.55 (1.02)	36.7	17.8	51	24	11.3	6.0	2.5

The average population (7.12) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

Table 5. Population dynamics of thrips in rabi season, 1999-2000.

Obs. No.	Date of obs.	Meteo. weeks	No. of thrips/plant	Temp. °C		Humidity(%)		Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
				Max.	Min.	A.M.	P.M.			
1.	27-12-99	52	2.55 (1.74)	29.0	10.7	75	29	10.4	4.0	2.6
2.	3-1-2000	1	3.85 (2.08)	28.0	8.0	76	25	10.6	3.4	3.2
3.	10-1-2000	2	6.90 (2.72)	29.7	10.0	73	30	10.7	4.2	3.3
4.	17-1-2000	3	10.10 (3.25)	31.2	13.5	75	35	10.7	4.6	3.9
5.	24-1-2000	4	13.10 (3.68)	30.6	11.4	76	27	10.8	4.5	3.5
6.	31-1-2000	5	9.45 (3.15)	31.2	10.7	74	35	10.6	4.4	3.3
7.	7-2-2000	6	8.72 (3.03)	30.5	12.6	72	33	10.5	4.5	4.1
8.	14-2-2000	7	7.68 (2.86)	31.0	14.0	68	43	9.5	5.0	5.1
9.	21-2-2000	8	5.40 (2.42)	30.7	13.2	77	51	9.3	4.8	5.2
10.	28-2-2000	9	4.59 (2.25)	31.8	13.4	72	28	8.3	4.8	3.6
11.	6-3-2000	10	3.20 (1.92)	34.5	13.2	62	25	11.1	5.2	4.0
12.	13-3-2000	11	1.05 (1.24)	35.4	12.8	58	29	11.2	5.7	4.3

The average population (6.38) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

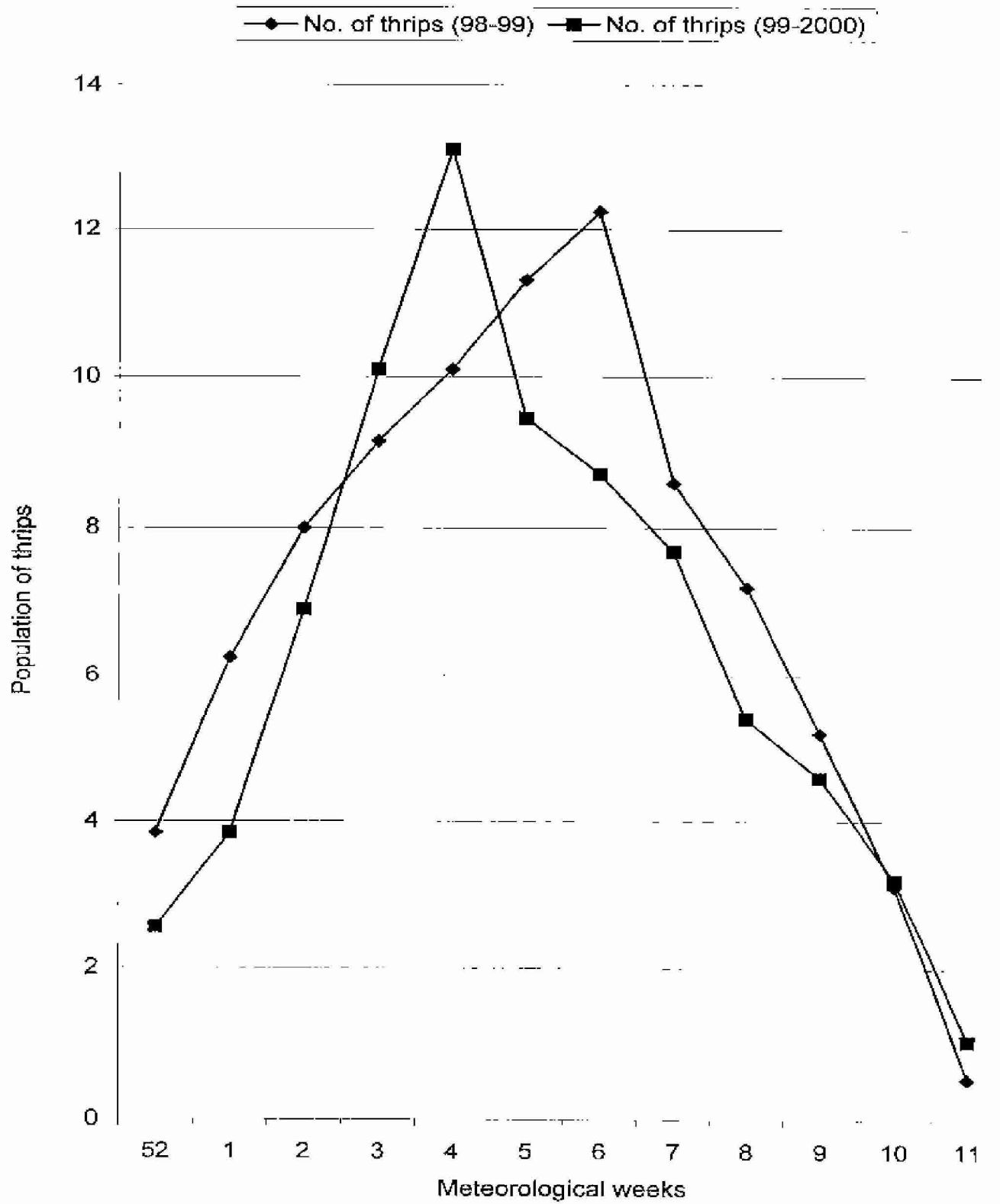


Fig. 3. Population dynamics of thrips in different meteorological weeks.

year 1998-99 are presented in Table 6 and graphically presented in Fig. 4.

The results revealed that the first appearance of *Helicoverpa armigera* on leaves was noticed in second week of January (2nd meteorological week) when temperature and relative humidity were 26 °C and 71 per cent respectively. The population of the pest was subsequently increased upto first week of February and again decreased in subsequent weeks. The maximum population of *Helicoverpa armigera* on leaves was recorded in last week of January (0.10 per plant) when temperature was 20.7°C and RH was 51 per cent. As regards *Helicoverpa armigera* on capsules, the first appearance of the pest was in last week of January (5th meteorological week) when temperature and relative humidity were 21.1°C and 50.5 per cent respectively. The pest population increased subsequently and the maximum population (0.10) was recorded in second week of February (7th meteorological week) when temperature and RH were 23.3°C and 56.5 per cent respectively. The average population throughout season was 0.04 per plant on leaves and on capsules.

During the year 1999-2000 the incidence of *Helicoverpa armigera* on leaves was recorded firstly in second week of January (2nd meteorological week) when temperature was 19.8°C and RH was 51.5 per cent, peaked in

Table 6. Population dynamics of *Helicoverpa armigera* in rabi season, 1998-99.

Obs. No.	Date of obs.	Meteo. weeks	No. of <i>H. armigera</i> on Leaves	Capsuls	Temp. °C		Humidity(%)		Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
					Max.	Min.	A.M.	P.M.			
1.	25-12-98	52	0.00 (0.70)	0.00 (0.70)	27.8	7.9	78	28	10.6	3.4	2.6
2.	1-1-99	1	0.00 (0.70)	0.00 (0.70)	28.0	7.8	80	31	10.2	3.8	2.3
3.	8-1-99	2	0.05 (0.74)	0.00 (0.70)	26.2	6.9	71	30	10.4	4.2	3.0
4.	15-1-99	3	0.05 (0.74)	0.00 (0.70)	28.7	9.0	78	29	10.4	4.4	2.8
5.	22-1-99	4	0.10 (0.77)	0.00 (0.70)	30.5	11.0	74	28	10.7	4.9	1.6
6.	29-1-99	5	0.10 (0.77)	0.05 (0.74)	30.5	11.7	74	27	10.9	4.2	2.2
7.	5-2-99	6	0.10 (0.77)	0.05 (0.74)	30.5	15.6	83	38	10.0	4.6	1.0
8.	12-2-99	7	0.05 (0.74)	0.10 (0.77)	32.0	14.7	77	36	10.7	4.8	4.5
9.	19-2-99	8	0.05 (0.74)	0.10 (0.77)	34.5	14.7	66	38	11.2	5.0	2.9
10.	26-2-99	9	0.00 (0.70)	0.10 (0.77)	35.5	15.8	69	29	11.2	6.3	3.4
11.	5-3-99	10	0.00 (0.70)	0.05 (0.74)	36.2	16.5	60	28	11.5	6.6	3.4
12.	12-3-99	11	0.00 (0.70)	0.00 (0.70)	36.7	17.8	51	24	11.3	6.0	2.5

The average population (0.04) (0.04) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

Table 7. Population dynamics of *Helicoverpa armigera* in rabi season, 1999-2000.

Obs. No.	Date of obs.	Meteo. weeks	No. of <i>H. armigera</i> on Leaves	Temp. °C		Humidity (%)		Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
				Max.	Min.	A.M.	P.M.			
1.	27-12-99	52	0.00 (0.70)	29.0	10.7	75	29	10.4	4.0	2.6
2.	3-1-2000	1	0.00 (0.70)	28.0	8.0	76	25	10.6	3.4	3.2
3.	10-1-2000	2	0.05 (0.74)	29.7	10.0	73	30	10.7	4.2	3.3
4.	17-1-2000	3	0.05 (0.74)	31.2	13.5	75	35	10.7	4.6	3.9
5.	24-1-2000	4	0.10 (0.77)	30.6	11.4	76	27	10.8	4.5	3.5
6.	31-1-2000	5	0.10 (0.77)	31.2	10.7	74	35	10.6	4.4	3.3
7.	7-2-2000	6	0.10 (0.77)	30.5	12.6	72	33	10.5	4.5	4.1
8.	14-2-2000	7	0.05 (0.74)	31.0	14.0	68	43	9.5	5.0	5.1
9.	21-2-2000	8	0.05 (0.74)	30.7	13.2	77	51	9.3	4.8	5.2
10.	28-2-2000	9	0.00 (0.70)	31.8	13.4	72	28	8.3	4.8	3.6
11.	6-3-2000	10	0.00 (0.70)	34.5	13.2	62	25	11.1	5.2	4.0
12.	13-3-2000	11	0.00 (0.70)	35.4	12.8	58	29	11.2	5.7	4.3

The average population (0.04) (0.04) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

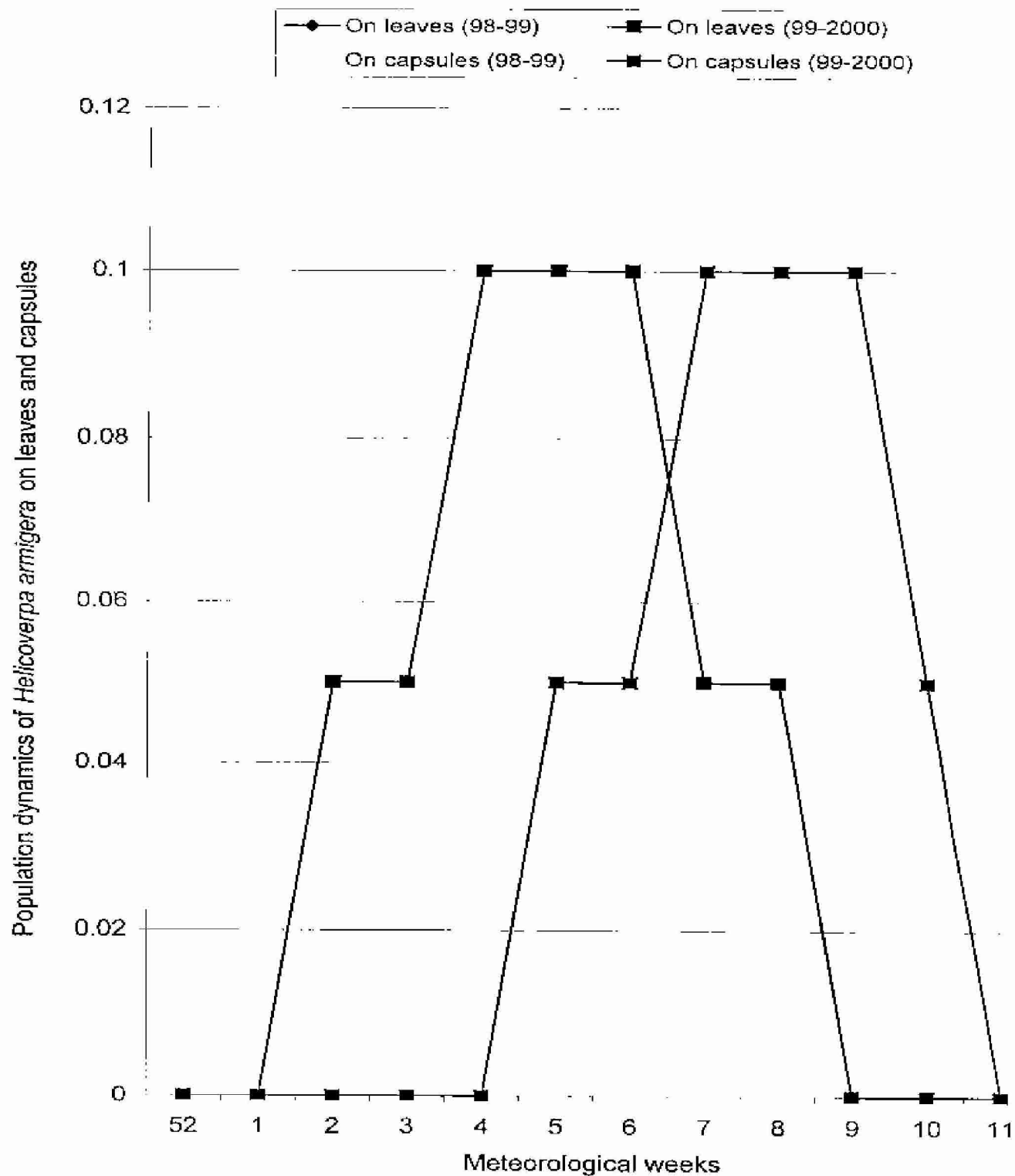


Fig. 4. Population dynamics of *Helicoverpa armigera* on leaves and capsules in different meteorological weeks.

last week of January (4th meteorological week) when temperature and relative humidity were 21°C and 51.5 per cent respectively. As regards the incidence of *Helicoverpa armigera* on capsules first appearance of the pest was in last week of January (5th meteorological week) when temperature was 20.95 °C and relative humidity was 54.5 per cent. Population increased gradually and reached peak in second week of February (7th meteorological week) when temperature and RH were 22.5 °C and 55.5 per cent respectively and thereafter declined gradually. The average population throughout season was similar to that of the first, (Table 7 and Fig 4).

4.1.4 Population dynamics of safflower caterpillar

The observations on population dynamics of safflower caterpillar during the year 1998-99 were recorded and are presented in Table 8 and graphically depicted in Fig 5.

Table 8 revealed that the first appearance of the pest was noticed in second week of January (2nd meteorological week) when temperature was 16.5 °C and RH was 50.5 per cent. Thereafter population was subsequently increased and maximum population was observed (0.10 safflower caterpillars per plant) from 4th week of January to 1st week of February. Pest population was constant upto first week of February and thereafter declined gradually. The average population throughout season was 0.04 per plant.

Table 8. Population dynamics of safflower caterpillar in rabi season, 1998-99.

Obs. No.	Date of obs.	Meteo. weeks	No. of saff. caterpillar on leaves	Temp. °C Max. Min.	Humidity (%) A.M. P.M.	Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
1.	25-12-98	52	0.00 (0.70)	27.8 7.9	78 28	10.6	3.4	2.6
2.	1-1-99	1	0.00 (0.70)	28.0 7.8	80 31	10.2	3.8	2.3
3.	8-1-99	2	0.05 (0.74)	26.2 6.9	71 30	10.4	4.2	3.0
4.	15-1-99	3	0.05 (0.74)	28.7 9.0	78 29	10.4	4.4	2.8
5.	22-1-99	4	0.10 (0.77)	30.5 11.0	74 28	10.7	4.9	1.6
6.	29-1-99	5	0.10 (0.77)	30.5 11.7	74 27	10.9	4.2	2.2
7.	5-2-99	6	0.10 (0.77)	30.5 15.6	83 38	10.0	4.6	1.0
8.	12-2-99	7	0.05 (0.74)	32.0 14.7	77 36	10.7	4.8	4.5
9.	19-2-99	8	0.05 (0.74)	34.5 14.7	66 38	11.2	5.0	2.9
10.	26-2-99	9	0.00 (0.70)	35.5 15.8	69 29	11.2	6.3	3.4
11.	5-3-99	10	0.00 (0.70)	36.2 16.5	60 28	11.5	6.6	3.4
12.	12-3-99	11	0.00 (0.70)	36.7 17.8	51 24	11.3	6.0	2.5

The average population (0.04) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

Table 9. Population dynamics of safflower caterpillar in rabi season, 1999-2000.

Obs. No.	Date of obs.	Meteo. weeks	No. of saff. caterpillar on leaves	Temp. °C Max. Min.	Humidity(%) A.M. P.M.	Bright sunshine hours	Evapo-ration (mm)	Wind velocity km/hr
1.	27-12-99	52	0.00 (0.70)	29.0 10.7	75 29	10.4	4.0	2.6
2.	3-1-2000	1	0.05 (0.74)	28.0 8.0	76 25	10.6	3.4	3.2
3.	10-1-2000	2	0.05 (0.74)	29.7 10.0	73 30	10.7	4.2	3.3
4.	17-1-2000	3	0.10 (0.77)	31.2 13.5	75 35	10.7	4.6	3.9
5.	24-1-2000	4	0.10 (0.77)	30.6 11.4	76 27	10.8	4.5	3.5
6.	31-1-2000	5	0.15 (0.80)	31.2 10.7	74 35	10.6	4.4	3.3
7.	7-2-2000	6	0.10 (0.77)	30.5 12.6	72 33	10.5	4.5	4.1
8.	14-2-2000	7	0.05 (0.74)	31.0 14.0	68 43	9.5	5.0	5.1
9.	21-2-2000	8	0.05 (0.74)	30.7 13.2	77 51	9.3	4.8	5.2
10.	28-2-2000	9	0.00 (0.70)	31.8 13.4	72 28	8.3	4.8	3.6
11.	6-3-2000	10	0.00 (0.70)	34.5 13.2	62 25	11.1	5.2	4.0
12.	13-3-2000	11	0.00 (0.70)	35.4 12.8	58 29	11.2	5.7	4.3

The average population (0.05) throughout season,

Figures in parenthesis are $\sqrt{x+0.5}$ values.

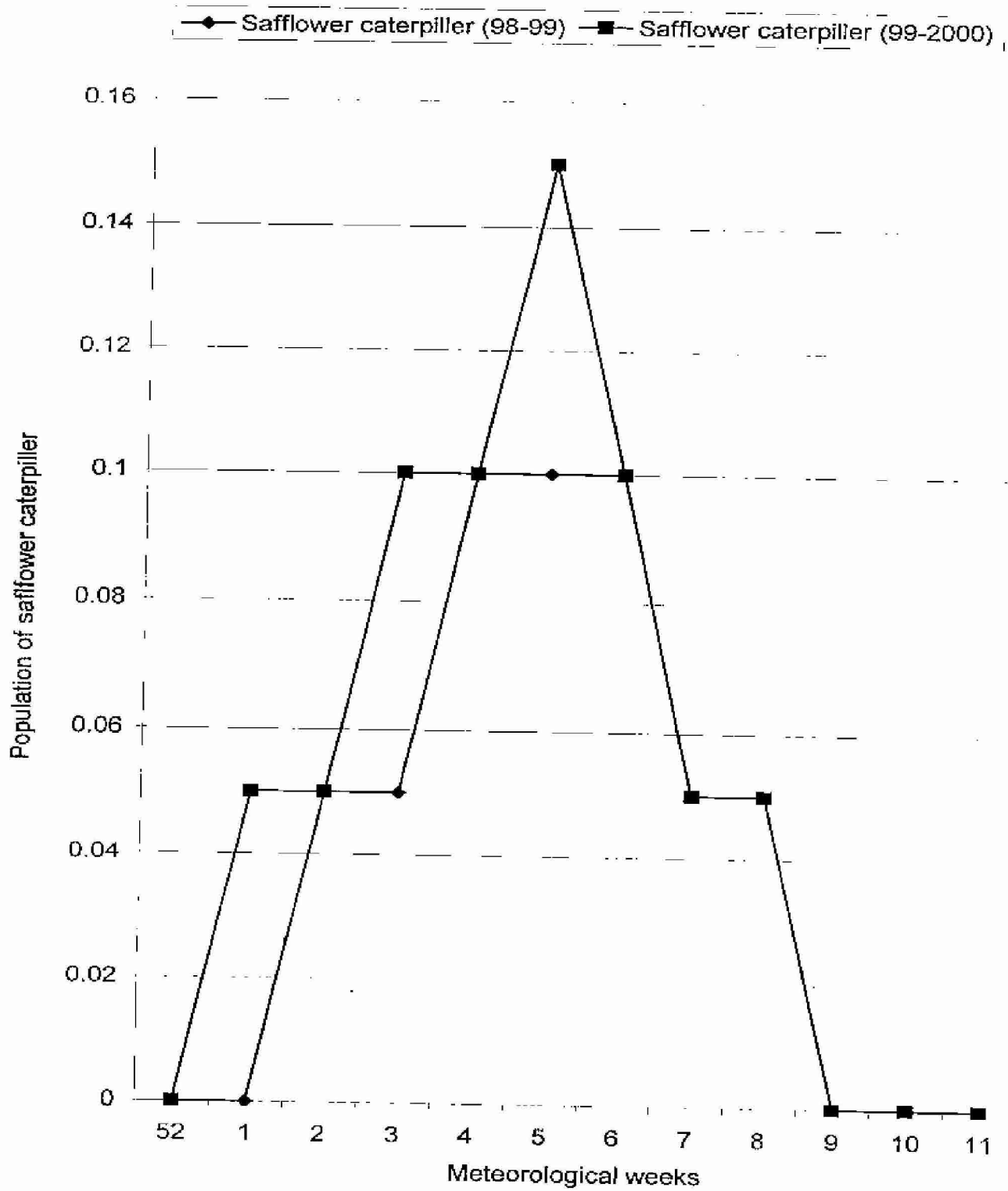


Fig. 5. Population dynamics of safflower caterpillar in different meteorological weeks.

During the year 1999-2000, the first appearance of safflower caterpillar was in first week of January (1st meteorological week) when temperature and relative humidity were 18.0 °C and 50.5 per cent respectively. The pest population increased gradually and peaked in last week of January (0.15) (5th meteorological week) when temperature and relative humidity were 20.9 °C and 54.5 per cent respectively. The average population of safflower caterpillar was 0.05 per plant throughout season (Table 9 and Fig. 5).

4.1.5 Relationship between weather parameters and pests of safflower

The relation between weather parameters and different pests of safflower was studied, path analysis was performed to the correlation, combined effects as well as direct and indirect effects of weather parameters on incidence of different pests of safflower during rabi seasons of 1998-99 and 1999-2000 were worked out and presented in Tables from 10 to 19.

4.1.5.1 Correlation studies and direct-indirect effect of abiotic factors on the population of aphid

The results of direct-indirect effects of weather parameters and correlation with abiotic factors on aphid population during the year 1998-99 are presented in Table 10.

Table 10. Combined direct and indirect effect of the abiotic factors on the populations of aphids, recorded in rabi season, 1998-99.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-2.3428	-2.1612	1.7677	0.1797	-1.9727	-2.1136	-0.6474	-0.2880
Temp. Min.	1.5576	1.6885	-0.9677	0.2324	1.0469	1.3859	0.2442	-0.0230
% RH AM	-0.5501	-0.4179	0.7291	0.3306	-0.6157	-0.5386	-0.1928	0.5990*
% RH PM	-0.0198	0.0355	0.1171	0.2582	-0.0919	-0.0464	0.0081	0.5320
Bright sunshine hours	1.0130	0.7459	-1.0159	-0.4284	1.2030	0.9229	0.5381	-0.4580
Evaporation	0.1500	0.1365	-0.1228	-0.0299	0.1276	0.1663	0.0503	-0.3281
Wind velocity	-0.0956	-0.0500	0.0915	-0.0109	-0.1548	-0.1046	-0.3461	-0.3460

* Significant at 5 per cent level ($r = 0.5760$).

Table 11. Combined direct and indirect effect of the abiotic factors on the populations of aphids, recorded in rabi season, 1999-2000.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-0.4688	-0.2930	0.4050	0.0401	-0.0890	-0.4327	-0.1917	-0.2194
Temp. Min.	0.1795	0.2871	-0.1164	0.1285	-0.1028	0.2343	0.2037	0.2571
% RH AM	-0.3585	-0.1682	0.4150	0.1000	-0.1247	-0.3210	-0.1267	0.3473
% RH PM	-0.0127	0.0666	0.0359	0.1488	-0.0651	0.0319	0.1091	0.5855*
Bright sunshine hours	0.0442	-0.0833	-0.0699	-0.1018	0.2326	-0.0067	-0.0683	-0.2396
Evaporation	0.2832	0.2503	-0.2373	0.0656	-0.0089	0.3068	0.1972	-0.0085
Wind velocity	0.1139	0.1976	-0.0850	0.2042	-0.0817	0.1790	0.2785	0.4018

* Significant at 5 per cent level. ($r = 0.5760$).

It was revealed that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity. Maximum temperature exhibited highest negative direct effect followed by wind velocity. Morning relative humidity exhibited significantly positive correlation with aphid population.

During the year 1999-2000, morning relative humidity exhibited highest positive direct effect followed by evaporation and minimum temperature. Maximum temperature exhibited negative direct effect. Evening relative humidity exhibited significantly positive correlation with aphid population (Table 11).

4.1.5.2 Correlation studies and direct-indirect effect of abiotic factors on the population of thrips

The results of direct-indirect effects of weather parameters and correlation with abiotic factors on thrips population during the year 1998-99 are presented in Table 12.

It was observed that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity. Maximum temperature exhibited highest negative direct effect followed by wind velocity. Morning relative humidity and bright sunshine hours showed significantly positive correlation with thrips population.

Table 12. Combined direct and indirect effect of the abiotic factors on the populations of thrips, recorded in rabi season, 1998-99.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-2.1948	-2.0246	1.6559	0.1683	-1.8480	-1.9800	-0.6065	-0.4920
Temp. Min.	1.0265	1.1128	-0.6378	0.1531	0.6900	0.9134	0.1609	-0.2603
% RH AM	-0.5621	-0.4270	0.7450	0.3378	-0.6291	-0.5504	-0.1970	0.7238*
% RH PM	-0.0244	0.0438	0.1444	0.3184	-0.1134	-0.0573	0.0100	0.4937
Bright sunshine hours	0.8920	0.6568	-0.8946	-0.3772	1.0594	0.8127	0.4738	-0.6064*
Evaporation	0.4757	0.4328	-0.3895	-0.0948	0.4045	0.5273	0.1954	-0.4490
Wind velocity	-0.1049	-0.0549	0.1004	-0.0120	-0.1698	-0.1147	-0.3796	-0.3789

Table 13. Combined direct and indirect effect of the abiotic factors on the populations of thrips, recorded in rabi season, 1999-2000.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-0.7443	-0.4652	0.6430	0.0637	-0.1413	-0.6870	-0.2980	-0.2910
Temp. Min.	0.1355	0.2167	-0.0879	0.0970	-0.0776	0.1769	0.1537	0.0546
% RH AM	-1.2689	-0.5955	1.4688	0.3539	-0.4414	-1.1360	-0.4501	0.5125
% RH PM	0.0566	-0.2964	-0.1596	-0.6624	0.2898	-0.1417	-0.4872	0.1924
Bright sunshine hours	0.1095	-0.2066	-0.1735	-0.2525	0.5771	-0.0167	-0.1727	0.0446
Evaporation	1.2565	1.1109	-1.0528	0.2913	-0.0394	1.3613	0.8695	-0.1816
Wind velocity	0.1641	0.2907	-0.1256	0.3014	-0.1226	0.2617	0.4098	0.0250

Table 13 revealed that morning relative humidity exhibited highest positive direct effect followed by evaporation and bright sunshine hours during the year 1999-2000. Maximum temperature exhibited highest negative direct effect followed by evening relative humidity.

4.1.5.3 Correlation studies and direct-indirect effect of abiotic factors on the population of *Helicoverpa armigera* on leaves

The results of direct-indirect effects of weather parameter and correlation with abiotic factors on the population of *Helicoverpa armigera* on leaves during the year 1998-99 are presented in Table 14.

It was observed that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity. Maximum temperature exhibited highest negative direct effect followed by wind velocity and evaporation. Maximum temperature, bright sunshine hours, evaporation and wind velocity showed non-significantly negative correlation with the population of *Helicoverpa armigera* on leaves.

The results of direct-indirect effects of weather parameter and correlation with abiotic factors on the population of *Helicoverpa armigera* on leaves during the year 1999-2000 are presented in Table 15.

Table 14. Combined direct and indirect effect of the abiotic factors on the populations of *Helicoverpa armigera* on leaves, recorded in rabi season, 1998-99.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-2.3041	-2.1255	1.7384	0.1767	-1.9401	-2.0786	-0.6367	-0.0547
Temp. Min.	1.6683	1.8085	-1.0365	0.2489	1.1213	1.4844	0.2615	0.1698
% RH AM	-0.5164	-0.3923	0.6845	0.3104	-0.5780	-0.5046	-0.1810	0.3471
% RH PM	-0.0160	0.0287	0.0944	0.2083	-0.0742	-0.0375	0.0066	0.3656
Bright sunshine hours	1.3417	0.9880	-1.3456	-0.5674	1.5935	1.2225	0.7127	-0.2107
Evaporation	-0.0471	-0.0429	0.0386	0.0094	-0.0401	-0.0522	-0.0158	-0.1652
Wind velocity	-0.1811	-0.0948	0.1733	-0.0207	-0.2932	-0.1981	-0.6555	-0.5081

Table 15. Combined direct and indirect effect of the abiotic factors on the populations of *Helicoverpa armigera*, on leaves, recorded in rabi season, 1999-2000.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-0.7169	-0.4481	0.6194	0.0613	-0.1361	-0.6617	-0.2931	-0.2170
Temp. Min.	-0.0713	-0.1141	0.0463	-0.0511	0.0409	-0.0932	-0.0810	0.0312
% RH AM	-0.9816	-0.4606	1.1362	0.2738	-0.3415	-0.8788	-0.3468	0.4039
% RH PM	0.0101	-0.0528	-0.0284	-0.1180	0.0516	-0.0252	-0.0865	0.3376
Bright sunshine hours	0.1122	-0.2116	-0.1777	-0.4587	0.5912	-0.0171	-0.1735	0.1179
Evaporation	1.3673	1.2089	-1.1457	0.3170	-0.0429	1.4813	0.9521	-0.0954
Wind velocity	0.0632	0.1096	-0.0472	0.1133	-0.0453	0.0993	0.1545	0.1256

The data presented in Table 15 revealed that evaporation exhibited highest positive direct effect followed by morning relative humidity and bright sunshine hours. Maximum temperature exhibited highest negative direct effect followed by evening relative humidity and minimum temperature. Maximum temperature and evaporation exhibited non-significantly negative correlation with *Helicoverpa armigera* population.

4.1.5.4 Correlation studies and direct-indirect effect of abiotic factors on the population of *Helicoverpa armigera* on capsules

The results of direct-indirect effects of weather parameter and correlation with abiotic factors on the population of *Helicoverpa armigera* on capsules during the year 1998-99 are presented in Table 16.

Table 16 revealed that bright sunshine hours exhibited highest positive direct effect followed by morning relative humidity and minimum temperature. Maximum temperature exhibited negative direct effect. Minimum temperature exhibited significantly positive correlation with the population of *Helicoverpa armigera* on capsules. Morning relative humidity exhibited non-significantly negative correlation with the pest population.

It is evident from the data presented in Table 17 that maximum temperature exhibited highest positive direct

Table 16. Combined direct and indirect effect of the abiotic factors on the populations of *Helicoverpa armigera* on capsules, recorded in rabi season, 1998-99.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-0.3199	-0.2951	0.2414	0.0245	-0.2694	-0.2886	-0.0884	0.5423
Temp. Min.	0.5199	0.5636	-0.3230	0.0776	0.3494	0.4626	0.0815	0.6022*
% RH AM	-0.5294	-0.4022	0.7017	0.2182	-0.5925	-0.5184	-0.1855	0.0545
% RH PM	-0.0379	0.0680	0.2239	0.4938	-0.1758	-0.0888	0.0156	0.5738
Bright sunshine hours	0.7920	0.5832	-0.7943	-0.3349	0.9406	0.7216	0.4207	0.3965
Evaporation	0.0601	0.0546	-0.0492	-0.0120	0.0511	0.0666	0.0201	0.4179
Wind velocity	0.0575	0.0301	-0.0551	0.0066	0.0931	0.0629	0.2082	0.4722

* Significant at 5 % level. (r = 0.5760)

Table 17. Combined direct and indirect effect of the abiotic factors on the populations of *Helicoverpa armigera* on capsules, recorded in rabi season, 1999-2000.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	0.8621	0.5388	-0.7448	-0.0737	0.1636	0.7957	0.3525	0.1519
Temp. Min.	0.1435	0.2296	-0.0931	0.1027	-0.0822	0.1873	0.1629	0.5862*
% RH AM	0.2635	0.1236	-0.3050	-0.0735	0.0917	0.2359	0.0931	-0.0265
% RH PM	-0.0321	0.1681	0.0905	0.3757	-0.1644	0.0804	0.2755	0.6035*
Bright sunshine hours	-0.1440	0.2716	0.2281	0.3320	-0.7588	0.0220	0.2227	-0.7902
Evaporation	-1.0425	-0.9216	0.8735	-0.2417	0.0327	-1.1294	-0.7259	0.3514
Wind velocity	0.1014	0.1760	-0.0757	0.1819	-0.0728	0.1595	0.2481	0.6289

* Significant at 5 % level. (r = 0.5760)

effect followed by evening relative humidity and wind velocity. Evaporation exhibited highest negative direct effect followed by bright sunshine hours and morning relative humidity. Minimum temperature, evening relative humidity and wind velocity showed significantly positive correlation whereas morning relative humidity showed non-significantly negative correlation with the pest population. Bright sunshine hours showed significantly negative correlation with the population of *H. armigera* on capsules during the year 1999-2000.

4.1.5.5 Correlation studies and direct-indirect effect of abiotic factors on the population of safflower caterpillar

The results of direct-indirect effects of weather parameter and correlation with abiotic factors on the population of safflower caterpillar during the year 1998-99 are presented in Table 18.

Table 18 revealed that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity. Maximum temperature exhibited highest negative direct effect followed by wind velocity, Maximum temperature, minimum temperature, bright sunshine hours, evaporation and wind velocity showed non-significantly negative correlation with the population of safflower caterpillar.

Table 18. Combined direct and indirect effect of the abiotic factors on the populations of safflower caterpillar recorded in rabi season, 1998-99.

Abiotic factor	Temperature(°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	-3.1345	-2.8915	2.3650	0.2404	-2.6393	-2.8278	-0.8662	-0.3015
Temp. Min.	1.6831	1.8246	-1.0457	0.2511	1.1313	1.4976	0.2639	-0.0733
% RH AM	-0.3054	-0.2320	0.4047	0.1835	-0.3418	-0.2990	-0.1070	0.4345
% RH PM	-0.0229	0.0411	0.1356	0.2990	-0.1064	-0.0538	0.0094	0.3401
Bright sunshine hours	1.2885	0.9488	-1.2922	-0.5449	1.5303	1.1740	0.6845	-0.3901
Evaporation	0.3529	0.3210	-0.2889	-0.0704	0.3001	0.3911	0.1182	-0.2963
Wind velocity	-0.1632	-0.0854	0.1561	-0.0186	-0.2642	-0.1785	-0.5906	-0.4878

Table 19. Combined direct and indirect effect of the abiotic factors on the populations of safflower caterpillar recorded in rabi season, 1999-2000.

Abiotic factor	Temperature (°C)		% RH		Bright sunshine hours	Evaporation (mm)	Wind velocity (km/hr)	Correlation r-values
	Max.	Min.	A.M.	P.M.				
Temp. Max.	0.5690	0.3557	-0.4916	-0.0487	0.1080	0.5252	0.2278	-0.3139
Temp. Min.	0.0382	0.0611	-0.0248	0.0273	-0.0219	0.0498	0.0433	-0.1597
% RH AM	-0.9001	-0.4224	1.0418	0.2510	-0.3131	-0.8058	-0.3193	0.4987
% RH PM	-0.0146	0.0765	0.0412	0.1709	-0.0748	0.0366	0.1257	0.2535
Bright sunshine hours	0.1057	-0.1993	-0.1673	-0.2436	0.5567	-0.0161	-0.1666	0.2038
Evaporation	-0.1883	-0.1665	0.1578	-0.0437	0.0059	-0.2040	-0.1303	-0.2926
Wind velocity	0.0763	0.1351	-0.0584	0.1401	-0.0570	0.1217	0.1905	-0.0288

The results of direct-indirect effects of weather parameter and correlation with abiotic factors on the population of safflower caterpillar during the year 1999-2000 are presented in Table 19.

It is observed from the data presented in Table 19 that morning relative humidity exhibited highest positive direct effect followed by maximum temperature and bright sunshine hours. Evaporation exhibited negative direct effect.

Maximum temperature, minimum temperature, evaporation and wind velocity showed non-significantly negative correlation with the population of safflower caterpillar.

4.2 Assessment of crop losses due to safflower pest complex

4.2.1 Population of aphids

The data pertaining to population of aphids are presented in Table 20.

The differences in varieties during 1998-99 and 1999-2000 were found to be significant. The spray treatments and interaction effects during both the seasons were found to be significant in respect of aphid population.

The aphid population on Lats₁ was significantly low as compared to Co-1 during 1998-99 and 1999-2000.

Table 20. Population of aphids as affected by various treatments.

Treatments	Population of aphids per plant	
	1998-99	1999-2000
Varieties		
V ₁	58.20 (7.66)	49.48 (7.06)
V ₂	174.84 (13.24)	182.46 (13.52)
S.E. $\pm$	0.06	0.04
C.D. at 5%	0.20	0.14
Treatments		
T ₁	14.68 (3.89)	18.42 (4.34)
T ₂	98.40 (9.94)	92.64 (9.65)
T ₃	10.24 (3.27)	9.82 (3.21)
T ₄	166.36 (12.91)	170.34 (13.07)
S.E. $\pm$	0.09	0.06
C.D. at 5%	0.29	0.21
Interaction		
V ₁ T ₁	16.48 (4.12)	17.76 (4.27)
V ₁ T ₂	38.57 (6.25)	42.02 (6.52)
V ₁ T ₃	5.68 (2.48)	6.45 (2.63)
V ₁ T ₄	60.95 (7.83)	63.52 (8.00)
V ₂ T ₁	27.80 (5.31)	28.43 (5.37)
V ₂ T ₂	55.58 (7.48)	61.42 (7.86)
V ₂ T ₃	10.39 (3.30)	9.40 (3.14)
V ₂ T ₄	154.47 (12.44)	162.47 (12.76)
S.E. $\pm$	0.13	0.09
C.D. at 5%	0.39	0.29

Figures in parenthesis are $\sqrt{x+0.5}$ values

Further, the results indicated that significantly lowest population of aphid was recorded in the plots where the crop was treated completely throughout growth period (T_3) and in the plots where crop was protected during vegetative stage to control aphids (T_1). The aphid population was significantly low in the plots treated during reproductive stage for controlling *Helicoverpa* infestation (T_2) as compared to the plots kept untreated throughout growth period (T_4) during 1998-99 and 1999-2000.

Significantly lowest population of aphids was recorded in Lats₁ with T_1 and T_3 treatment combinations in both the seasons. In case of Co-1, lowest population of aphid was recorded in T_3 .

4.2.2 Population of thrips

The data pertaining to population of thrips are presented in Table 21.

Both the varieties, spray treatments and interaction effects during 1998-99 and 1999-2000 revealed significant results in respect of lowering the thrips population.

Comparatively low thrip population was recorded during 1999-2000 as compared to 1998-99. The treatments T_1 and T_3 were at par during 1998-99. Significant reduction in thrip population was observed in T_1 and T_3 as compared to T_2 and T_4 in both the years.

Table 21. Population of thrips as affected by various treatments.

Treatments	Population of thrips per plant	
	1998-99	1999-2000
Varieties		
V ₁	7.27 (2.78)	6.58 (2.66)
V ₂	10.42 (3.30)	12.64 (3.62)
S.E. $\pm$	0.03	0.03
C.D. at 5%	0.09	0.09
Treatments		
T ₁	2.65 (1.77)	2.34 (1.68)
T ₂	8.22 (2.95)	7.90 (2.89)
T ₃	2.38 (1.69)	1.98 (1.57)
T ₄	11.32 (3.43)	10.86 (3.37)
S.E. $\pm$	0.04	0.04
C.D. at 5%	0.13	0.12
Interaction		
V ₁ T ₁	2.72 (1.79)	3.17 (1.91)
V ₁ T ₂	6.28 (2.60)	6.69 (2.68)
V ₁ T ₃	1.71 (1.48)	2.03 (1.59)
V ₁ T ₄	10.32 (3.28)	10.89 (3.37)
V ₂ T ₁	3.94 (2.10)	4.05 (2.13)
V ₂ T ₂	7.20 (2.77)	7.41 (2.81)
V ₂ T ₃	2.40 (1.70)	2.50 (1.73)
V ₂ T ₄	12.50 (3.60)	13.32 (3.71)
S.E. $\pm$	0.06	0.06
C.D. at 5%	0.18	0.18

Figures in parenthesis are $\sqrt{x+0.5}$ values

During 1999-2000, T_3 had lowest population of thrips as compared to T_1 , T_2 and T_4 .

4.2.3 Population of *Helicoverpa armigera* on leaves

The data pertaining to population of *Helicoverpa armigera* on leaves are presented in Table 22.

The differences in population in two varieties during 1998-99 and 1999-2000 were significant. The spray treatments and interaction effects were significant in both the seasons.

The population of *Helicoverpa armigera* on leaves was higher in variety Co-1 than in Lats₁ in both the seasons.

Further the results indicated that significantly lowest population of *Helicoverpa armigera* on leaves was recorded in the plots where the crop was treated completely throughout growth period (T_3) and in the plots where the crop was protected during vegetative stage (T_1). The population of the pest was significantly low in the plots treated during reproductive stage (T_2) as compared to the plots kept untreated throughout growth period (T_4) during 1998-99 and 1999-2000.

4.2.4 Population of *Helicoverpa armigera* on capsules

The data pertaining to population of *Helicoverpa armigera* on capsules are presented in Table 23.

Table 22. Population of *Helicoverpa armigera* on leaves as affected by various treatments

Treatments	Population of <i>H. armigera</i> on leaves	
	1998-99	1999-2000
Varieties		
V ₁	0.04 (0.73)	0.06 (0.74)
V ₂	0.05 (0.74)	0.07 (0.75)
S.E. $\pm$	0.002	0.001
C.D. at 5%	0.008	0.005
Treatments		
T ₁	0.04 (0.73)	0.05 (0.74)
T ₂	0.08 (0.76)	0.07 (0.75)
T ₃	0.02 (0.72)	0.03 (0.72)
T ₄	0.12 (0.78)	0.14 (0.80)
S.E. $\pm$	0.004	0.002
C.D. at 5%	0.012	0.007
Interaction		
V ₁ T ₁	0.04 (0.73)	0.04 (0.73)
V ₁ T ₂	0.06 (0.74)	0.07 (0.75)
V ₁ T ₃	0.02 (0.72)	0.03 (0.72)
V ₁ T ₄	0.14 (0.80)	0.16 (0.81)
V ₂ T ₁	0.05 (0.74)	0.06 (0.74)
V ₂ T ₂	0.08 (0.76)	0.09 (0.76)
V ₂ T ₃	0.03 (0.72)	0.04 (0.73)
V ₂ T ₄	0.15 (0.80)	0.18 (0.82)
S.E. $\pm$	0.005	0.003
C.D. at 5%	0.017	0.010

Figures in parenthesis are $\sqrt{x+0.5}$ values.

Table 23. Population of *Helicoverpa armigera* on capsules as affected by various treatments

Treatments	Population of <i>H. armigera</i> on capsules	
	1998-99	1999-2000
Varieties		
V ₁	0.18 (0.82)	0.20 (0.83)
V ₂	0.76 (1.12)	0.84 (1.15)
S.E. $\pm$	0.002	0.002
C.D. at 5%	0.008	0.006
Treatments		
T ₁	0.70 (1.09)	0.64 (1.06)
T ₂	0.16 (0.81)	0.12 (0.78)
T ₃	0.06 (0.74)	0.09 (0.76)
T ₄	0.85 (1.16)	0.94 (1.20)
S.E. $\pm$	0.004	0.002
C.D. at 5%	0.012	0.008
Interaction		
V ₁ T ₁	0.70 (1.09)	0.72 (1.10)
V ₁ T ₂	0.17 (0.81)	0.20 (0.83)
V ₁ T ₃	0.07 (0.75)	0.08 (0.76)
V ₁ T ₄	0.87 (1.17)	0.92 (1.19)
V ₂ T ₁	0.76 (1.12)	0.79 (1.13)
V ₂ T ₂	0.20 (0.83)	0.22 (0.84)
V ₂ T ₃	0.08 (0.76)	0.09 (0.76)
V ₂ T ₄	0.95 (1.20)	0.99 (1.22)
S.E. $\pm$	0.005	0.004
C.D. at 5%	0.017	0.012

Figures in parenthesis are $\sqrt{x+0.5}$ values.

Both the varieties, spray treatments and interaction effects during 1998-99 and 1999-2000 revealed significant results in respect of lowering the population of *Helicoverpa armigera* on capsules. The population of *Helicoverpa armigera* on capsules was more on the variety Co-1 as compared to Lats₁.

Table 23 revealed that significantly lowest population of *Helicoverpa armigera* on capsules was recorded in the plots where the crop was protected completely throughout growth period (T₃) and in the plots where the crop was protected during reproductive stage (T₂) during both the seasons.

Significantly lower population of *Helicoverpa armigera* on capsules was recorded in Lats₁ with T₂ and T₃ treatment combinations. In case of Co-1, lowest population of *Helicoverpa armigera* was recorded in T₃ treatment combination in both the seasons.

4.2.5 Population of safflower caterpillar

The data pertaining to the population of safflower caterpillar are presented in Table 24.

Both the varieties, spray treatments and interaction effects during 1998-99 and 1999-2000 revealed significant results in respect of lowering the population of safflower caterpillar.

Table 24. Population of safflower caterpillar as affected by various treatments

Treatments	Population of safflower caterpillar	
	1998-99	1999-2000
Varieties		
V ₁	0.05 (0.74)	0.08 (0.76)
V ₂	0.08 (0.76)	0.10 (0.77)
S.E. $\pm$	0.002	0.001
C.D. at 5%	0.007	0.005
Treatments		
T ₁	0.03 (0.72)	0.02 (0.72)
T ₂	0.06 (0.74)	0.07 (0.75)
T ₃	0.01 (0.71)	0.02 (0.72)
T ₄	0.12 (0.78)	0.16 (0.81)
S.E. $\pm$	0.003	0.002
C.D. at 5%	0.010	0.008
Interaction		
V ₁ T ₁	0.02 (0.72)	0.03 (0.72)
V ₁ T ₂	0.05 (0.74)	0.07 (0.75)
V ₁ T ₃	0.01 (0.71)	0.01 (0.71)
V ₁ T ₄	0.14 (0.80)	0.16 (0.81)
V ₂ T ₁	0.05 (0.74)	0.06 (0.74)
V ₂ T ₂	0.07 (0.75)	0.07 (0.75)
V ₂ T ₃	0.02 (0.72)	0.03 (0.72)
V ₂ T ₄	0.18 (0.82)	0.18 (0.82)
S.E. $\pm$	0.005	0.003
C.D. at 5%	0.015	0.011

Figures in parenthesis are $\sqrt{x+0.5}$ values.

Comparatively, higher population of safflower caterpillar was recorded during 1999-2000 as compared to 1998-99. Significant reduction in pest population was observed in T_1 and T_3 as compared to T_2 and T_4 during first season. During the year, 1999-2000 T_4 recorded highest population of the pest whereas T_1 and T_3 were at par with each other.

4.2.6 Effect of treatments on various parameters

Biometric parameters

The data on biometric parameters are presented in Table 25 and 26 and graphically represented in Fig. 6.

4.2.6.1 Plant height

The varieties, spray treatments and interaction effects were found to be significant in both the seasons.

The height of the plants in Lats₁ was recorded significantly more as compared to Co-1 in both the seasons.

The plant height in the treatments of protection during vegetative stage (T_1), protection during reproductive stage (T_2) and complete protection throughout growth period (T_3) was significantly more as compared to unsprayed plots throughout growth period (T_4). Similar trend was obtained during 1999-2000.

Significant reduction in height was observed in Lats₁ with T_4 Combination, while the height was found to be increased in the same variety with T_1 , T_2 and T_3

Table 25. Biometric parameters as influenced by various treatments.

Treatments	Plant height (cm)		Length of shoot (cm)	
	1998-99	1999-2000	1998-99	1999-2000
Varieties				
V ₁	70.20	68.48	59.40	58.90
V ₂	62.35	59.90	57.00	55.28
S.E. $\pm$	0.01	0.09	0.03	0.02
C.D. at 5%	0.05	0.27	0.11	0.08
Treatments				
T ₁	75.42	73.58	65.72	63.80
T ₂	72.46	70.68	62.90	61.28
T ₃	82.00	79.90	73.20	70.56
T ₄	56.00	54.20	48.50	46.92
S.E. $\pm$	0.02	0.12	0.05	0.03
C.D. at 5%	0.08	0.38	0.16	0.11
Interaction				
V ₁ T ₁	76.24	73.58	68.48	66.90
V ₁ T ₂	72.00	70.24	66.00	64.92
V ₁ T ₃	84.36	81.16	77.38	75.46
V ₁ T ₄	55.38	52.20	50.64	47.50
V T	62.94	60.28	57.20	56.48
V ₂ T ₂	59.40	57.92	54.38	53.00
V ₂ T ₃	70.46	70.00	64.38	64.00
V ₂ T ₄	54.00	52.70	49.90	48.68
S.E. $\pm$	0.03	0.18	0.07	0.05
C.D. at 5%	0.11	0.54	0.22	0.16

combinations in both the seasons. Similar trend was observed in the variety Co-1 during 1998-99 and 1999-2000 (Table 25).

4.2.6.2 Length of shoot

The varieties, spray treatments and interaction effects were found to be significant in both the seasons.

Length of shoot in the variety Lats₁ was slightly more as compared to Co-1 in both the trials.

Table 25 revealed that length of shoot was not affected significantly in T₁, T₂ and T₃ treatments but increased significantly in the same treatments over T₄ during both the seasons.

During 1998-99 and 1999-2000, length of shoot was affected significantly in T₄ treatment combination with Lats₁ as compared to T₁, T₂ and T₃ combinations with the same variety. In co-1 with T₃ combination, significant increase in length of shoot was observed as compared to T₁ and T₂ combinations, while T₁ and T₂ combinations with the same variety were found to be at par with each other in both the seasons.

In 1998-99 and 1999-2000, the variety Lats₁ with T₁ and T₂ combinations found at par with each other.

4.2.6.3 Number of leaves per plant

The varieties, spray treatments and interaction effects were found to be significant in both the seasons.

Table 26. Biometric parameters as influenced by various treatments.

Treatments	No. of leaves/plant		No. of spines/leaf	
	1998-99	1999-2000	1998-99	1999-2000
Varieties				
V ₁	60.40	55.28	62.40	58.92
V ₂	54.36	50.62	56.82	53.00
S.E. $\pm$	0.03	0.019	0.03	0.01
C.D. at 5%	0.10	0.057	0.09	0.04
Treatments				
T ₁	55.94	57.20	54.00	56.28
T ₂	49.48	52.40	48.20	50.00
T ₃	64.34	61.38	62.98	64.00
T ₄	45.00	42.76	42.36	40.00
S.E. $\pm$	0.04	0.027	0.04	0.02
C.D. at 5%	0.14	0.081	0.14	0.06
Interaction				
V ₁ T ₁	62.38	64.20	60.00	64.00
V ₁ T ₂	57.90	55.00	56.20	52.38
V ₁ T ₃	68.00	70.94	66.00	68.32
V ₁ T ₄	48.00	50.94	44.90	46.20
V ₂ T ₁	56.50	59.24	54.00	52.68
V ₂ T ₂	53.00	54.36	50.00	48.20
V ₂ T ₃	64.48	66.20	65.20	64.94
V ₂ T ₄	45.40	42.00	44.00	42.38
S.E. $\pm$	0.06	0.038	0.06	0.03
C.D. at 5%	0.20	0.115	0.19	0.09

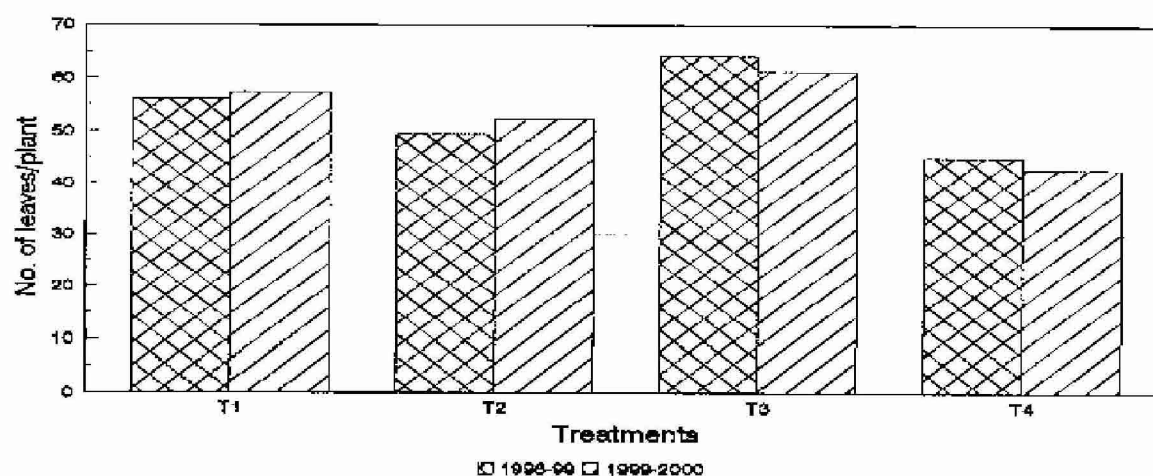
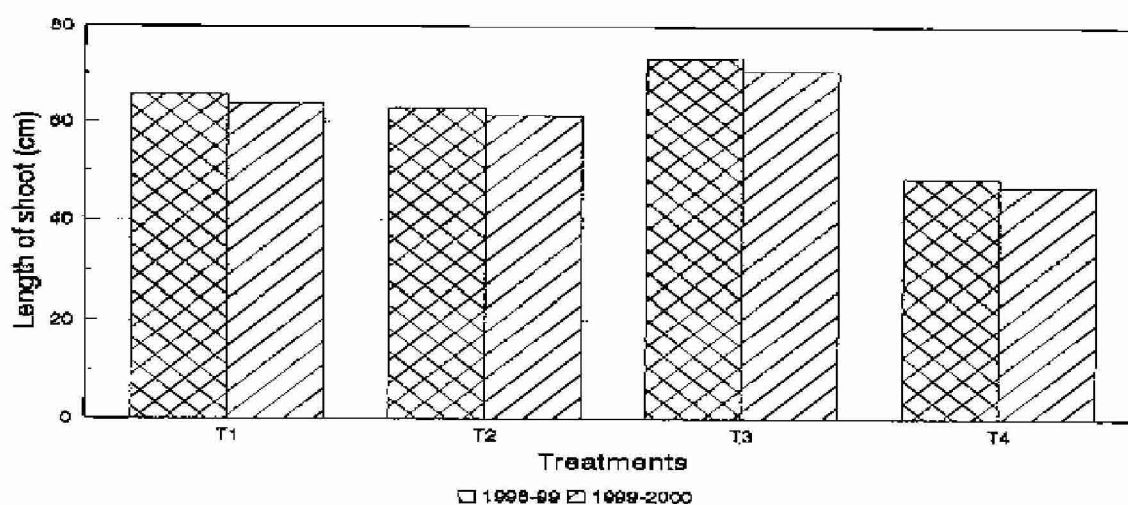
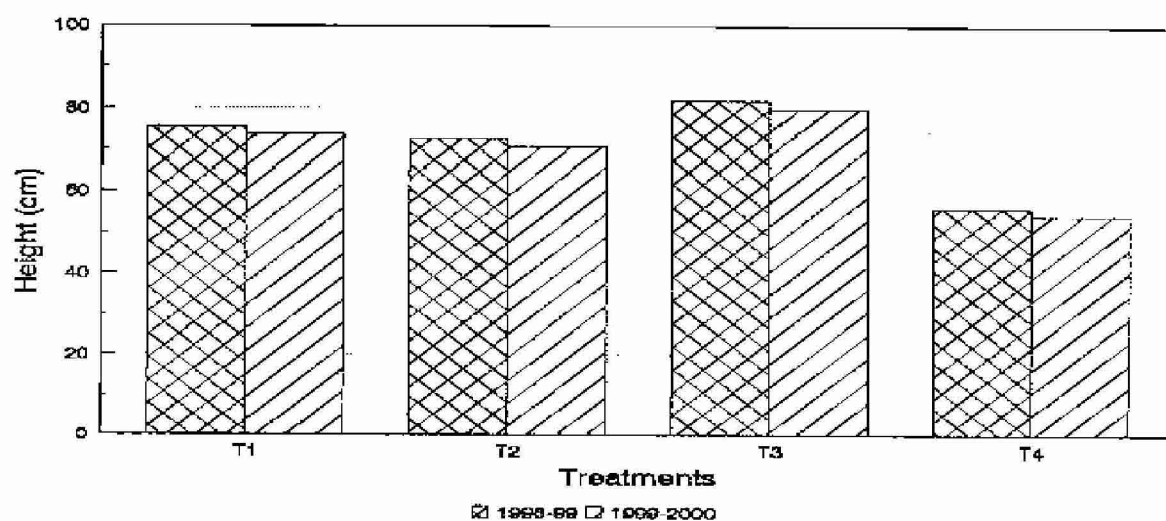


Fig. 6. Biometric parameters as influenced by various treatments

Increase in number of leaves per plant was observed in Lats₁ as compared to Co-1 during both the seasons.

During 1998-99 and 1999-2000, significant reduction was observed in the treatment T₄ as compared to rest of the treatments. In the treatment T₃, significant increase in number of leaves was observed over T₁ and T₂. Whereas in 1999-2000, the number of leaves per plant were found to be increased in T₁ and T₂ than in 1998-99.

Significant reduction was found in number of leaves corresponding to the combination of treatment T₄ with Lats₁ in both the seasons. Number of leaves were found to be increased significantly during 1999-2000 in T₁ and T₃ combinations with co-1 over T₄. During 1998-99 and 1999-2000, T₁ and T₃ combinations of both the varieties were found to be significant over T₂ (Table 26).

4.2.6.4 Number of spines per leaf

The varieties, spray treatments and interaction effects were found to be significant in both the seasons. Number of spines per leaf in Lats₁ were recorded more as compared to Co-1 in both the seasons.

Number of spines per leaf in the treatments of protection during vegetative stage (T₁), protection during reproductive stage (T₂) and complete protection during reproductive stage (T₃) were significantly more as compared

to unsprayed plots throughout growth period (T_4). Similar trend was obtained during 1999-2000.

Significant reduction in number of spines per leaf was observed in Lats₁ with T_4 combination, while the spines were found to be increased in the same variety with T_1 , T_2 and T_3 combinations in both the seasons. Similar trend was observed in the variety co-1 during 1998-99 and 1999-2000 (Table 26).

Yield and yield components

The relevant data pertaining to yield in kg/ha and yield components are presented in Table 27 and graphically depicted in Fig. 7.

4.2.6.5 Number of capitula per plant

The varieties, spray treatments and interaction effects were found to be significant in both the seasons.

Number of capitula per plant were significantly more in Lats₁ than in co-1 in both the trials. Significantly more number of capitula per plant were obtained from T_1 and T_3 where as, they were significantly reduced in T_2 and T_4 treatments in both the years.

During 1998-99 and 1999-2000, significant increase in number of capitula per plant was observed in treatment combination of T_1 and T_3 with both the varieties i.e. Lats₁ and Co-1 as compared to the combination of T_2 and T_4 . Lats₁ with T_2 combination recorded significantly more number of

Table 27. Yield and yield components as influenced by various treatments.

Treatments	No.of capitula/ plant		No.of seeds/ capsule		Yield (kg/ha)	
	98-99	99-2000	98-99	99-2000	98-99	99-2000
Varieties						
V ₁	20.70	22.00	26.00	24.20	1650.00	1642.00
V ₂	11.80	13.00	13.65	11.00	778.68	770.92
S.E. $\pm$	0.04	0.04	0.03	0.03	38.42	41.18
C.D. at 5%	0.13	0.13	0.09	0.09	116.00	123.90
Treatments						
T ₁	18.40	17.50	24.38	22.58	1532.00	1524.00
T ₂	16.82	15.40	21.00	19.30	1510.00	1500.00
T ₃	21.20	19.80	27.58	25.36	1672.00	1668.00
T ₄	12.00	11.40	14.20	12.00	760.00	752.00
S.E. $\pm$	0.06	0.06	0.04	0.04	43.20	45.18
C.D. at 5%	0.18	0.19	0.14	0.13	132.62	139.70
Interaction						
V ₁ T ₁	18.40	18.00	25.72	25.48	1674.00	1667.00
V ₁ T ₂	17.72	17.54	22.98	22.74	1668.00	1664.00
V ₁ T ₃	23.40	23.20	30.12	29.54	1686.00	1682.00
V ₁ T ₄	13.82	13.54	16.24	16.10	1622.00	1614.00
V ₂ T ₁	17.90	17.70	23.00	23.00	922.00	916.00
V ₂ T ₂	15.62	15.62	21.46	21.18	870.00	864.00
V ₂ T ₃	22.40	22.10	28.54	28.36	1032.00	1024.00
V ₂ T ₄	11.00	10.60	13.00	12.28	720.00	713.00
S.E. $\pm$	0.08	0.08	0.06	0.06	50.22	52.20
C.D. at 5%	0.26	0.26	0.19	0.19	152.60	156.00

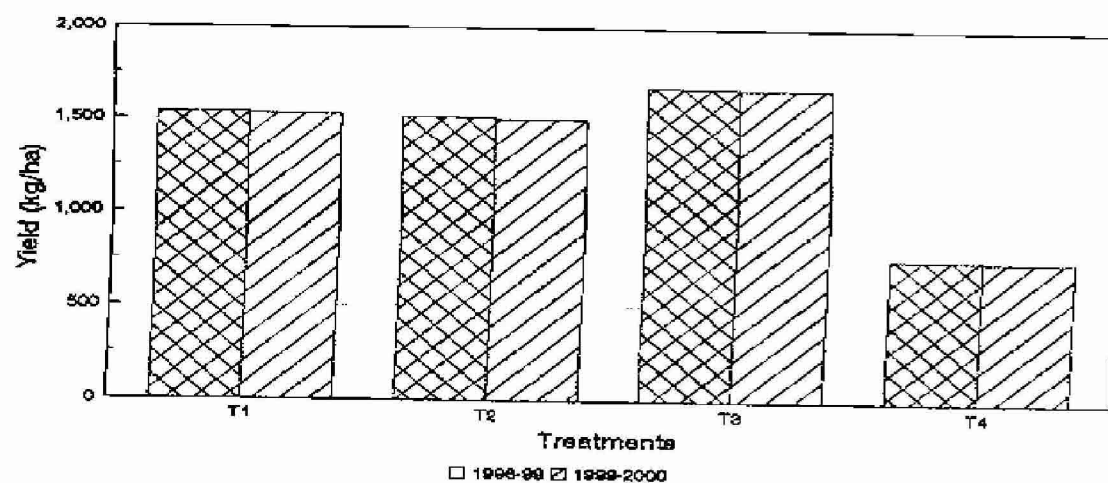
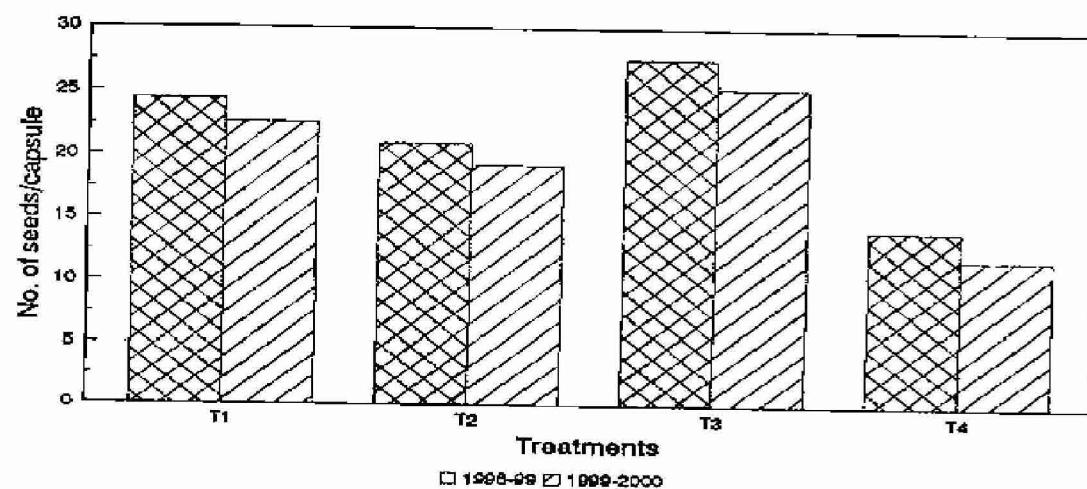
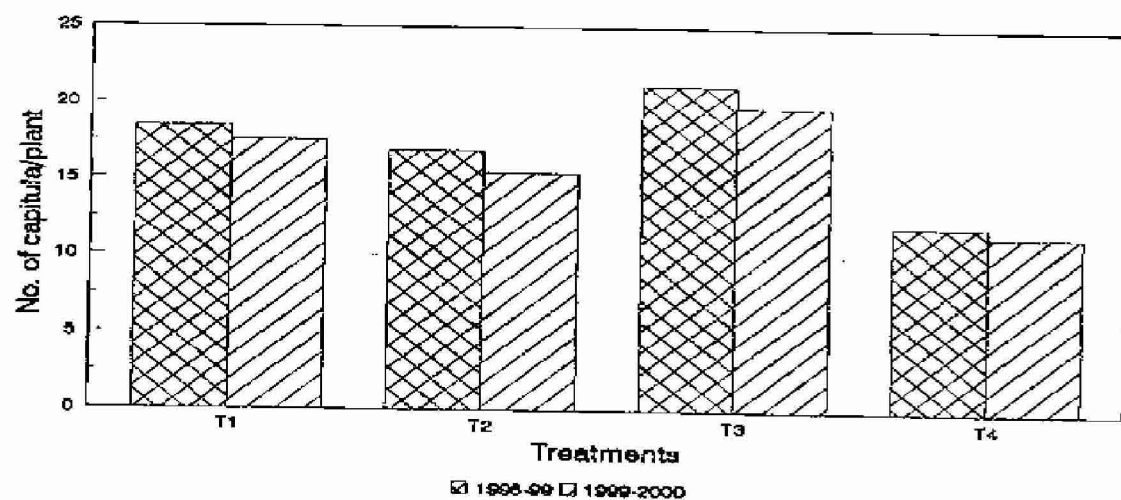


Fig. 7. Yield and yield components as influenced by various treatments

capitula per plant as compared to T_4 combination. Significantly more number of capitula per plant were observed in T_4 combination of Lats₁ than of Co-1.

4.2.6.6 Number of seeds per capsule

The varieties, spray treatments and interaction effects were found to be significant in both the seasons.

Number of seeds per capsule were significantly more in Lats₁ than in Co-1 in both the years.

During 1998-99 and 1999-2000, significant reduction was observed in the treatment T_4 as compared to rest of the treatments. In the treatment T_3 , significant increase in number of seeds per capsule was observed over T_1 and T_2 .

Significant reduction was found in number of seeds per capsule corresponding to the combination of treatment T_4 with Lats₁ in both the seasons. Similar was the trend with Co-1 in both the seasons. Number of seeds per capsule were found to be increased significantly during 1998-99 and 1999-2000 in T_1 and T_3 combinations with Lats₁ and Co-1 over T_4 . T_1 and T_3 combinations of both the varieties in both the years were found to be significant over T_2 .

4.2.6.7 Yield of safflower

The varieties, spray treatments and interaction effect were found to be significant in both the seasons.

Table 28. Yield of safflower as affected by various treatments.

Treatments	Yield(kg/ha)		Pooled mean

	1998-99	1999-2000	
Varieties			
V ₁	1650	1642	1646
V ₂	778	770	774
S.E. ±	38.42	41.18	40.26
C.D. at 5%	116.00	123.90	121.19
Treatments			
T ₁	1532	1524	1528
T ₂	1510	1500	1505
T ₃	1672	1668	1670
T ₄	760	752	756
S.E. ±	43.20	45.18	43.00
C.D. at 5%	132.62	139.70	129.18
Interaction			
V ₁ T ₁	1674	1667	1670
V ₁ T ₂	1668	1664	1666
V ₁ T ₃	1686	1682	1684
V ₁ T ₄	1622	1614	1618
V ₂ T ₁	922	916	919
V ₂ T ₂	870	864	867
V ₂ T ₃	1032	1024	1028
V ₂ T ₄	720	713	716
S.E. ±	50.22	52.20	48.00
C.D. at 5%	152.60	156.00	149.76

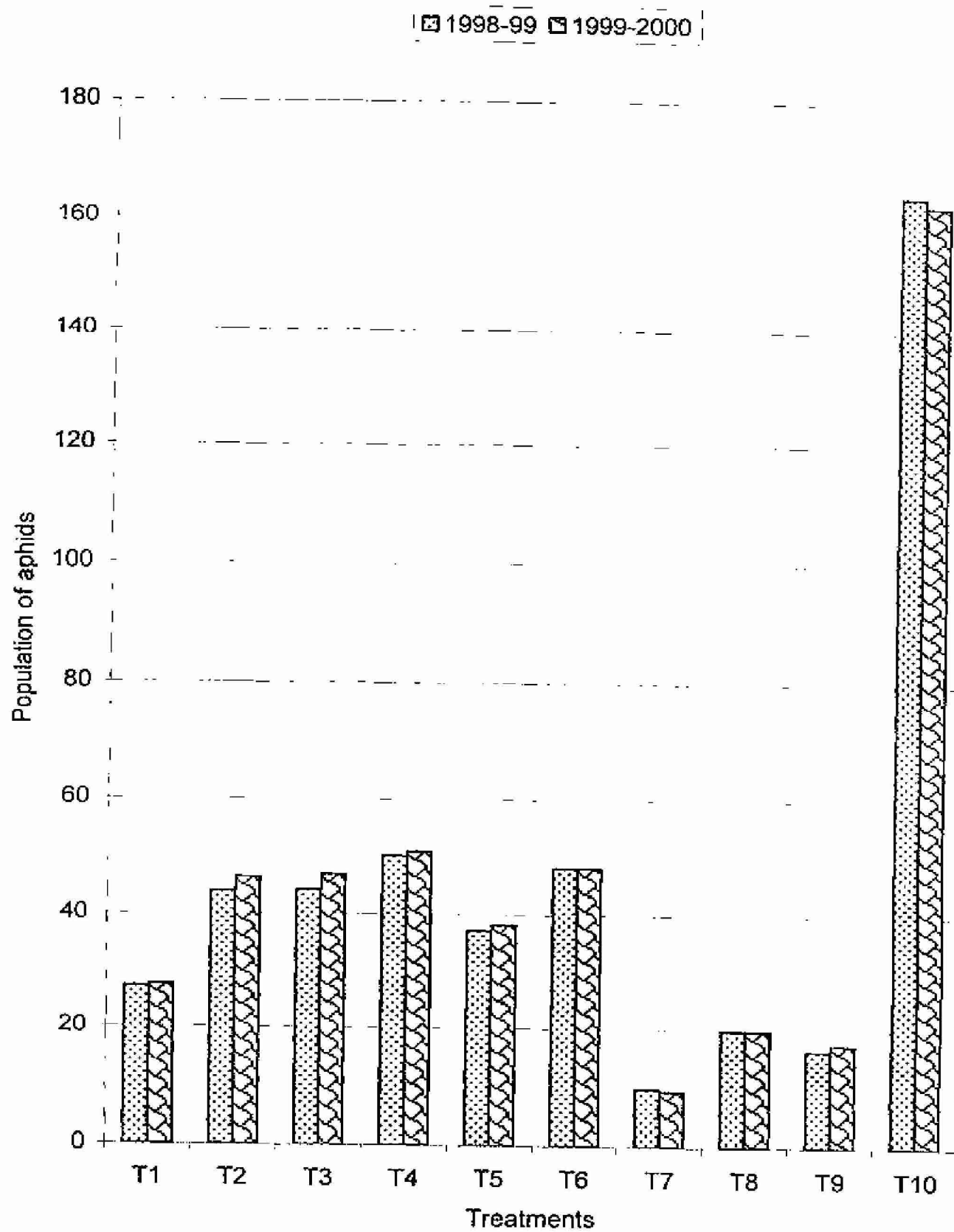


Fig. 8. Bio-efficacy of plant products against safflower aphids

Significantly increased safflower seed yield in Lats₁ was recorded than that of Co-1 in both the years.

In both the seasons, the treatment T₁ and T₃ recorded significantly higher yield of safflower over T₂ and T₄. Likewise the yield in T₂ was also increased significantly as compared to T₄ in both the trials. Significant reduction was found in yield of safflower corresponding to the combination of treatment T₄ followed by T₂ with Co-1 in 1998-99 as well as in 1999-2000. Lats₁ with T₂ combination recorded the yield which was at par with T₁ combination with the same variety in both the years similar results were also obtained in pooled analysis of both the seasons (Table 28.)

4.2.7 Crop losses due to safflower pest complex

The data pertaining to per cent losses assessed due to safflower pest complex in various parameters are presented in Table 29.

4.2.7.1 Effect on Biometric parameters

4.2.7.1.1 Plant height

Sucking pest complex reduced the plant height by 3.98 and 7.20 per cent in Lats₁ and Co-1 during 1998-99 while 4.46 and 8.00 per cent during 1999-2000 respectively.

Helicoverpa armigera also affected the plant height. During 1998-99 and 1999-2000, 1.40 and 1.16 per cent reduction in the height was observed in Co-1, while

the height of Lats₁ was not much affected during the same period.

Safflower caterpillar reduced the plant height by 0.38 and 0.40 per cent in Lats₁ while 0.46 and 0.50 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

4.2.7.1.2 Length of shoot

Feeding due to the sucking pest complex had also affected the length of shoot. The reduction in length of shoot of Lats₁ and Co-1 during 1998-99 was 2.72 and 5.38 per cent respectively and 3.10 and 5.74 per cent in Lats₁ and Co-1 during 1999-2000.

Similarly, due to infestation of *Helicoverpa armigera* 0.54 per cent and 0.48 per cent reduction in Lats₁ during first and second season was noted. In Co-1, 0.74 per cent reduced length of shoot was obtained in 1998-99 and 0.46 per cent in 1999-2000.

In Lats₁, 0.29 and 0.32 per cent reduction was observed during 1998-99 and 1999-2000 in length of shoot due to safflower caterpillar. While in Co-1, 0.33 and 0.35 per cent reduction was noticed in first and second season respectively.

4.2.7.1.3 Number of leaves per plant

Sucking pest complex reduced the number of leaves per plant by 2.00 and 2.58 per cent in Lats₁ and Co-1 during 1998-99, while 1.98 and 2.76 per cent during 1999-2000 respectively.

Attack of *Helicoverpa armigera* also affected the number of leaves per plant. During 1998-99 and 1999-2000, 0.16 and 0.10 per cent reduction in number of leaves was observed in Lats₁ while 0.30 and 0.34 per cent in Co-1 during both the seasons was observed.

Safflower caterpillar reduced more number of leaves in Co-1 than in Lats₁. The pest reduced the number of leaves per plant by 0.90 and 0.98 per cent in Co-1 and 0.46 and 0.54 per cent in Lats₁ during 1998-99 and 1999-2000.

4.2.7.1.4 Number of spines per leaf

Influence of sucking pest complex on number of spines per leaf was not observed in Lats₁ while 1.52 and 1.20 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

The effect of *Helicoverpa armigera* in reducing number of spines was nil in Lats₁ during 1998-99 while 0.02 per cent reduction was noted during 1999-2000. However, 0.06 and 0.08 per cent reduction in number of spines per leaf was recorded in Co-1 during 1998-99 and 1999-2000.

Influence of safflower caterpillar on number of spines per leaf was not observed in Lats₁ while 0.16 and 0.18 per cent was noted in Co-1 during 1998-99 and 1999-2000 respectively.

4.2.7.2 Effect on yield and yield components

4.2.7.2.1 Number of capitula per plant

Incidence of sucking pest complex had also significantly affected the number of capitula per plant. The reduction in number of capitula of Lats₁ was 8.42 and 8.68 per cent in 1998-99 and 1999-2000 respectively while 10.94 and 11.36 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

The reduction in number of capitula as influenced by *Helicoverpa armigera* was more in Co-1 as compared to Lats₁. The reduction in number of capitula during 1998-99 and 1999-2000 was 1.34 and 1.66 per cent in Lats₁ while 2.94 and 3.00 per cent in Co-1 respectively.

Very low response was obtained in reducing number of capitula due to safflower caterpillar infestation. In Lats₁, number of capitula were reduced by 0.24 per cent during 1998-99 and 0.28 per cent during 1999-2000. The per cent reduction in number of capitula in Co-1 was 0.32 and 0.36 per cent during first and second season, respectively.

4.2.7.2.2 Number of seeds per capsule

Sucking pest complex reduced the number of seeds per capsule by 7.98 and 8.32 per cent in Lats₁ and 10.84 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

Helicoverpa armigera infestation also affected the number of seeds per capsule. During 1998-99 and 1999-2000,

3.00 and 3.16 per cent reduction in number of seeds was observed in Lats₁ while 3.74 and 4.12 per cent in Co-1 during the same period.

Very low response was obtained in reducing number of seeds per capsule due to safflower caterpillar. The loss in number of seeds per capsule was more in Co-1 than in Lats₁ during both the seasons.

4.2.7.2.3 Yield of safflower

In present investigation, sucking pest complex viz., aphids and thrips had affected the yield considerably. The losses to the tune of 17.35 and 18.46 per cent were recorded in Lats₁ and 23.36 and 24.40 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

Marked reduction in yield due to *Helicoverpa armigera* was observed in Co-1 as compared to Lats₁. During 1998-99, 5.38 per cent loss in yield was noted in Lats₁ While in Co-1, 8.58 per cent loss was recorded. During 1999-2000, in Lats₁ 6.10 per cent loss and 9.10 per cent loss in Co-1 was obtained.

Very low response was noticed in reducing yield due to safflower caterpillar. The cultivar, Lats₁ recorded 1.72 and 1.86 per cent loss during 1998-99 and 1999-2000 respectively. As regards Co-1, per cent loss was more in second season as compared to first season.

Table 29. Per cent crop losses due to safflower pest complex.

Chracters	Sucking pest complex		Helicoverpa armigera		Safflower caterpillar							
	Lats ₁	Co-1	Lats ₁	Co-1	Lats ₁	Co-1						

	1998- 99-	1998- 99-	1998- 99-	1998- 99-	1998- 99-	1998- 99-						
	99 2000	99 2000	99 2000	99 2000	99 2000	99 2000						

Biometric parameters												
Plant height (cm)	3.98	4.46	7.20	8.00	0.76	0.94	1.40	1.16	0.38	0.40	0.46	0.50
Length of shoot (cm)	2.72	3.10	5.38	5.74	0.54	0.48	0.74	0.46	0.29	0.32	0.33	0.35
No. of leaves/plant	2.00	1.98	2.58	2.76	0.16	0.10	0.30	0.34	0.46	0.54	0.90	0.98
No. of spines/leaf	0.00	0.00	1.52	1.20	0.00	0.02	0.06	0.08	0.00	0.00	0.16	0.18
Yield and yield components												
No. of cpitula/plant	8.42	8.68	10.94	11.36	1.34	1.66	2.94	3.00	0.24	0.28	0.32	0.36
No. of seeds/capsule	7.98	8.32	10.20	10.84	3.00	3.16	3.74	4.12	1.00	0.78	1.12	1.24
Yield (kg/ha)	17.35	18.46	23.36	24.40	5.38	6.10	8.58	9.10	1.72	1.86	1.94	2.00

4.3 Management of safflower pest complex through botanical insecticides

4.3.1 Bio-efficacy of plant products against safflower aphids

The data on population of aphids per plant are presented in Table 30 and graphically depicted in Fig. 8.

It is evident from the Table 30 that all the insecticidal treatments were significantly superior over control in both the seasons. During 1998-99, significantly low population of aphids was recorded in all the treatments. Lowest population of aphid was recorded in methyl demeton 0.05 per cent (T_7) and was significantly superior over nimbicidin 0.5 per cent (T_1), bioneem 0.3 per cent (T_2), neem oil 3.0 per cent (T_3), castor oil 1.0 per cent (T_4), neemark 1.0 per cent (T_5), neem gold 0.5 per cent (T_6) Thiamethoxam 0.01 per cent (T_8) and endosulphan 0.05 per cent (T_9). Significant differences were not observed between the treatments T_1 and T_5 , T_5 and T_9 , T_4 and T_6 .

During 1999-2000, also lowest population of pest was recored in methyl demeton 0.05 per cent (T_7) and was significantly superior over rest of the treatments. Endosulphan 0.05 per cent (T_9) was at par with thiamethoxam 0.01 Per cent (T_8). Neem gold 0.5 per cent (T_6) was at par with castor oil 1.0 per cent (T_4). Significant

Table 30. Bioefficacy of plant products against safflower aphids (pooled 1998-99 and 1999-2000)

Sr. No.	Treatments	Conc. (%)	No. of aphids per plant		Pooled mean
			1998-99	1999-2000	
1.	Nimbicidin	0.5	27.09 (5.99)	27.47 (5.28)	5.63 (2.47)
2.	Bioneem	0.3	43.92 (6.66)	46.30 (6.84)	6.75 (2.69)
3.	Neem oil	3.0	44.17 (6.68)	46.89 (6.88)	6.78 (2.69)
4.	Castor oil	1.0	50.20 (7.12)	50.92 (7.17)	7.14 (2.76)
5.	Neemark	1.0	37.19 (6.13)	38.21 (6.22)	6.17 (2.58)
6.	Neemgold	0.5	48.13 (6.97)	48.14 (6.97)	6.97 (2.73)
7.	Methyl demeton	0.05	9.46 (3.18)	9.25 (3.12)	3.15 (1.91)
8.	Thiamethoxam	0.01	19.80 (4.50)	19.70 (4.49)	4.49 (2.23)
9.	Endosulphan	0.05	16.39 (6.28)	17.44 (4.23)	5.25 (2.39)
10.	Untreated control	--	164.06 (12.82)	162.41 (12.76)	12.79 (3.64)
S.E. $\pm$			0.08	0.09	0.11
C.D. at 5%			0.25	0.27	0.35

Figures in parenthesis are $\sqrt{x+0.5}$ values.

difference were not observed between the treatments T_2 , T_3 and T_6 .

Results of the pooled analysis for the year 98-99 and 99-2000 revealed that the treatment T_7 recorded lowest population of aphid and was significantly superior over rest of the treatments except T_8 . The treatment T_9 was superior over T_4 , However it was at par with T_1 , T_2 , T_3 , T_5 and T_6 . The treatment T_7 was at par with T_8 . However it is superior over rest of the treatments.

4.3.2 Bio-efficacy of plant products against safflower thrips

The data on population of thrips per plant are presented in Table 31 and graphically depicted in Fig. 9.

It is evident from Table 31 that all the insecticidal treatments were significantly superior over control in both the seasons. During 1998-99, lowest population of thrips was recorded in methyl demeton 0.05 per cent (T_7) and gave significantly lowest thrips population over the other treatments. Endosulphan 0.05 per cent (T_9) was at par with thiamethoxam 0.01 per cent (T_8) and however, it was significantly superior over rest of the treatments. The treatment T_1 was at par with T_2 and T_5 however it was significantly superior over rest of the treatments.

Table 31. Bio-efficacy of plant products against safflower thrips (pooled 1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	No. of thrips per plant		Pooled mean
			1998-99	1999-2000	
1.	Nimbicidin	0.5	3.20 (1.92)	3.28 (1.96)	1.94 (1.56)
2.	Bioneem	0.3	3.29 (1.94)	3.41 (1.97)	1.95 (1.56)
3.	Neem oil	3.0	3.79 (2.07)	3.90 (2.09)	2.08 (1.60)
4.	Castor oil	1.0	3.80 (2.07)	3.84 (2.08)	2.07 (1.60)
5.	Neemark	1.0	3.33 (1.95)	3.34 (1.95)	1.95 (1.56)
6.	Neemgold	0.5	3.77 (2.06)	3.77 (2.06)	2.06 (1.60)
7.	Methyl demeton	0.05	2.08 (1.60)	2.12 (1.61)	1.60 (1.44)
8.	Thiamethoxam	0.01	2.54 (1.74)	2.52 (1.73)	1.73 (1.49)
9.	Endosulphan	0.05	2.47 (1.72)	2.44 (1.71)	1.71 (1.48)
10.	Untreated control	--	9.44 (3.15)	9.52 (3.16)	3.15 (1.91)
S.E. $\pm$			0.02	0.02	0.02
C.D. at 5%			0.07	0.06	0.07

Figures in parenthesis are $\sqrt{x+0.5}$ values.

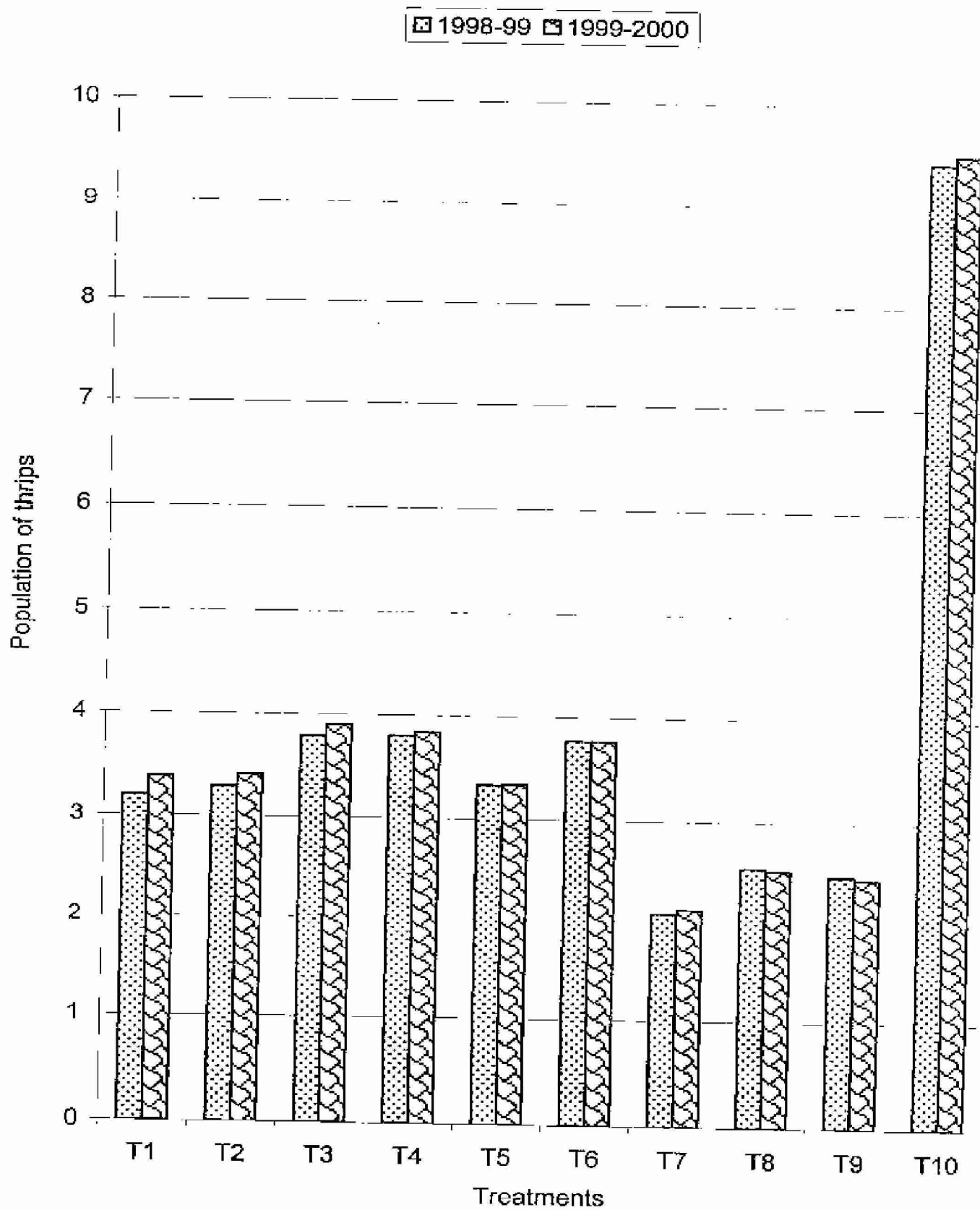


Fig. 9. Bio-efficacy of plant products against safflower thrips

During 1999-2000 lowest population of thrips, was recorded in methyl demeton 0.05 per cent (T_7) and was significantly superior over rest of the treatments. The treatment (T_9) was at par with (T_8) and was significantly superior over rest of the treatments. Neemark 1.0 per cent (T_5) influenced the thrips population significantly than neem gold 0.5 per cent (T_6), castor oil 1.0 per cent (T_4), neem oil 3.0 per cent (T_3), methyl demeton 0.05 per cent (T_7), endosulphan 0.05 per cent (T_9) and thiamethoxam 0.01 Per cent (T_8) but did not differ significantly from the response of nimbicidin 0.5 per cent (T_1) and bioneem 0.3 per cent (T_2).

It is evident from the pooled data that the treatment T_7 recorded lowest population of thrips and was superior over T_1 , T_2 , T_3 , T_4 , T_5 and T_6 except T_8 and T_9 . The treatment T_1 was at par with T_2 , T_3 , T_4 , T_5 and T_6 however it was significantly superior over T_7 , T_8 , and T_9 .

4.3.3 Bio-efficacy of plant products against *Helicoverpa armigera* on leaves

The data on population of *Helicoverpa armigera* on leaves are presented in Table 32 and graphically depicted in Fig. 10.

It is evident from the Table 32 that all the insecticidal treatments were significantly superior over control in both the seasons. During 1998-99, methyl demeton

Table 32. Bio-efficacy of plant products against *Helicoverpa armigera* on leaves (pooled 1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	No. of <i>H. armigera</i> on leaves		Pooled mean
			1998-99	1999-2000	
1.	Nimbicidin	0.5	0.06 (0.74)	0.07 (0.75)	0.74 (1.13)
2.	Bioneem	0.3	0.05 (0.74)	0.05 (0.74)	0.74 (1.11)
3.	Neem oil	3.0	0.07 (0.75)	0.07 (0.75)	0.75 (1.11)
4.	Castor oil	1.0	0.06 (0.74)	0.06 (0.74)	0.74 (1.11)
5.	Neemark	1.0	0.03 (0.72)	0.04 (0.73)	0.72 (1.10)
6.	Neemgold	0.5	0.05 (0.74)	0.05 (0.74)	0.74 (1.11)
7.	Methyl demeton	0.05	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
8.	Thiamethoxam	0.01	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
9.	Endosulphan	0.05	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
10.	Untreated control	--	0.17 (0.81)	0.18 (0.82)	0.81 (1.14)
S.E. $\pm$			0.003	0.003	0.004
C.D. at 5%			0.009	0.010	0.012

Figures in parenthesis are $\sqrt{x+0.5}$ values.

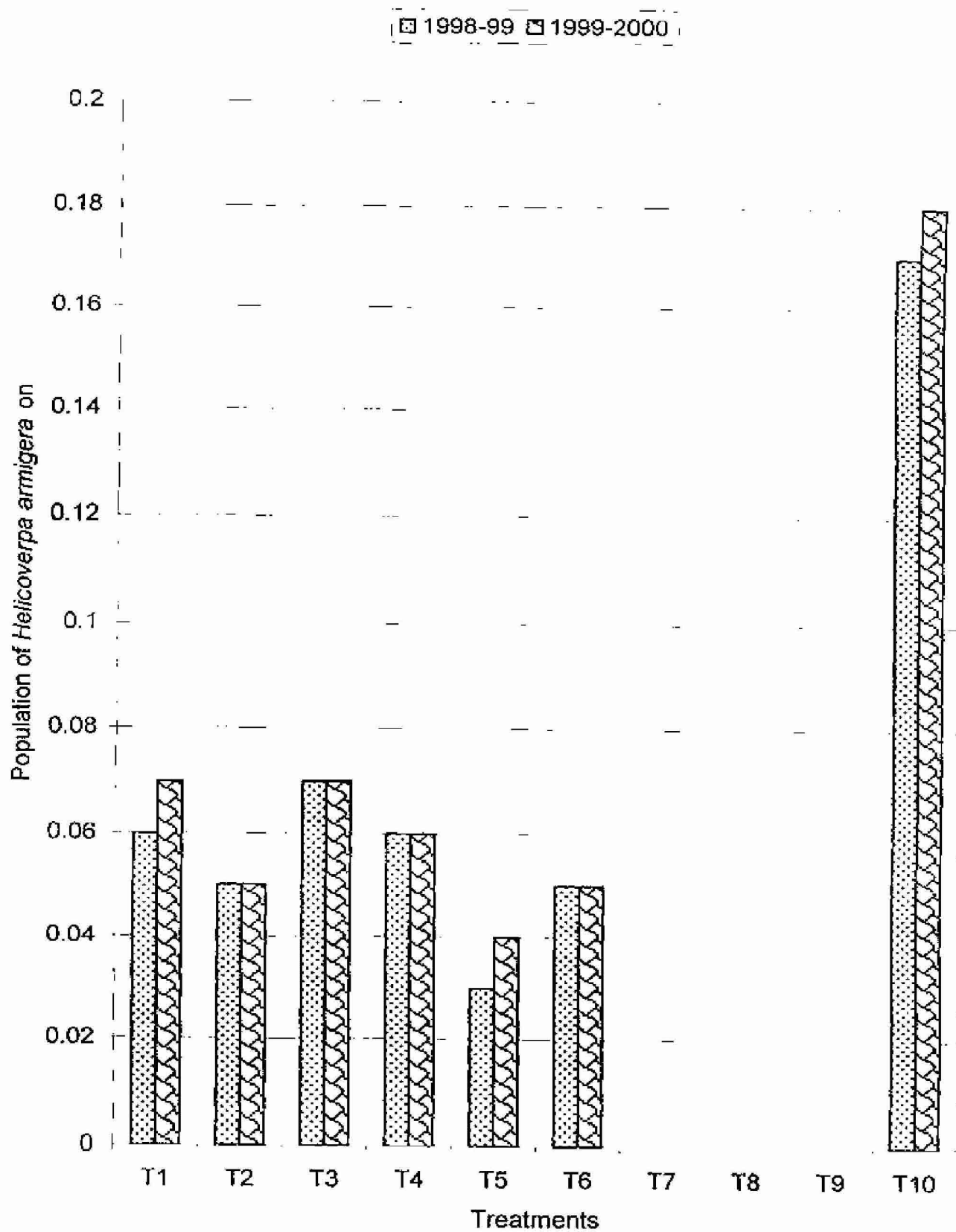


Fig. 10. Bio-efficacy of plant products against *Helicoverpa armigera* on leaves

0.05 per cent (T_7), thiamethoxam 0.01 per cent (T_8) and endosulphan 0.05 per cent (T_9) were at par with each other and were superior over neemark 1.0 per cent (T_5), nimbicidin 0.5 per cent (T_1), bioneem 0.3 per cent (T_2), castor oil 1.0 per cent (T_4) and neem oil 3.0 per cent (T_3). The treatments T_1 , T_2 , T_4 and T_6 were at par with each other and significantly superior over T_3 .

During 1999-2000, methyl demeton 0.05 per cent (T_7) influenced the population of *Helicoverpa armigera* on leaves significantly than neemark 1.0 per cent (T_5), bioneem 0.3 per cent (T_2), castor oil 1.0 per cent (T_4), neem gold 0.5 per cent (T_6), nimbicidin 0.5 per cent (T_1) and neem oil 3.0 per cent (T_3) but did not differ significantly from the response of thiamethoxam 0.01 per cent (T_8) and endosulphan 0.05 per cent (T_9).

The pooled data of two years 1998-99 and 1999-2000 presented in Table 32 revealed that all the insecticidal treatments were significantly superior over control in reducing the population of *Helicoverpa armigera* on leaves. Lowest population of *Helicoverpa armigera* was recorded in methyl demeton 0.05 per cent (T_7) and was at par with thiamethoxam 0.01 per cent (T_8) and endosulphan 0.05 per cent (T_9) but all these three treatments were significantly superior over rest of the treatments. Significant differences were not observed between the treatments T_2 , T_3 , T_4 and T_6 .

4.3.4 Bio-efficacy of plant products against *Helicoverpa armigera* on capsules

The data on population of *Helicoverpa armigera* on capsules are presented in Table 33 and graphically depicted in Fig. 11.

Table 33 revealed that all the insecticidal treatments were significantly superior over control in both seasons.

Significantly lowest population of *Helicoverpa armigera* on capsules during 1998-99 was recorded in the treatment methyl demeton 0.05 per cent (T_9). These treatments were found to be at par with each other and significantly superior over rest of the treatments. The treatments T_1 was superior over T_3 but at par with T_2 , T_4 and T_6 .

During 1999-2000, the treatment with methyl demeton 0.05 per cent influenced the population of the pest significantly than nimbicidin (0.5) per cent, bioneem (0.3) per cent, neem oil 3.0 per cent, castor oil 1.0 per cent, neemark 1.0 per cent and neem gold 0.5 per cent but did not differ significantly from the response of thiamethoxam 0.01 per cent and endosulphan 0.05 per cent. The treatment T_1 was superior over T_6 but was at par with T_2 , T_3 and T_4 .

Results of the pooled analysis for the years 1998-99 and 1999-2000 revealed that methyl demeton 0.05 per cent

Table 33. Bio-efficacy of plant products against *Helicoverpa armigera* on capsules (pooled 1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	No. of <i>H. armigera</i> on capsules		Pooled mean
			1998-99	1999-2000	
1.	Nimbicidin	0.5	0.06 (0.74)	0.06 (0.74)	0.74 (1.11)
2.	Bioneem	0.3	0.05 (0.74)	0.06 (0.74)	0.74 (1.11)
3.	Neem oil	3.0	0.07 (0.75)	0.06 (0.74)	0.74 (1.11)
4.	Castor oil	1.0	0.06 (0.74)	0.05 (0.74)	0.74 (1.11)
5.	Neemark	1.0	0.04 (0.73)	0.04 (0.73)	0.73 (1.10)
6.	Neemgold	0.5	0.06 (0.74)	0.07 (0.75)	0.74 (1.11)
7.	Methyl demeton	0.05	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
8.	Thiamethoxam	0.01	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
9.	Endosulphan	0.05	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
10.	Untreated control	--	0.13 (0.79)	0.12 (0.78)	0.78 (1.13)
S.E. $\pm$			0.004	0.004	0.004
C.D. at 5%			0.013	0.012	0.012

Figures in parenthesis are $\sqrt{x+0.5}$ values.

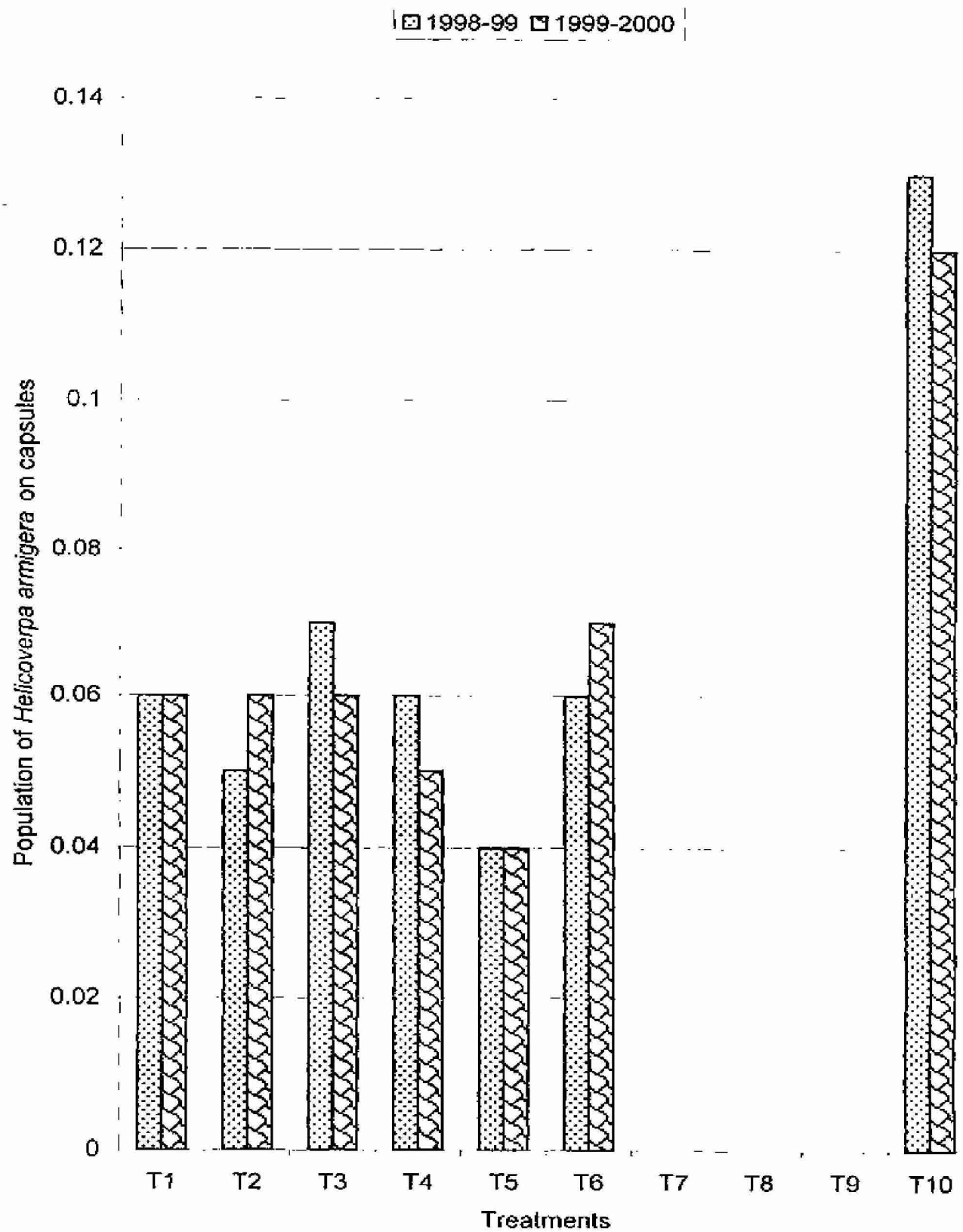


Fig. 11. Bio-efficacy of plant products against *Helicoverpa armigera* on capsules

(T₇) recorded lowest population of *Helicoverpa armigera* on capsules and was significantly superior over rest of the treatments except T₈ and T₉. There were no significant differences between the treatments T₁, T₂, T₃, T₄ and T₆.

4.3.5 Bio-efficacy of plant products against safflower caterpillar

The data on population of safflower caterpillar are presented in Table 34 and graphically depicted in Fig.12.

It is evident from Table 34 that all the insecticidal treatments were significantly superior over control in both seasons.

During 1998-99, lowest population of safflower caterpillar was recorded in methyl demeton 0.05 per cent (T₇) and was significantly superior over nimbicidin 0.5 per cent (T₁), bioneem 0.3 per cent (T₂), neem oil 3.0 per cent (T₃), Castor oil 1.0 per cent (T₄), neemark 1.0 per cent (T₅), neem gold 0.5 per cent (T₆) and thiamethoxam 0.01 per cent (T₈) but was at par with endosulphan 0.05 per cent (T₉). Bioneem 0.3 per cent (T₂) was significantly superior over neem gold 0.5 per cent (T₆) but was at par with castor oil 1.0 per cent (T₄), neemark 1.0 per cent (T₅) and nimbicidin 0.5 per cent (T₁).

During 1999-2000, methyl demeton 0.05 per cent (T₇) influenced the population of safflower caterpillar

Table 34. Bio-efficacy of plant products against safflower caterpillar (pooled 1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	No. of safflower caterpillar on leaves		Pooled mean
			1998-99	1999-2000	
1.	Nimbicidin	0.5	0.03 (0.72)	0.04 (0.73)	0.72 (1.10)
2.	Bioneem	0.3	0.03 (0.72)	0.03 (0.72)	0.72 (1.10)
3.	Neem oil	3.0	0.04 (0.73)	0.05 (0.74)	0.73 (1.10)
4.	Castor oil	1.0	0.02 (0.72)	0.03 (0.72)	0.72 (1.10)
5.	Neemark	1.0	0.02 (0.72)	0.02 (0.72)	0.72 (1.10)
6.	Neemgold	0.5	0.04 (0.73)	0.05 (0.74)	0.73 (1.10)
7.	Methyl demeton	0.05	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
8.	Thiamethoxam	0.01	0.01 (0.71)	0.02 (0.72)	0.71 (1.10)
9.	Endosulphan	0.05	0.00 (0.70)	0.00 (0.70)	0.70 (1.09)
10.	Untreated control	--	0.17 (0.81)	0.18 (0.82)	0.81 (1.14)
S.E. $\pm$			0.005	0.005	0.007
C.D. at 5%			0.017	0.015	0.022

Figures in parenthesis are $\sqrt{x+0.5}$ values.

1998-99 1999-2000

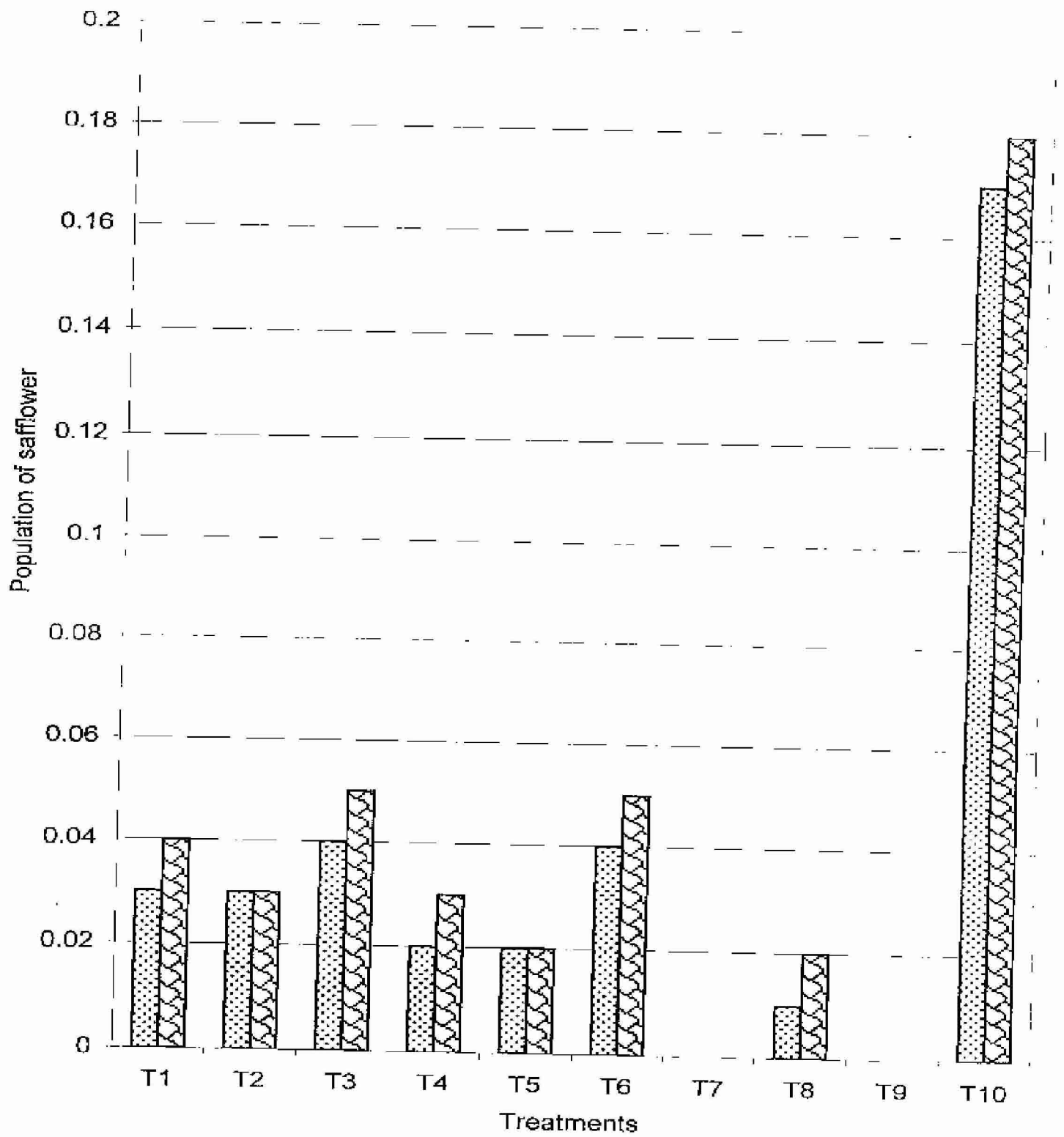


Fig. 12. Bio-efficacy of plant products against safflower caterpillar

significantly than bioneem 0.03 per cent (T_2), neem oil 3.0 per cent (T_3), castor oil 1.0 per cent (T_4), neem gold 0.5 per cent (T_6) and thiamethoxam 0.01 Per cent (T_8) but did not differ significantly from the response of endosulfan 0.05 per cent (T_9).

The pooled data of two years 1998-99 and 1999-2000 presented in Table 34 revealed that all the insecticidal treatments were significantly superior over control in reducing the population of safflower caterpillar on leaves. Lowest population of safflower caterpillar was recorded in methyl demeton 0.05 per cent spray (T_7) and was at par with endosulphan 0.05 per cent (T_9). There were no significant differences between the treatments T_1 , T_2 , T_3 , T_4 , T_5 , T_6 and T_8 .

4.3.6. Bioefficacy of plant products on yield of safflower

The data on yield of safflower during 1998-99 and 1999-2000 are presented in Table 35 and graphically depicted in Fig. 13.

Table 35 revealed that all the insecticidal treatments were significantly superior over control in both the seasons.

During 1998-99, highest yield of safflower was recorded in methyl demeton 0.05 per cent spray (T_7) and (T_1), bineem 0.03 per cent (T_2), neem oil 3.0 per cent

Table 35. Bio-efficacy of plant products on yield of safflower (Pooled 1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	Yield(kg/ha)		Pooled mean
			1998-99	1999-2000	
1.	Nimbicidin	0.5	1040.12	1045.86	1042.99
2.	Bioneem	0.3	847.76	850.68	849.22
3.	Neem oil	3.0	812.96	814.80	813.88
4.	Castor oil	1.0	778.77	775.82	777.29
5.	Neemark	1.0	886.48	891.75	889.11
6.	Neem gold	0.5	807.50	809.64	808.57
7.	Methyl demeton	0.05	1155.81	1158.20	1157.00
8.	Thiamethoxam	0.01	1127.87	1132.45	1130.16
9.	Endosulfan	0.05	1138.00	1140.62	1139.31
10.	Untreated control --		722.74	727.10	724.92
S.E. $\pm$			41.20	42.38	41.64
C.D. at 5%			125.72	130.46	127.00

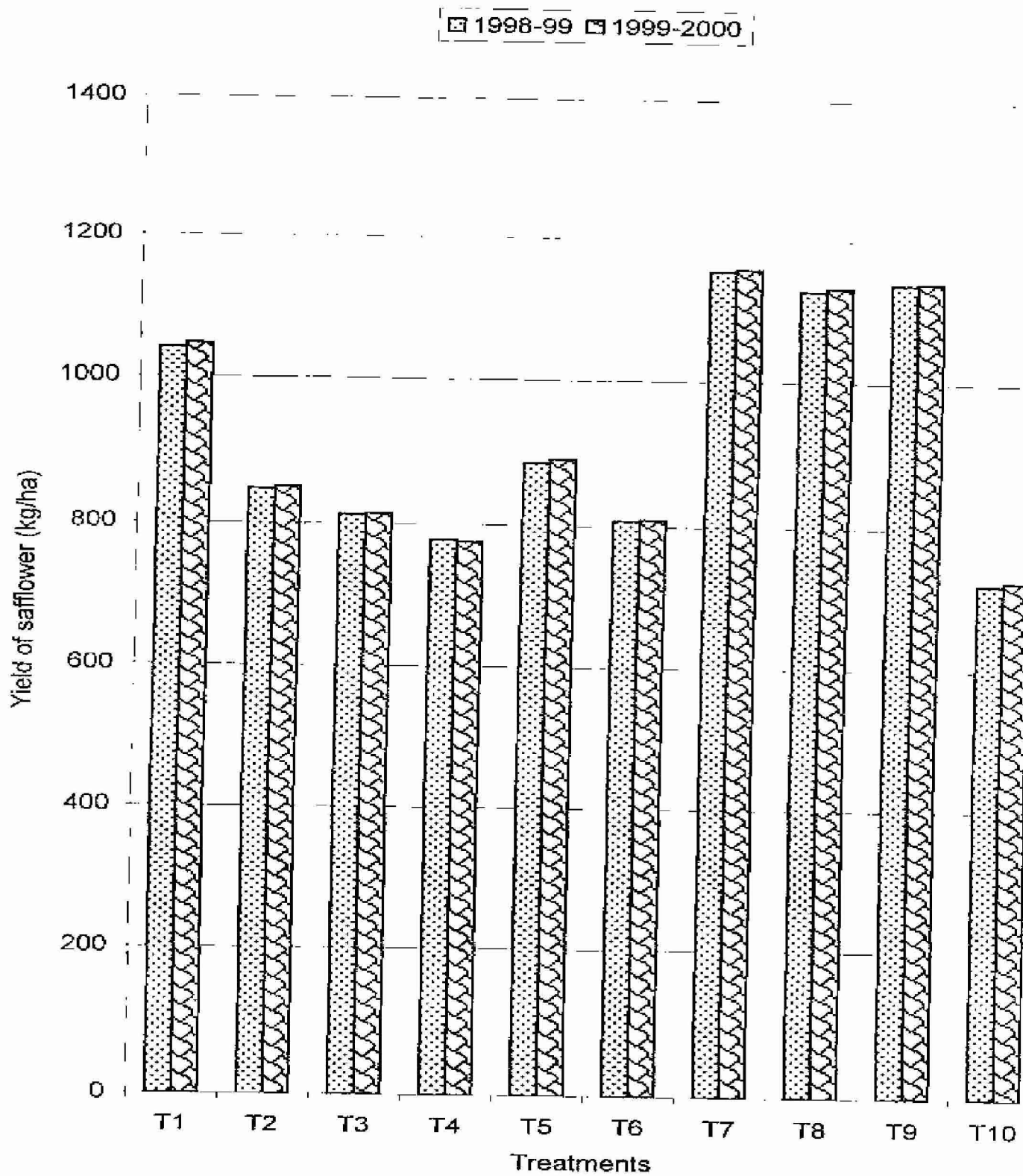


Fig. 13. Bio-efficacy of plant products on yield of safflower

(T₃), castor oil 1.0 per cent (T₄), neemark 1.0 per cent (T₅) and neem gold 0.5 per cent (T₆). However it was at par with tiamethoxam 0.01 Per cent (T₈) and endosulfan 0.05 per cent (T₉). The treatment (T₄) was at par with T₃ and T₆.

During 1999-2000, also the treatment T₇ was at par with T₈ and T₉ but significantly superior over T₁, T₂, T₃, T₄, T₅, and T₆. There were no significant differences between the treatments T₃, T₄ and T₆.

Results of the pooled analysis for the years 1998-99 and 1999-2000 revealed that highest yield of safflower was recorded in methyl demeton 0.05 per cent spray (T₇) and was significantly superior over rest of the treatments except T₈ and T₉. The spray of nimbicidin 0.5 per cent (T₁) was significantly superior over bioneem 0.3 per cent (T₂) neem oil 3.0 per cent (T₃), castor oil 1.0 per cent (T₄), neemark 1.0 per cent (T₅) and neem gold 0.5 per cent (T₆).

4.3.7 Effect of plant products on number of capsules per plant

The data on number of capsules per plant during 1998-99 and 1999-2000 are presented in Table 36 and graphically depicted in Fig. 14.

During 1998-99, all the chemical insecticides were significantly superior over the plant originated insecticides. Castor oil 1.0 per cent spray (T₄) was at par with untreated control (T₁₀) and neem gold 0.5 per cent

Table 36. Effect of plant products on number of capsules per plant (1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	No. of capsules/plant	
			1998-99	1999-2000
1.	Nimbicidin	0.5	10.00 (3.24)	9.66 (3.18)
2.	Bioneem	0.3	7.94 (2.90)	7.28 (2.78)
3.	Neem oil	3.0	7.20 (2.77)	7.00 (2.73)
4.	Castor oil	1.0	5.94 (2.53)	5.68 (2.48)
5.	Neemark	1.0	8.58 (3.01)	8.00 (2.91)
6.	Neem gold	0.5	6.92 (2.72)	6.50 (2.64)
7.	Methyl demeton	0.05	16.20 (4.08)	15.80 (4.03)
8.	Thiamethoxam	0.01	11.63 (3.48)	11.00 (3.39)
9.	Endosulphan	0.05	14.00 (3.80)	13.26 (3.70)
10.	Untreated control	--	6.32 (2.61)	6.28 (2.60)
S.E. $\pm$			0.08	0.08
C.D. at 5%			0.24	0.25

Figures in parenthesis are $\sqrt{x+0.5}$ values.

1998-99 1999-2000

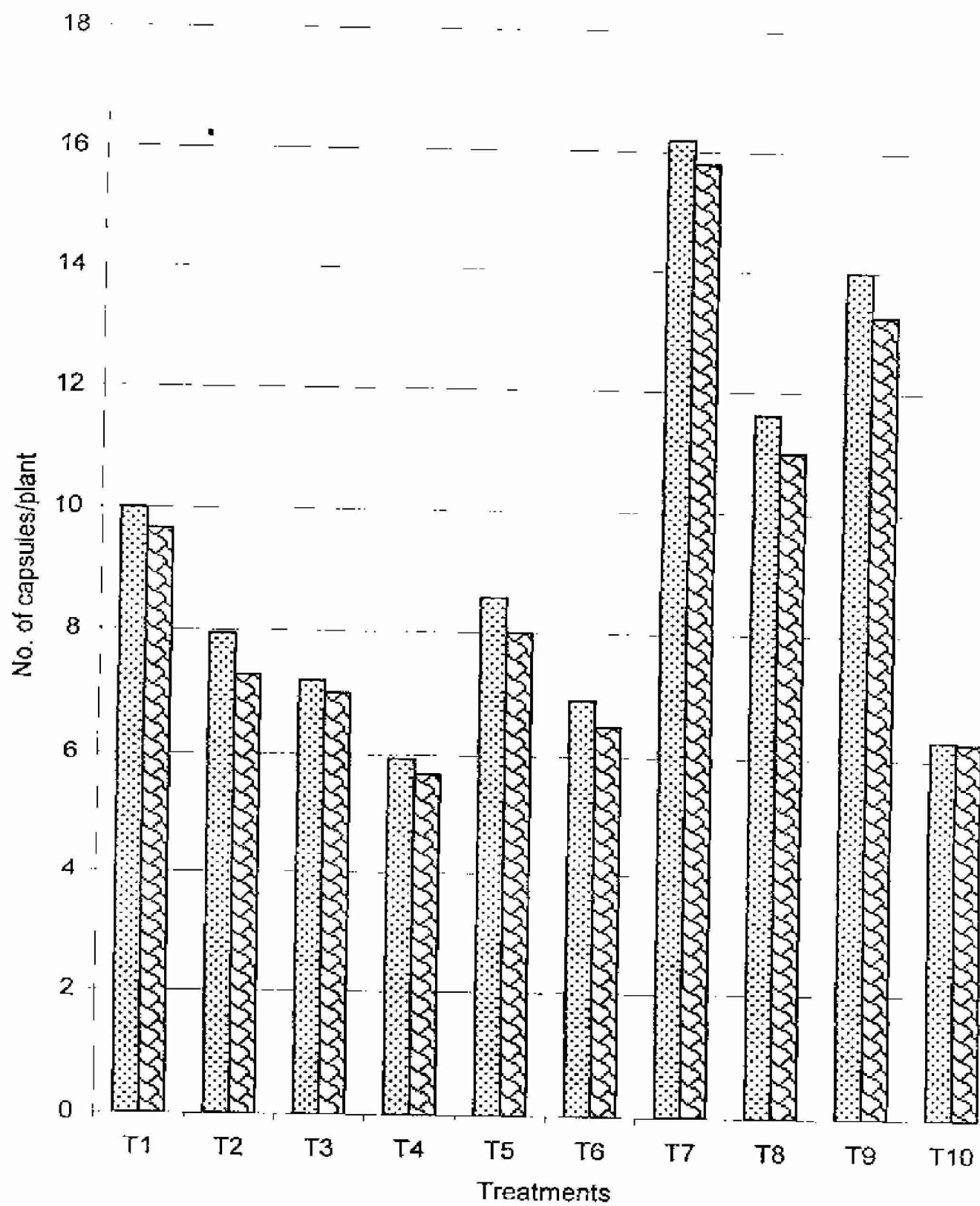


Fig. 14. Effect of plant products on number of capsules per plant

(T₆). Highest number of capitulas per plant were recorded in methyl demeton 0.05 per cent spray (T₇) followed by endosulphan 0.05 per cent (T₉) and thiamethoxam 0.01 Per cent (T₈). There no singificant differences between the treatments T₃, T₆, and T₁₀.

During 1999-2000, highest number of capsules per plant were recorded in methyl demeton 0.05 prer cent spray (T₇) and was significantly superior over rest of the treatments. Endosulfan 0.05 per cent (T₉) influenced the number of capsules per plant significantly than nimbicidin 0.5 per cent (T₁), bioneem 0.3 per cent (T₂), neem oil 3.0 per cent (T₃), castor oil 1.0 per cent (T₄), neemark 1.0 per cent (T₅), neem gold 0.5 per cent (T₆), and thiamethoxam 0.01 Per cent (T₈).

4.3.8 Effect of plant products on total grain weight per plant

The data on total grain weight (gms) per plant during 1998-99 and 1999-2000 are presented in Table 37 and graphically depicted in Fig. 15.

Table 37 revealed that all the insecicidal treatments were significantly superior over control in both the seasons. During 1998-99, highest grain weight per plant was recorded in methyl demeton 0.05 per cent (T₇) and was significantly superior over nimbicidin 0.5 per cent (T₁), bioneem 0.3 per cent (T₂), neem oil 3.0 per cent (T₃),

Table 37. Effect of plant products on total grain weight per plant (1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	Total grain weight/plant	
			1998-99	1999-2000
1.	Nimbicidin	0.5	9.44 (3.15)	9.00 (3.08)
2.	Bioneem	0.3	8.00 (2.91)	7.94 (2.90)
3.	Neem oil	3.0	7.90 (2.89)	7.28 (2.78)
4.	Castor oil	1.0	5.94 (2.53)	5.30 (2.40)
5.	Neemark	1.0	8.68 (3.02)	8.10 (2.93)
6.	Neem gold	0.5	6.20 (2.58)	6.00 (2.54)
7.	Methyl demeton	0.05	14.00 (3.80)	13.58 (3.75)
8.	Thiamethoxam	0.01	11.20 (3.42)	11.10 (3.40)
9.	Endosulphan	0.05	13.00 (3.67)	12.74 (3.63)
10.	Untreated control	--	4.20 (2.16)	4.16 (2.15)
S.E. $\pm$			0.08	0.08
C.D. at 5%			0.24	0.24

Figures in parenthesis are $\sqrt{x+0.5}$ values.

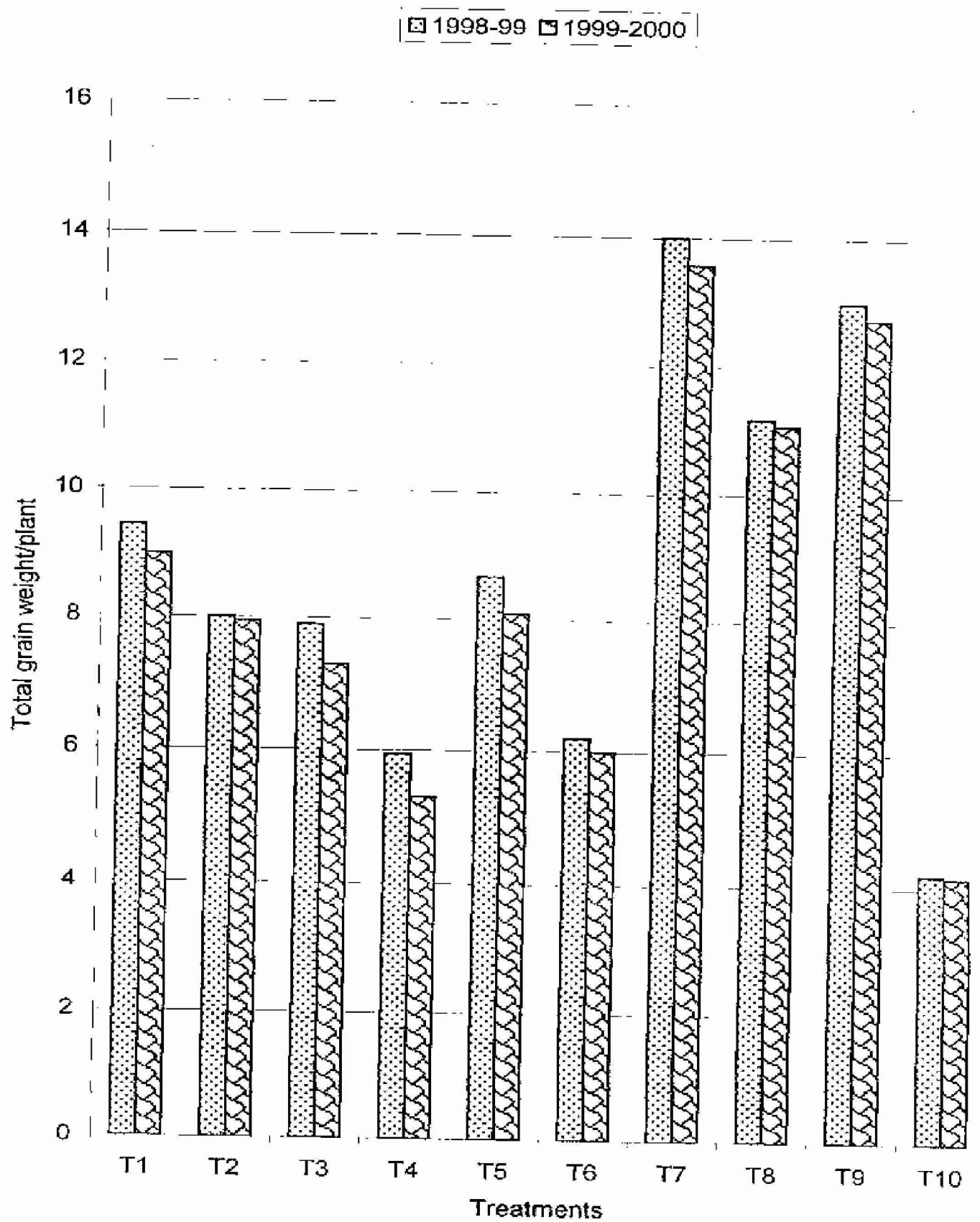


Fig. 15. Effect of plant products on total grain weight per plant

castor oil 1.0 per cent (T_4), neemark 1.0 per cent (T_5), neem gold 0.5 per cent (T_6) and thiamethoxam 0.01 Per cent (T_8) but was at par with endosulfan 0.05 per cent (T_9). There were no significant differences between the treatments T_4 and T_6 , T_1 and T_5 , T_7 and T_9 .

During 1999-2000, highest grain weight (gms) was recorded in methyl demeton 0.05 per cent spray (T_7) and was significantly superior over rest of the treatments except endosulfan 0.05 per cent (T_9). Castor oil 1.0 per cent (T_4) was at par with neem gold 0.5 per cent (T_6). There were no significant differences between the treatments T_1 , T_2 and T_5 .

4.3.9 Effect of plant products on 100 seed weight

The data on weight of 100 seeds during 1998-99 and 1999-2000 are presented in Table 38 and graphically depicted in Fig.16.

Table 38 revealed that during 1998-99, weight of 100 seeds was highest in methyl demeton 0.05 per cent spray (T_7) followed by endosulfan 0.05 per cent (T_9) and thiamethoxam 0.01 Per cent T_8 . There were no significant differences between the treatments T_1 , T_2 , T_3 , T_4 , T_5 , T_6 , T_7 , T_8 and T_9 . Methyl demeton 0.05 per cent (T_7), thiamethoxam 0.01 Per cent (T_8), endosulfan 0.05 per cent (T_9) and nimbicidin 0.5 per cent (T_1) were significantly superior over control.

Table 38. Effect of plant products on 100 seed weight
(1998-99 and 1999-2000).

Sr. No.	Treatments	Conc. (%)	100 grain weight (g)	
			1998-99	1999-2000
1.	Nimbicidin	0.5	4.84 (2.31)	4.80 (2.30)
2.	Bioneem	0.3	4.60 (2.25)	4.55 (2.24)
3.	Neem oil	3.0	4.50 (2.23)	4.48 (2.23)
4.	Castor oil	1.0	4.00 (2.12)	3.96 (2.11)
5.	Neemark	1.0	4.76 (2.29)	4.72 (2.28)
6.	Neem gold	0.5	4.20 (2.16)	4.16 (2.15)
7.	Methyl demeton	0.05	5.20 (2.38)	5.18 (2.38)
8.	Thiamethoxam	0.01	5.12 (2.37)	5.10 (2.36)
9.	Endosulphan	0.05	5.16 (2.37)	5.15 (2.37)
10.	Untreated control	--	3.62 (2.02)	3.57 (2.01)
S.E. $\pm$			0.09	0.09
C.D. at 5%			0.28	0.29

Figures in parenthesis are $\sqrt{x+0.5}$ values.

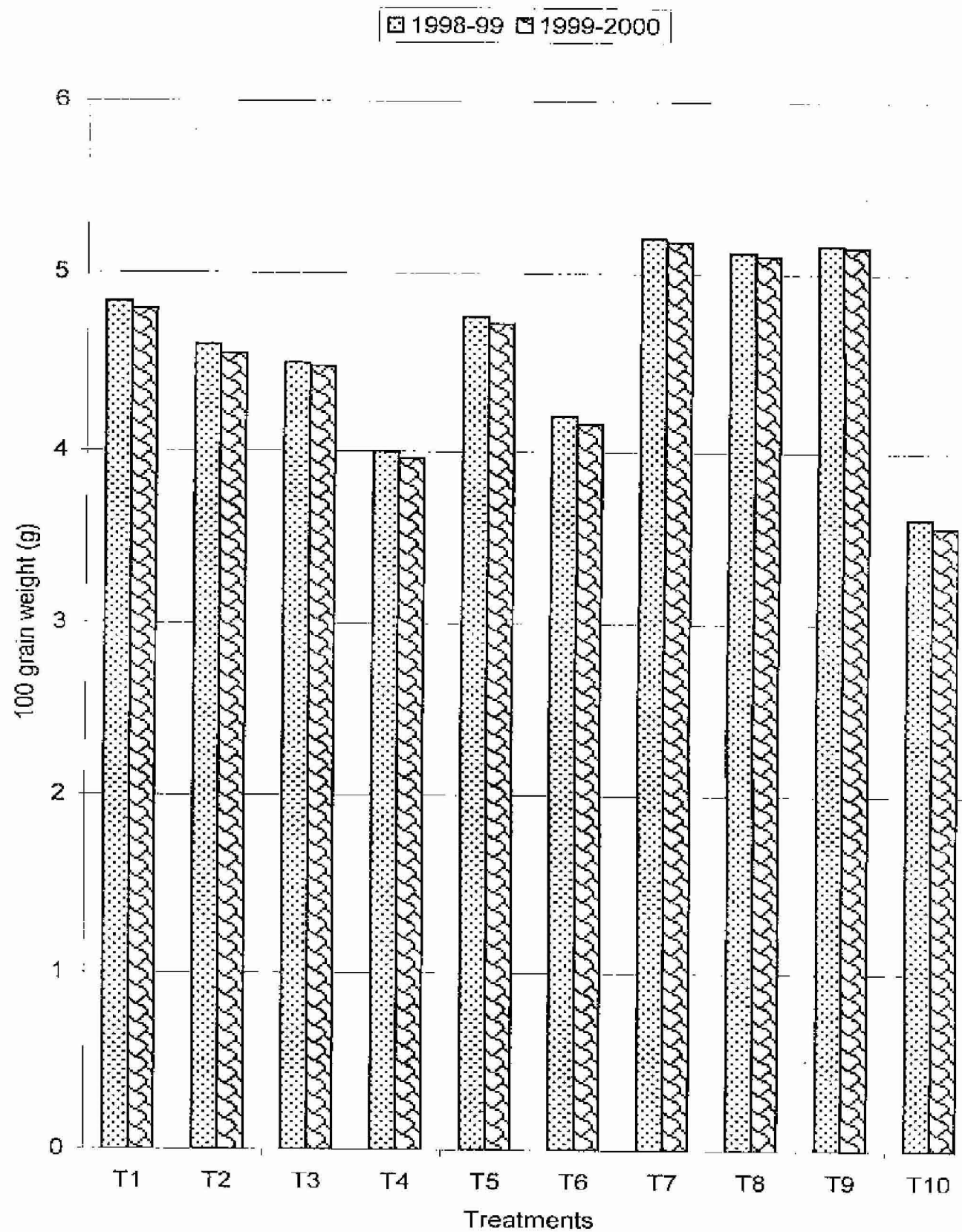


Fig. 16. Effect of plant products on 100 seed weight

During 1999-2000, nimbididin 0.5 per cent (T_1), thiamethoxam 0.01 Per cent (T_8), endosulfan 0.5 per cent (T_9) and methyl demeton 0.05 per cent (T_7) were significantly superior over control but they were at par with each other in effect. Similarly, no significant differences were noted between the treatments with castor oil 1.0 per cent (T_4), neem gold 0.5 per cent (T_6), neem oil 3.0 per cent (T_3), bioneem 0.3 per cent (T_2) and neemark 1.0 per cent (T_5).

4.4 Screening of various varieties of safflower for resistance to aphid

Twenty promising cultivars of safflower were screened for their reaction to tolerance/susceptibility against aphid, *Uroleucon sonchi* (Linn.) during winter seasons of 1998-99 and 1999-2000. The results are presented in Table 39 and 40.

4.4.1 Screening of varieties against aphid (1998-99)

From Table 39, it could be seen that, out of the 20 safflower cultivars tested, only one safflower cultivar i.e Lats₂ showed 1.0 aphid infestation index (AII) i.e. highly tolerant to aphids. The entries namely CTV₃₀ x Lats₁, A₁, GMU-7868, PBNS-12, PBNS-11, F₄ F₅ No.62, GMU-1787 and sel-48 were observed to be tolerant i.e. 1.65 AII. The seven entries viz., GMU-7047, S₄ x Lats₂, PBNS-51, PBNS-10, LASF-29, A₁ x 19-185 and Sharda attained the grade

Table 39. Screening of promising cultivars for their tolerance/susceptibility against safflower aphid (1998-99).

Grade	% drying of premature leaves due to aphids	Number of entries	Grade category
1	0 to 20	Lats ₂	Highly tolerant
2	21 to 40	CTV ₃₀ x Lats ₁ , A ₁ , GMU-7868, PBNS-12, PBNS-11, F ₄ F ₅ No.62, GMU-1787, Sel-48	Tolerant
3	41 to 60	GMU-7047, S ₄ x Lats ₂ , PBNS-51, PBNS-10, LASF-29, A ₁ x 19-185, Sharda	Moderately tolerant
4	61 to 80	HUS-305, PSF ₁₄ , Sel-4	Susceptible
5	81 to 100	Co-1	Highly susceptible

Table 40. Screening of promising cultivars for their tolerance/susceptibility against safflower aphid (1999-2000).

Grade	% drying of premature leaves due to aphids	Number of entries	Grade category
1	0 to 20	Lats ₂	Highly tolerant
2	21 to 40	CTV ₃₀ x Lats ₁ , PBNS-12, PBNS-11, F ₄ F ₅ No.62, GMU-1787, Sel-48	Tolerant
3	41 to 60	A ₁ , GMU-7868, GMU-7047, S ₄ x Lats ₂ , PBNS-51, PBNS-10, LASF-29, A ₁ x 19-185, Sharda	Moderately tolerant
4	61 to 80	HUS-305, PSF ₁₄ , Sel-4	Susceptible
5	81 to 100	Co-1	Highly susceptible

41 to 60 (AII) so observed moderately tolerant. While three cultivars viz., HUS-305, PSF-14 and Sel-4 were found to be susceptible to aphids as they acquired 61 to 80 grade (AII). Remaining one entry viz., Co-1 (susceptible check) recorded 81 to 100 AII and so was highly susceptible to aphids.

4.4.2 Screening of varieties against aphid (1999-2000)

From Table 40, it is evident that, out of the 20 safflower cultivars tested, only one cultivar namely Lats₂ showed highly tolerance to aphids (AII-1). Six entries viz., CTV₃₀ x Lats₁, PBNS-12, PBNS-11, F₄F₅ No.62, GMU-1787 and sel-48 were tolerant. While nine cultivars viz., A₁ GMU-7868, GMU-7047, S₄ x Lats₂, PBNS-51, PBNS-10, LASF 29, A₁ x 19-185 and Sharda showed moderately tolerance to aphids. Three cultivars namely HUS-305, PSF14 and sel-4 were found to be susceptible to aphids. Remaining one entry namely co-1 (susceptible check) was highly susceptible to aphid.

Promising safflower cultivars alongwith average aphid infestation index and average number of aphids per plant throughout season are presented in Table 41 and 42.

During 1998-99, Lats₂ showed 38 average number of aphids per plant and 34.84 gms average yield per plant throughout season, (AII-1). 64 aphids per plant were recorded on the cultivar, CTV₃₀ x Lats₁ along with 28.40

Table 41. Promising safflower lines showing tolerance to aphids (1998-99).

Sr. No.	Name of germplasm lines	Average aphid infestation index	Av.no.of aphids per plant	Average yield per plant (g)
1.	Lats ₂	1.0	38	34.84
2.	CTV ₃₀ x Lats ₁	1.3	64	28.40
3.	A ₋₁	1.7	92	25.46
4.	GMU-7868	1.8	105	22.90
5.	PBNS-12	2.0	119	18.88
6.	PBNS-11	1.9	110	20.00
7.	F ₄ F ₅ No.62	1.6	84	26.48
8.	GMU-1787	1.8	102	23.88
9.	Sel-48	1.7	95	24.70

Table 42. Promising safflower lines showing tolerance to aphids (1999-2000).

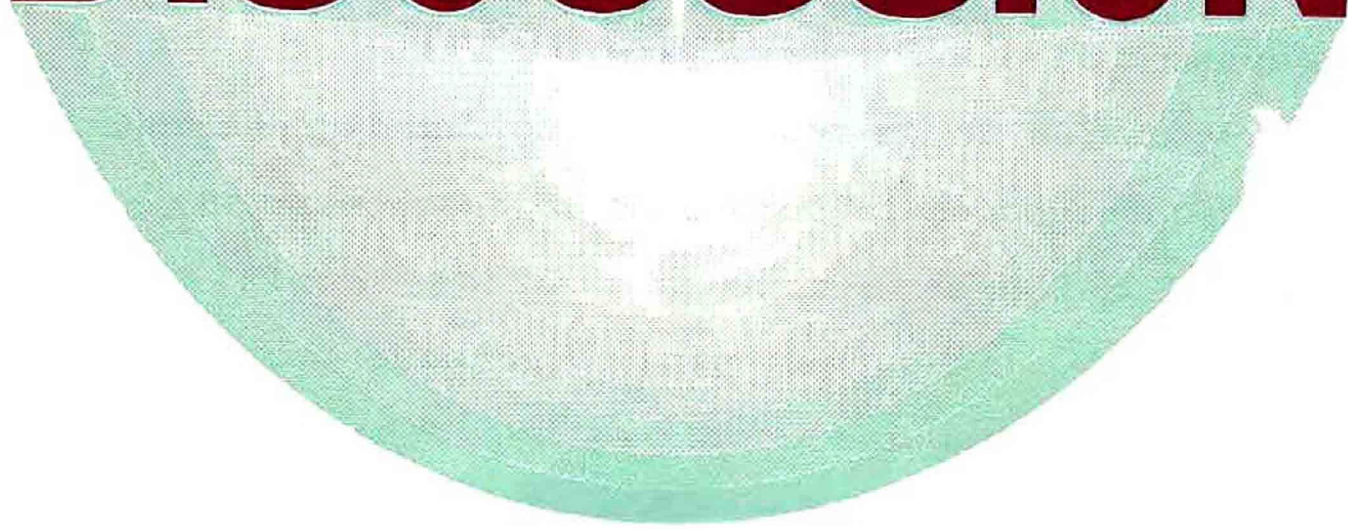
Sr. No.	Name of germplasm lines	Average aphid infestation index	Av.no.of aphids per plant	Average yield per plant (g)
1.	Lats ₂	1.0	42	32.76
2.	CTV ₃₀ x Lats ₁	1.3	70	28.00
3.	PBNS-12	2.0	125	17.10
4.	PBNS-11	1.9	115	19.64
5.	F ₄ F ₅ No.62	1.6	90	26.00
6.	GMU-1787	1.8	105	21.94
7.	Sel-48	1.7	98	24.00

gms. average yield per plant (AII 1.3). The entry namely A-1 (AII-1.7) recorded 92 aphids per plant throughout season and 25.46 gms. average yield per plant. The germplasm line viz., GMU-7868 (AII-1.8) showed 105 aphids per plant throughout season and 22.90 gms, average yield per plant. The variety PBNS-12 (AII-2.0) recorded 119 aphids per plant and 18.68 gms average yield. Average number of aphids were 110 on the cultivar PBNS-11 (AII 1.9) and 20.0 gms average yield per plant . The entry namely F_4F_5 No.62 (AII1.6) recorded 84 aphids per plant and 26.48 gms average yield per plant. Regarding average number of aphids and yield per plant, the entries viz., GMU-1787 and Sel-48 were at par with each other.

During 1999-2000, lowest population of aphids and highest average yield per plant was recorded in the cultivars namely $Lats_2$, $CTV_{30} \times Lats_1$ (AII 1.3) showed 70 aphids per plant and 28.00 gms. average yield per plant. Highest number of aphids per plant and lowest yield was recorded in the cultivar PBNS-12 which was at par with PBNS-11. The entries namely F_4F_5 No.62 (AII 1.6) and Sel.48 (AII 1.7) were at par with each other regarding average number of aphids and average yield per plant. The germplasm line GMU-1787 (AII 1.8) recorded 105 aphids per plant and 21.94 gms. average yield per plant.

Overall, it can be concluded from the results of present investigation that safflower cultivar, Lats₂ was found highly tolerant and gave highest yield as compared to others. The cultivars, CTV₃₀ x Lats₁, F₄F₅ No. 62, A-1 Sel-48 and GMU-1787 were also tolerant as they acquired IInd grade of AII and gave good yields of safflower.

DISCUSSION



Chapter V

DISCUSSION

Safflower, *Carthamus tinctorius* Linn. is the major oilseed crop of Marathwada region of Maharashtra state grown on residual moisture during winter season. In the recent years, new problems of pest complexes are arising due to changing patterns of cultivation. Safflower suffers heavily from pests especially safflower aphid, *Uroleucon sonchi* Linn., which alone causes losses to the extent of 60 to 80 per cent. It was therefore felt, necessary to generate information on development of suitable strategies for the management of this crop so as to reduce losses due to safflower aphid. The present studies included the population dynamics, loss assessment, bio-efficacy of various neem based products and screening of various varieties of safflower for aphid resistance. The results obtained are discussed in this chapter in the light of previous research work.

5.1 Population dynamics of pests of safflower

5.1.1 Population dynamics of aphids

The study on population dynamics of aphid on safflower conducted during winter seasons of 1998-99 and 1999-2000, revealed that the first appearance of aphid was

noted in the last week of December (52nd Meteorological week) in both the seasons when temperatures and relative humidity were 17.8°C and 53 per cent and 19.8°C and 52 per cent respectively. The pest activity increased gradually and heavy incidence (190.60 aphids per plant in 1998-99 and 182.0 aphids per plant in 1999-2000) was recorded in first week of February. Again the pest population decreased in both the seasons. The average population of aphid per plant was 92.04 during 1998-99 and 81.64 during 1999-2000 (Table 2 and Table 3).

Trehan and Halleppanwar (1949) reported that the pest appeared during the early stages of crop growth in November and later on the incidence increased considerably reaching peak towards flowering during the last week of December or the first week of January when the average maximum and minimum temperatures and relative humidity were 26.0°C, 19°C and 68.2 per cent, respectively. Subsequently, Chavan (1960) also noted that the aphids were serious on safflower during December to February. Further, Narayanan (1961) reported that during the early stage of crop growth, the pest appeared and later on the incidence increased considerably reaching a peak about a week or two before the plants develop flower buds which commenced during the last week of December or the first week of January, when the average temperatures were 26.0°C maximum and 19.0°C minimum with 68.2 per cent relative humidity.

Firke (1980) noticed that the aphids made their first appearance on the crop in the first week of December. Further build-up in population takes place depending upon the stage of the crop. The highest incidence was found in the month of January, when the minimum and maximum temperatures were 9.9 to 13.5°C and 27.4 to 29.0°C respectively and relative humidity 70 to 83 per cent with increase in temperature coupled with decrease in humidity, the incidence started declining and by the middle of February, no aphids were found on the crop.

Upadhyay et al. (1980) investigated the seasonal occurrence of the safflower aphid, *U. carthami* (H.R.L.) in relation to the weather conditions in Rajasthan. The aphids were first noticed in leaf whorls during the first week of December after which their number increased reaching a peak between Mid January and Mid-February. Aphid population declined and pest had disappeared by the end of March. The maximum aphid population was observed at temperature of 17°C and a relative humidity of 66.67 per cent. The population showed a sharp decline with an increase in temperature and fall in relative humidity. Thus the increase in aphid population was negatively correlated with temperature and positively correlated with relative humidity.

From the for going discussion, it is apparent that the observations recorded in the present investigations corroborate the findings of above workers.

5.1.2 Population dynamics of thrips

Table 4 and Table 5 revealed that the first appearance of thrips was noted in the last week of December (52nd Meteorological week) when temperature and relative humidity were 17.8°C and 53 per cent during 1998-99 and 19.8°C and 52 per cent during 1999-2000 respectively. Pest population was subsequently increased upto first week of February in 1998-99 and third week of January in 1999-2000. Again the pest population decreased in further meteorological weeks in both the seasons. Highest population of thrips (12.25 thrips/plant) was recorded in first week of February during 1998-99 and (13.10 thrips/plant) in third week of January during 1999-2000 (6th and 4th meteorological week).

Weiss and Beshear (1987) sampled the thrips in 1984 and 1985 on safflower plants that had been planted in Montana on 3 dates in April-May. In 1984, *Thrips tabaci* accounted for 57 per cent of the adults collected and *Frankliniella tritici* 42 per cent, the corresponding percentages in 1985 were 52 and 44. Regardless of planting date, *T. tabaci* was the first species detected. Population peaked on 12th and 15th July in the two years respectively.

Population of *F. tritici* peaked on 2nd and 8th August. It is suggested that *T. tabaci* over winters in the area, whereas *F. tritici* does not.

5.1.3 Population dynamics of *Helicoverpa armigera*

First appearance of *Helicoverpa armigera* on leaves was noted in second week of January (2nd meteorological week) when temperature and relative humidity were 26.2°C and 71. per cent respectively. Pest population increased upto first week of February and again decreased in subsequently meteorological weeks. The maximum population of *Helicoverpa armigera* on leaves was recorded in last week of January (0.10 per plant) when temperature was 20.7°C and RH was 51 % . As regards *Helicoverpa armigera* on capsules, the first appearance of the pest was in last week of January (5th Meteorological week) when temperature and relative humidity were 21.1°C and 50.5 % respectively. The pest population increased subsequently and the maximum population was recorded in second week of February (7th meteorological week) when temperature and relative humidity were 23.3°C and 56.5% respectively. The average population throughout season was 0.04 per plant on leaves and on capsules, (Table 6 and Fig. 4).

During the year, 1999-2000, *Helicoverpa armigera* on leaves was recorded firstly in second week of January (2nd meteorological week) when temperature was 19.8°C and

RH was 51.5 %) peaked in last week of January (4th meteorological week) when temperature and relative humidity were 21.0°C and 51.5% respectively. As regards, *Helicoverpa armigera* on capsules, first appearance of the pest was in last week of January (5th meteorological week) when temperature was 20.95°C and relative humidity was 54.5%. Population increased gradually and reached peak in second week of February (7th meteorological week) when temperature and RH were 21.5°C and 55.5% respectively and thereafter declined gradually, (Table 7 and Fig.4).

Information on this aspect is not available in the literature.

5.1.4 Population dynamics of safflower caterpillar

The first appearance of safflower caterpillar was noticed in second week of January (2nd meteorological week) when temperature was 16.5°C and RH was 50.5%. There after, population was subsequently increased and maximum population was observed (0.10 safflower caterpillar per plant) from 4th week of January to 1st week of February. Pest population was constant upto first week of February and thereafter declined gradually. The average population throughout season was 0.04 per plant (Table 8 and Fig.5).

During the year 1999-2000, the first appearance of the pest was in first week of January (1st meteorological week) when temperature and relative humidity were 18.0°C

and 50.5% respectively. The pest population increased gradually and peaked in last week of January (5th meteorological week) when temperature and relative humidity were 20.9°C and 54.5 % respectively. The average population of safflower caterpillar was 0.05 per plant throughout season (Table 9 and Fig.5).

Perusal of literature revealed that no other pertinent literature is available on this aspect.

5.1.5 Relationship between weather parameters and pests of safflower

5.1.5.1 Correlation studies and direct-indirect effect of abiotic factors on the population of aphid

It was evident from Table 10 that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity during 1998-99. Maximum temperature exhibited highest negative direct effect followed by wind velocity. Morning relative humidity exhibited significantly positive correlation with aphid population.

During the year 1999-2000, morning relative humidity exhibited highest positive direct effect followed by evaporation and minimum temperature. Maximum temperature exhibited negative direct effect. Evening relative humidity exhibited significantly positive correlation with aphid population (Table 11).

Upadhyay et al. (1980) reported that population of *Uroleucon carthami* showed a sharp decline with an increase in temperature and fall in relative humidity. Thus the increase in aphid population was negatively correlated with temperature and positively correlated with relative humidity.

Pote (1992) observed negatively significant correlations of aphid population with maximum and minimum temperatures, while the reaction of aphid population with morning and evening humidity was positively non-significant.

Bade and Kadam (1993) investigated that there was a negative significant correlation between aphid population and minimum temperature. Correlations were negative but non-significant for maximum temperature and morning and evening humidities. Akashe et al. (1995) also noted that the aphid population on safflower was negatively correlated with a number of weather parameters viz., maximum and minimum temperature, morning and evening humidity and rainfall.

The observations recorded in the present studies are in agreement with the observations reported by the earlier workers.

5.1.5.2 Correlation studies and direct-indirect effect of abiotic factors on the population of thrips

Table 12 revealed that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity during the year 1998-99. Maximum temperature exhibited highest negative direct effect followed by wind velocity. Morning relative humidity and bright sunshine hours showed significantly positive correlation with thrips population.

It is evident from Table 13 that during the year 1999-2000, morning relative humidity exhibited highest positive direct effect followed by evaporation and bright sunshine hours. Maximum temperature exhibited highest negative direct effect followed by evening relative humidity.

Perusal of literature reveals that no other pertinent literature is available on this aspect.

5.1.5.3 Correlation studies and direct indirect effect of abiotic factors on the population of *Helicoverpa armigera* on leaves

It was observed that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity during the year 1998-99. Maximum temperature exhibited highest negative direct effect followed by wind velocity and evaporation. Maximum

temperature, bright sunshine hours, evaporation and wind velocity showed non-significantly negative correlation with the population of *Helicoverpa armigera* on leaves (Table 14).

The data presented in Table 15 revealed that evaporation exhibited highest positive direct effect followed by morning relative humidity and bright sunshine hours on the population of *Helicoverpa armigera* on leaves, during the year 1999-2000. Maximum temperature exhibited highest negative direct effect followed by evening relative humidity and minimum temperature. Maximum temperature and evaporation exhibited non-significantly negative correlation with pest population.

No information on this aspect is available in the literature.

5.1.5.4 Correlation studies and direct-indirect effect of abiotic factors on the population of *Helicoverpa armigera* on capsules

It is evident from Table 16 that bright sunshine hours exhibited highest positive direct effect followed by morning relative humidity and minimum temperature. Maximum temperature exhibited negative direct effect. Minimum temperature exhibited significantly positive correlation with the population of *Helicoverpa armigera* on capsules. Morning relative humidity exhibited non-significantly negative correlation with the pest population.

Maximum temperature exhibited highest positive direct effect followed by evening relative humidity and wind velocity. Evaporation exhibited highest negative direct effect followed by bright sunshine hours and morning relative humidity. Minimum temperature, evening relative humidity and wind velocity showed significantly positive correlation where as morning relative humidity showed non-significantly negative correlation with the pest population. Bright sunshine hours showed significantly negative correlation with the population of *Helicoverpa armigera* on capsules during the year 1999-2000 (Table 17).

Perusal of literature reveals that no other pertinent literature is available on this aspect.

5.1.5.5 Correlation studies and direct-indirect effect of abiotic factors on the population of safflower caterpillar

Table 18 revealed that minimum temperature exhibited highest positive direct effect followed by bright sunshine hours and morning relative humidity on the population of safflower caterpillar during the year 1998-99. Maximum temperature exhibited highest negative direct effect followed by wind velocity. Maximum temperature, minimum temperature, bright sunshine hours, evaporation and wind velocity showed non-significantly negative correlation with the population of safflower caterpillar.

During the year 1999-2000, morning relative humidity exhibited highest positive direct effect followed by maximum temperature and bright sunshine hours on the population of safflower caterpillar. Evaporation exhibited negative direct effect . Maximum temperature, minimum temperature, evaporation and wind velocity showed non-significantly negative correlation with the pest population (Table 19).

Information on this aspect is not available in the literature.

5.2 Assessment of crop losses due to safflower pest complex

5.2.1 Population of aphids

The aphid population on Lats₁ was significantly low as compared to Co-1 during 1998-99 and 1999-2000. Significantly lowest population of aphid was recorded in the plots where the crop was treated completely throughout growth period (T₃) and in the plots where crop was protected during vegetative stage (T₁). The aphid population was significantly low in the plots treated during reproductive stage (T₂) as compared to the plots kept untreated throughout growth period (T₄) during both the trials (Table 20).

Significantly, lowest population of aphids was recorded in Lats₁ with T₁ and T₃ treatment combinations in

both the seasons. In case of Co-1, lowest population of aphid was recorded in T₃ treatment.

Suryawanshi and Pawar (1983) investigated that the number of aphids (*Uroleucon sonchi*) per leaf in untreated plots averaged 19.3 in the 1st season and 12.12 in the 2nd season as compared with 0.0 and 0.7 in treated plots with dimethoate (0.03%). Ghule et al. (1986) also noted that lowest cumulative number of aphids (10.05/plant) in plots applied with fertilizers and full protection and full protection without fertilizers application against the pest with 0.05% dimethoate at weekly interval.

The observations recorded in the present studies are in agreement with the observations reported by the earlier workers.

5.2.2 Population of thrips

Comparatively low thrip population was recorded during 1999-2000 as compared to 1998-99. The treatments T₁ and T₃ were at par during 1998-99. Significant reduction in thrip population was observed in T₁ and T₃ as compared to T₂ and T₄ in both the years. During 1999-2000, the treatment T₃ had lowest population of thrips as compared to T₁, T₂ and T₄ (Table 21).

Carlson (1966) noticed that the safflower buds are able to tolerate fairly large numbers of nymphal thrips (*Frankliniella occidentalis*) before the seed yield is

reduced significantly. He found that the density of nymphs averaged as high as 75 per bud when 10 adults per bud were introduced into the cages and there was no consequent drop in seed production.

5.2.3 Population of *Helicoverpa armigera* on leaves

Table 22 revealed that the differences in population of *Helicoverpa armigera* on leaves in two varieties during 1998-99 and 1999-2000 were significant. The spray treatments and interaction effects were significant in both the seasons. The population of *Helicoverpa armigera* on leaves was higher in variety Co-1 than in Lats₁ in both the seasons.

Significantly lowest population of aphid was recorded in the plots where the crop was treated completely throughout growth period (T_3) and in the plots where the crop was protected during vegetative stage (T_1). The population of the pest was significantly low in the plots treated during reproductive stage (T_2) as compared to the plots kept untreated throughout growth period (T_4) during 1998-99 and 1999-2000.

Pertinent literature is not available on this aspect, hence it can not be discussed further.

5.2.4 Population of *Helicoverpa armigera* on capsules

Both the varieties, spray treatments and interaction effects during 1998-99 and 1999-2000 revealed

significant results in respect of lowering the population of *H. armigera* on capsules. The population of the pest was more on the variety Co-1 as compared to Lats₁.

It is evident from Table 23 that significantly lowest population of *Helicoverpa armigera* on capsules was recorded in the plots where the crop was protected completely throughout growth period (T₃) and in the plots where the crop was protected during reproductive stage (T₂) during 1998-99 and 1999-2000. Lower population of *Helicoverpa armigera* on capsules was recorded in Lats₁ with T₂ and T₃ treatment combinations. In case of Co-1, lowest population of *Helicoverpa armigera* was recorded in T₃ treatment combination in both the seasons.

Information on this aspect is not available in the literature.

5.2.5 Population of safflower caterpillar

Both the varieties, spray treatments and interaction effects during 1998-99 and 1999-2000 revealed significant results in respect of lowering the population of safflower caterpillar. Comparatively higher population of safflower caterpillar was recorded during 1999-2000 as compared to 1998-99.

Significant reduction in pest population was observed in T₃ and T₁ as compared to T₂ and T₄ during first season. During the year, 1999-2000, T₄ recorded highest

population of the pest where as T_1 and T_3 were at par with each other (Table 24).

Information on this aspect is not available in the literature.

5.2.6 Effect of treatments on various parameters

Biometric parameters:

5.2.6.1 Plant height

Table 25 revealed that the height of the plants in $Lats_1$ was recorded significantly more as compared to Co-1 in both the seasons. The plant height in the treatments of protection during vegetative stage (T_1), protection during reproductive stage (T_2) and complete protection throughout growth period (T_3) was significantly more as compared to unsprayed plots throughout growth period (T_4). Similar trend was obtained during 1999-2000. Significant reduction in height was observed in $Lats_1$ with T_4 combination while the height was found to be increased in the same variety with T_1 , T_2 and T_3 combinations during 1998-99 and 1999-2000. Similar trend was observed in the variety Co-1 in both the seasons.

Information on this aspect is not available in the literature.

5.2.6.2 Length of shoot

The varieties, spray treatments and interaction effects were found to be significant in both the seasons.

Length of shoot in the variety Lats₁ was slightly more as compared to Co-1 in both the trials.

It is evident from Table 25 that length of shoot was not affected significantly in T₁, T₂ and T₃ treatments but increased significantly in the same treatments over T₄ during both the seasons. During 1998-99 and 1999-2000, length of shoot was affected significantly in T₄ treatment combination with Lats₁ as compared to T₁, T₂ and T₃ combinations with the same variety. Significant increase in length of shoot was observed in Co-1 with T₃ combination than with the T₁ and T₂ combinations, While T₁ and T₂ combinations with the same variety were found to be at par with each other in both the seasons. In 1998-99 and 1999-2000, the variety Lats₁ with T₁ and T₂ combinations found at par with each other.

Pertinent literature is not available on this aspect.

5.2.6.3 Number of leaves per plant

During 1998-99 and 1999-2000, significant reduction was observed in the treatment T₄ as compared to rest of the treatments. In the treatment T₃, significant increase in number of leaves was observed over T₁ and T₂. Whereas in 1999-2000, the number of leaves per plant were found to be increased in T₁ and T₂ than in 1998-99.

Significant reduction was found in number of leaves corresponding to the combination of treatment T_4 with Lats₁ in both the seasons. Number of leaves were found to be increased significantly during 1999-2000 in T_1 and T_3 combinations with Co-1 over T_4 . During both the trials, T_1 and T_3 combinations of both the varieties were found to be significant over T_2 (Table 26).

5.2.6.4 Number of spines per leaf

Number of spines per leaf in Lats₁ were recorded more as compared to Co-1 in both the seasons. Number of spines per leaf in the treatments of protection during vegetative stage (T_1), protection during reproductive stage (T_2), and complete protection throughout growth period (T_3) were significantly more as compared to unsprayed plots throughout growth period (T_4). Similar was the case in the second trial.

Significant reduction in number of spines per leaf was observed in Lats₁ with T_4 combination, while the spines were found to be increased in the same variety with T_1 , T_2 and T_3 combinations in both the seasons. Similar trend was observed in the variety Co-1 during 1998-99 and 1999-2000.

Effect of treatments on yield and yield components:

5.2.6.5 Number of capitula per plant

The varieties, spray treatments and interaction

effects were found to be significant in both the seasons. Significantly more number of capitula per plant were obtained from T_1 and T_3 where as they were significantly reduced in T_2 and T_4 treatments in both the years.

During 1998-99 and 1999-2000, significant increase in number of capitula per plant was observed in treatment combination of T_1 and T_3 with both the varieties i.e. $Lats_1$ and Co-1 as compared to the combination of T_2 and T_4 $Lats_1$ with T_2 combination recorded significantly more number of capitula per plant as compared to T_4 combination (Table 27).

Information on this aspect is not available in the literature.

5.2.6.6 Number of seeds per capsule

Number of seeds per capsule were significantly more in $Lats_1$ than in Co-1 in both the years. During 1998-99 and 1999-2000, significant reduction was observed in the treatment T_4 as compared to rest of the treatments. In the treatment T_3 , significant increase in number of seeds per capsule was observed over T_1 and T_2 .

Significant reduction was found in number of seeds per capsule corresponding to the combination of treatment T_4 with $Lats_1$ in both the seasons. Similar was the trend with Co-1 in both the seasons. Number of seeds per capsule were found to be increased significantly during 1998-99 and

1999-2000 in T_1 and T_3 combinations with $Lats_1$ and Co-1 over T_4 (Table 27).

5.2.6.7 Yield of safflower

Significantly increased safflower seed yield in $Lats_1$ was recorded than that of Co-1 in both the years. The treatment T_1 and T_3 recorded significantly higher yield of safflower over T_2 and T_4 in both the trials. Likewise, the yield in T_2 was also increased significantly as compared to T_4 in both the trials. Significant reduction was found in yield of safflower corresponding to the combination of treatment T_4 followed by T_2 with Co-1 in 1998-99 as well as 1999-2000. $Lats_1$ with T_2 combination recorded the yield which was at par with T_1 combination with the same variety in both the years (Table 27 and 28).

Pooled analysis of both the years showed similar results.

5.2.7 Crop losses due to safflower pest complex

5.2.7.1 Effect of on biometric parameters

5.2.7.1.1 Plant height

Sucking pest complex reduced the plant height by 3.98 and 7.20 per cent in $Lats_1$ and Co-1 during 1998-99 while 4.46 and 8.0 per cent during 1999-2000 respectively. *Helicoverpa armigera* also affected the plant height. During 1998-99 and 1999-2000, 1.40 and 1.16 per cent reduction in the height was observed in Co-1, while the height of $Lats_1$

was not much affected during the same period. Safflower caterpillar reduced the plant height by 0.38 per cent and 0.40 per cent in Lats₁ while 0.46 and 0.50 per cent in Co-1 during 1998-99 and 1999-2000 respectively (Table 29).

Suryawanshi and Pawar (1980) recorded 3.17 per cent loss in plant height due to safflower aphid. Mulavekar (1982) also noted that 23.03 per cent loss in average plant height is caused due to *Uroleucon sonchi* in safflower. Narangalkar and Shivpuje (1990) investigated that *Uroleucon compositae* caused (3.30) per cent loss in plant height in untreated plot of safflower.

The present findings are in confirmation with the findings of the above workers.

5.2.7.1.2 Length of shoot

Incidence of sucking pest complex had also affected the length of shoot. The reduction in length of shoot of Lats₁ and CO-1 during 1998-99 was 2.72 and 5.38 per cent respectively and 3.10 and 5.74 per cent in Lats₁ and Co-1 during 1999-2000.

Similarly, due to infestation of *Helicoverpa armigera* 0.54 per cent and 0.48 per cent reduction in Lats₁ during first and second season was noted. In Co-1, 0.74 per cent reduced length of shoot was obtained in 1998-99 and 0.46 per cent in 1999-2000.

In Lats₁, 0.29 and 0.32 per cent reduction was observed during 1998-99 and 1999-2000 in length of shoot due to safflower caterpillar. While in Co-1, 0.33 and 0.34 per cent reduction was noticed in first and second seasons respectively (Table 29).

Pertinent literature is not available on this aspect.

5.2.7.1.3 Number of leaves per plant

Sucking pest complex reduced the number of leaves per plant by 2.00 and 2.58 per cent in Lats₁ and Co-1 during 1998-99 while 1.98 and 2.76 per cent during 1999-2000 respectively.

Attack of *Helicoverpa armigera* also affected the number of leaves per plant. During 1998-99 and 1999-2000 0.16 and 0.10 per cent reduction in number of leaves was observed in Lats₁ while 0.30 and 0.34 per cent in Co-1 during both the seasons was observed. Similarly, safflower caterpillar reduced more number of leaves in Co-1 than in Lats₁. The pest reduced the number of leaves per plant by 0.90 and 0.98 per cent in Co-1 and 0.46 and 0.54 per cent in Lats₁ during 1998-99 and 1999-2000 respectively (Table 29).

Information on this aspect is not available in the literature.

5.2.7.1.4 Number of spines per leaf

Influence of sucking pest complex on number of spines per leaf was not observed in Lats₁ while 1.52 and 1.20 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

The effect of *Helicoverpa armigera* on number of spines was nil in Lats₁ during 1998-99 while 0.02 per cent during 1999-2000. However 0.06 and 0.08 per cent reduction in number of spines per leaf was recorded in Co-1 during 1998-99 and 1999-2000.

Influence of safflower caterpillar on number of spines per leaf was not observed in Lats₁ while 0.16 and 0.18 per cent in Co-1 during 1998-99 and 1999-2000 respectively (Table 29).

5.2.7.2 Effect on yield and yield components

5.2.7.2.1 Number of capitula per plant

Incidence of sucking pest complex had also significantly affected the number of capitula per plant. The reduction in number of capitula of Lats₁ was 8.42 and 8.68 per cent in 1998-99 and 1999-2000 respectively while 10.94 and 11.36 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

The reduction in number of capitula as influenced by *Helicoverpa armigera* was more in Co-1 as compared to Lats₁. Per cent reduction in number of capitula during

1998-99 and 1999-2000 was 1.34 and 1.66 in Lats₁ while 2.94 and 3.00 per cent in Co-1 respectively. In Lats₁, number of capitula were reduced by 0.24 per cent during 1998-99 and 0.28 per cent during 1999-2000 due to safflower caterpillar. The per cent reduction in number of capitula in Co-1 was 0.32 and 0.36 per cent during first and second season respectively (Table 29).

Suryawanshi and Pawar (1980) reported 32.71 per cent loss in number of capitula per plant due to safflower aphid. Mulavekar (1982) also noted that in safflower, *Uroleucon sonchi* is responsible for causing 55.95 per cent loss in number of capitula per plant. Similar results were got by Narangalkar and Shivpuje (1990) who investigated that percentage loss due to *Uroleucon compositae* in untreated plot of safflower was 18.06 per cent in terms of number of capitula per plant.

5.2.7.2.2 Number of seeds per capsule

Table 29 revealed that sucking pest complex reduced the number of seeds per capsule by 7.98 and 8.32 per cent in Lats₁ and 10.20 and 10.84 per cent in Co-1 during 1998-99 and 1999-2000 respectively.

Helicoverpa armigera infestation also affected the number of seeds per capsule. During 1998-99 and 1999-2000, 3.00 and 3.16 per cent reduction in number of seeds was observed in Lats₁ while 3.74 and 4.12 per cent in Co-1

during the same period. There was very little influence on number of seeds per capsule due to safflower caterpillar. Per cent loss in number of seeds per capsule was more in Co-1 than in Lats₁ during both the seasons.

Suryawanshi and Pawar (1980) reported 26.35 per cent loss in number of seeds per capitulum due to safflower aphid. Mulavekar (1982) observed 4.26 per cent loss in test weight of 1000 seeds due to *Uroleucon sonchi* in safflower. Narangalkar and Shivpuje (1990) also investigated that per cent loss due to *Uroleucon compositae* in untreated plot of safflower in terms of number of seeds per capsule was 21.02 per cent.

The present findings are in confirmation with the earlier workers.

5.2.7.2.3 Yield of safflower

In present investigation, sucking pest complex viz., aphids and thrips had affected the yield considerably. The losses to the tune of 17.35 and 18.46 per cent were recorded in Lats₁ and 23.36 and 24.40 per cent in Co-1 during 1998-99 and 1999-2000 respectively. The effect of *Helicoverpa armigera* infestation was comparatively less in yield of Lats₁ and Co-1 in both the seasons. Reduction in yield due to *Helicoverpa armigera* was more in Co-1 as compared to Lats₁. During 1998-99, 5.38 per cent loss in yield due to *Helicoverpa armigera* was more in Co-1 as

compared to Lats₁. During 1998-99, 5.38 per cent loss in yield was noted in Lats₁ while in Co-1, 8.58 per cent loss was recorded. During 1999-2000, in Lats₁ 6.10 per cent loss and 9.10 per cent loss in Co-1 was obtained. Lats₁ recorded 1.72 and 1.86 per cent loss during 1998-99 and 1999-2000 due to safflower caterpillar. As regards Co-1, per cent loss was more in second season as compared to first season (Table 29).

Narayanan (1961) reported that the plants affected by *Dactynotus carthami* do not bear flowers and in severe cases cause loss in yield to the tune of 60 to 80 per cent. Carlson (1972) found that seed losses upto 32 per cent can occur when *Myzus persicae* increase to about 20 or more per head for an extended period. Moderate infestations of 500 aphids per plant can cause enough plant stunting to result in a 69.00 per cent seed loss. Karve et al. (1978) also recorded 55 per cent losses in seed yield of safflower due to *Dactynotus carthami*

Bhumannavar and Thontadarya (1979_b) observed that the extent of reduction in the seed yield due to *Dactynotus compositae* was 36.05 per cent as compared to fully protected crop. Similar results were obtained by Rathore (1983) who found that the aphid caused the yield loss of about 16, 20 to 25, 35, 55 and 52 to 60 per cent respectively at Kanpur

(U.P.), Hyderabad (A.P.), Jabalpur (M.P.), Parbhani (M.S.) and Udaipur (Rajasthan), the all-India average being about 37 per cent. Narangalkar and Shivpuje (1990) investigated that the per cent loss in seed yield due to aphid infestation was 30.19 per cent. They also found that due to aphid infestation on safflower, about 389 kg/ha of seed yield was reduced and can be avoided by application of a suitable insecticide.

The observations recorded in the present studies are in agreement with the observations reported by the earlier workers.

5.3 Management of safflower pest complex through botanical insecticides

5.3.1 Bio-efficacy of plant products against safflower aphids

It is evident from Table 30 that all the insecticidal treatments were significantly superior over control in both the seasons. During 1998-99, significantly low population of aphids was recorded in all the treatments. Lowest population of the pest was recorded in methyl demeton 0.05 per cent spray (T₇) and was significantly superior over other conventionals and all botanicals.

During 1999-2000 also, lowest population of the pest was recorded in methyl demeton 0.05 per cent (T₇) and

was significantly superior over rest of the treatments. Endosulphan 0.05 per cent (T_9) was at par with thiamethoxam 0.01 per cent (T_8). Neem gold 0.5 per cent (T_6) was at par with castor oil 1.0 per cent (T_4). Significant differences were not observed between the treatments T_2 , T_3 and T_6 .

Results of the pooled analysis for the years 1998-99 and 1999-2000 revealed that the treatment ' T_7 ' recorded lowest population of aphid and was significantly superior over rest of the treatments except ' T_8 ' (Table 30 and Fig. 8).

Bindra and Rathore (1967) and Lanjewar (1976) reported that single application of 0.025 per cent phosphamidon, dimethoate or methyl demeton at the end of January or beginning of February or two sprays of malathion 0.05 per cent at an interval of 10 days during same period reduced the population of *Uroleucon sonchi* on safflower. Similarly Sharma (1979) studied comparative efficacy of endosulphan, phosphamidon, methyl demeton and dimethoate against safflower aphid by aerial spray. Phosphamidon 312.5 ml/ha proved better for controlling the safflower aphid. The other insecticides in their order of decreasing efficacy were endosulphan, dimethoate and methyl demeton.

Rathore and Pathak (1982) found that methyl demeton at 250 ml a.i./ha was the most effective compound followed by monocrotophos at 400 ml a.i./ha and dimethoate at 300 ml a.i./ha. Treatment with methyl demeton also resulted in the highest seed yield and appeared to be selective to the coccinellid predators, *Menochilus sexmaculatus* Fabr., *Coccinella septempunctata* Linn. and *Brumus suturalis* Fabr. Kushwala (1983) and Budhraj et al. (1985) also reported that *U. compositae* is effectively controlled by methyl-demeton, dimethoate, monocrotophos and quinalphos at the rate of 500 ml (0.05 per cent) per hectare.

Devkumar et al. (1986) evaluated hexane extracted oil, deterpenated pure oil, lipid associated limonoids, all derived from fresh neem seeds, limonoidal residues from expeller grade neem oil and groundnut oil in the laboratory against *Dactynotus carthami* and found that only those compounds containing limonoids were aphidicidal. Azadirachtin was found to be highly toxic to *D. carthami*.

Singh et al. (1988) evaluated the efficacy of endosulphan 35 EC, dimethoate 30 EC, Phosphamidon 85 WSC and neem seed powder against *Uroleucon carthami* on safflower and found that two sprays of endosulphan at the rate of 800 ml or dimethoate at the rate of 750 ml/ha at fortnightly interval gave the most effective control.

The present results are in agreement with the

findings of above workers.

5.3.2 Bio-efficacy of plant products against safflower thrips

During the year 1998-99, all the insecticidal treatments were significantly superior over control. Lowest population of thrips was recorded in methyl demeton 0.05 per cent (T_7) and gave significantly lowest thrips over the other treatments. Endosulphan 0.05 per cent (T_9) was at par with thiamethoxam 0.01 per cent (T_8) and however, it was significantly superior over rest of the treatments. The treatment ' T_1 ' was at par with ' T_2 ' and ' T_5 ', however it was significantly superior over rest of the treatments.

During 1999-2000, lowest population of thrips was recorded in methyl demeton 0.05 per cent (T_7) and was significantly superior over rest of the treatments. The treatment ' T_1 ' was at par with ' T_2 ' and ' T_5 ' was significantly superior over rest of the treatments. Neemark 1.0 per cent (T_9) influenced the thrips population significantly than neem gold 0.5 per cent (T_6), castor oil 1.0 per cent (T_4), neem oil 3.0 per cent (T_3), methyl demeton 0.05 per cent (T_7), endosulphan 0.05 per cent (T_9) and thiamethoxam 0.01 per cent (T_8) but did not differ significantly from the response of nimbicidin 0.5 per cent (T_1) and bioneem 0.3 per cent (T_2).

Pooled data of 1998-99 and 1999-2000 revealed that the treatment 'T₇' recorded lowest population of thrips and was superior over T₁, T₂, T₃, T₄, T₅ and T₆ except T₈ and T₉. The treatment 'T₁' was at par with T₂, T₅, T₃, T₄ and T₆, however it was significantly superior over T₇, T₈, and T₉, (Table 31 and Fig. 9).

Carlson and Witt (1977) observed that methidathion and oxydemeton methyl effectively reduced bud damage from feeding by the western flower thrips, *Frankliniella occidentalis* (Pergande) and *Lygus hesperus* (Knight) on safflower. Both insecticides at 0.56 kg a.i./ha effectively controlled thrips damage and 2 applications (at prebloom and at onset of bloom) were superior to one and seed yields were significantly better over control.

5.3.3 Bio-efficacy of plant products against *Helicoverpa armigera* on leaves

Table 32 revealed that all the insecticidal treatments were significantly superior over control in both the seasons. During 1998-99, methyl demeton 0.05 per cent (T₇), thiamethoxam 0.01 per cent (T₈) and endosulphan 0.05 per cent (T₉) were at par with each other and were superior over neemark 1.0 per cent (T₅), nimbicidin 0.5 per cent (T₁), bioneem 0.3 per cent (T₂), castor oil 1.0 per cent (T₄), and neem oil 3.0 per cent (T₃). The treatments T₁, T₂, T₄ and T₆ were at par with each other and significantly

During 1999-2000, methyl demeton 0.05 per cent (T₇) influenced the population of *Helicoverpa armigera* on leaves significantly than neemark 1.0 per cent (T₅), bioneem 0.3 per cent (T₂), castor oil 1.0 per cent (T₄), neem gold 0.5 per cent (T₆), nimbicidin 0.5 per cent (T₁) and neem oil 3.0 per cent (T₃) but did not differ significantly from the response of thiamethoxam 0.01 per cent (T₈) and endosulphan 0.05 per cent (T₉).

The pooled data of two years (1998-99 and 1999-2000) revealed that all the insecticidal treatments were significantly superior over control in reducing the population of *Helicoverpa armigera* on leaves. Lowest population of *Helicoverpa armigera* was recorded in methyl demeton 0.05 per cent (T₇) and was at par with thiamethoxam 0.01 per cent (T₈) and endosulphan 0.05 per cent (T₉) but all these three treatments were significantly superior over rest of the treatments. significant differences were not observed between the treatments T₂, T₃, T₄ and T₆ (Table 32 and Fig. 10).

Information on this aspect is not available in the literature.

5.3.4 Bio-efficacy of plant products against *Helicoverpa armigera* on capsules

Table 33 revealed that all the insecticidal treatments were significantly superior over control in both the seasons.

Results of the pooled analysis for the years 1998-99 and 1999-2000, revealed that metasystox 0.05 per cent (T_7) recorded lowest population of *Helicoverpa armigera* on capsules and was significantly superior over rest of the treatments except T_8 and T_9 . There were no significant differences between the treatments T_1 , T_2 , T_3 , T_4 and T_6 .

Jha et al. (1997) studied the effects of sowing date and treatment with 0.025 per cent methyl demeton on *Trichoplusia orichalcea*, *Perigoea capensis* and *Helicoverpa armigera* on safflower during 1989-90. They reported that the treatment with demeton-s-methyl significantly reduced the population of larvae of *T. orichalcea* but populations of *C. capensis* and *H. armigera* were slightly greater in insecticide treated plots. The greatest mean population of *C. capensis* and *H. armigera* was obtained from plants sown on 4th date.

5.3.5 Bio-efficacy of plant products against safflower caterpillar

All the insecticidal treatments were significantly superior over control in both the seasons.

The pooled data of two years 1998-99 and 1999-2000 presented in Table 34 revealed that all the insecticidal treatments were significantly superior over control in reducing the population of safflower caterpillar. Lowest population of safflower caterpillar was recorded in methyl demeton 0.05 per cent spray (T_7) and was at par with endosulphan 0.05 per cent (T_9). There were no significant differences between the treatments T_1 , T_2 , T_3 , T_4 , T_5 , T_6 and T_8 .

Perusal of literature revealed that no other pertinent literature is available on this aspect.

5.3.6 Bio-efficacy of plant products on yield of safflower

All the insecticidal treatments were significantly superior over control in both the seasons.

Results of the pooled analysis for the years 1998-99 and 1999-2000 revealed that highest yield of safflower was recorded in methyl demeton 0.05 per cent spray (T_7) and was significantly superior over rest of the treatments except ' T_8 ' and ' T_9 '. The spray of nimbicidin 0.5 per cent

(T₁) was significantly superior over bioneem 0.3 per cent (T₂), neem oil 3.0 per cent (T₃), castor oil 1.0 per cent (T₄), neemark 1.0 per cent (T₅) and neem gold 0.5 per cent (T₆) (Table 35 fig. 13).

Carlson (1969) reported that seed yield of safflower increased from 1517 to 2059 lbs per acre by applying 0.5 lbs kg GS 1305 and 1 lbs endosulphan per acre. Gargav and Verma (1985) found that treatments of demeton-s-methyl (0.025 per cent) and phosphamidon (0.030 per cent) gave the highest yields in 1977-78 and 1978-79 respectively. Similar observations were made by Rathore and Pathak (1985) who stated that treatment with demeton-methyl also resulted in the highest seed yield and appeared to be selective to the coccinellid predators, *Menochilus sexmaculatus*, *Coccinella septempunctata* and *Brumus suturalis*.

From the foregoing discussion, it is apparent that the findings obtained in the present investigations corroborate the findings of above workers.

5.3.7 Effect of plant products on number of capsules per plant

Table 36 revealed that during 1998-99, all the chemical insecticides were significantly superior over the plant originated insecticides.

During 1999-2000, highest number of capsules per plant were recorded in methyl demeton 0.05 per cent spray (T_7) and was significantly superior over rest of the treatments.

This observation fall in line with those of Jakhmola and Yadav (1983), who investigated that phosphamidon, endosulphan, monocrotophos, vamidothion, dimethoate and methyl demeton, proved better in increasing the number of capsules per plant and there by increasing the yield of safflower.

Pertinent literature is not available on this aspect.

5.3.8 Effect of plant products on total grain weight per plant

All the insecticidal treatments were significantly

superior over control in both the seasons. During 1998-99, highest grain weight per plant was recorded in methyl demeton 0.05 per cent (T_7).

During 1999-2000, highest grain weight (gms) was recorded in methyl demeton 0.05 per cent spray (T_7) and was significantly superior over rest of the treatments except endosulphan 0.05 per cent (T_9).

Information on this aspect is not available in the literature.

5.3.9 Effect of plant products on 100 seed weight

It is evident from Table 38 that during 1998-99, weight of 100 seeds was highest in methyl demeton 0.05 per cent spray (T_7) followed by endosulphan 0.05 per cent (T_9) and thiamethoxam 0.01 per cent (T_8).

During 1999-2000, nimbecidin 0.5 per cent (T_1), thiamethoxam 0.01 per cent (T_8), endosulphan 0.05 per cent (T_9) and methyl demeton 0.05 per cent (T_7) were significantly superior over control but were at par with each other in effect.

Pertinent literature is not available on this aspect.

5.4 Screening of different varieties of safflower for aphid resistance

The results of pooled averages on screening of safflower cultivars against *Uroleucon sonchi* for their tolerance/susceptibility revealed that, out of the 20 entries screened, only Lats₁ was found to be highly tolerant. The 8 entries viz., CTV₃₀ x Lats₁, A₁, GMU-7868, PBNS-12, PBNS-11, F₄F₅ No. 62, GMU 1787 and Sel-48 were observed to be tolerant. While GMU-7047, S4 x Lats₂, PBNS-51, PBNS-10, LASF-29, A₁ x 19-185 and Sharda were moderately tolerant. These entries namely HUS-305, PSF14 and Sel-4 were susceptible to aphid. The only one cultivar Co 1 was highly susceptible to aphid.

In the present investigations, the germplasm lines found to be tolerant and moderately tolerant were somewhat spiny and succulent. The susceptible entries were very succulent and non-spiny.

Thakre (1972) screened about 163 lines of safflower against *Dactynotus carthami* at Akola and observed that none of the cultivars was completely immune to the attack of aphid, however six varieties namely LASF-29, Bijapur, No.168, No 7, I.C. 11930 and M.S. wild safflower were highly tolerant. Bankar (1984) concluded that among the 40 cultivars screened, the cultivars JL 2-2 and A-1 were the most promising.

Akashe et al. (1996) reassessed 16 promising safflower entries against aphids including 'Tara' and 'Sharda' and reported that out of these cultivars, GMU-174, 178, 1630, 5130 and PI-307077 were promising aphid tolerant sources.

These results are in confirmation with the findings of above workers.

Regarding spyness of safflower cultivar and infestation of aphid, similar results were got by Akashe et al. (1993_b) and revealed that most of the spiny and white flowered entries were more resistant to aphids which may be due to non-preference mechanism where as all non-spiny

entries were susceptible because of their more succulent nature of plant type.

Bhumannavar and Thontadarya (1979) screened 25 varieties of safflower to know the resistance to aphid and reported that spineless variety 'G-1145' recorded the least number of aphids (1990) per plant while G-929 A. a heavy spiny variety recorded maximum number of aphids (13225) per plant.

Deokar et al. (1984) tested 450 cultivars of safflower grown with or without normal plant protection treatments showed that untreated plots became infested by *Uroleucon carthami* in 50-90 days with 5 grades of infestation (upto 10, 11-20, 21-40, 41-60 and 61-90 aphids/2.5 cm stem) that were reflected in yield reduction. Comparison of these results in varieties with non-spiny, moderately spiny and very spiny stems showed that aphid incidence was negatively and yield positively correlated with plant spinyness.

The results of present study are similar with the results reported by earlier workers.

Suggestions of future line of work

The results obtained in present investigation needs further confirmation on following lines for constructive recommendations to the farmers in future for Marathwada region.

1. The environmental factors i.e. temperature and humidity plays an important role in occurrence of pest, so if long range studies are further conducted that would be helpful in developing forecasting models for formulating the exact control measures of the pest.
2. Being aphid as an important revage of safflower which is responsible for heavy losses in yield. So the concentration primarily be given on control of aphids.
3. Botanicals are also found equally effective as conventionals. They may be given prime importance in aphid control schedule of safflower.
4. The screening of different varieties of safflower for aphid resistance revealed the tolerance nature

of genotype 'Lats₂'. So this would be good donar parent which must be included in further resistance breeding programme.

'Lats₂' and botanicals may included as foremost IPM agent while formulating IPM schedule for safflower pest.

SUMMARY



Chapter VI

SUMMARY

Investigations were carried out at Marathwada Agricultural University, Parbhani to study the population dynamics of different pests of safflower, to assess the losses caused to safflower crop due to pest complex, to evaluate the efficacy of botanical insecticides against the pest complex of safflower and to screen the various varieties of safflower for aphid resistance during rabi seasons of 1998-99 and 1999-2000.

Important findings emerging from the present investigations are summarised below.

6.1.1 Population dynamics of pests of safflower

First appearance of aphid was noted in the last week of December in both the seasons when temperatures and relative humidity were 17.8°C and 53 per cent and 19.8°C and 52 per cent respectively. Heavy incidence of the pest was recorded in first week of February and thereafter population decreased in both the seasons.

First appearance of thrips was noted in the last week of December (52nd meteorological week). Population of the pest was subsequently increased upto first week of February in 1998-99 and third week of January in 1999-2000.

Again the pest population decreased in both the seasons. Highest population of thrips was recorded in first week of February during 1998-99 and third week of January during 1999-2000.

Incidence of *H. armigera* started in second week of January. Pest population was subsequently increased upto first week of February and again decreased in subsequent weeks. Maximum population of *H. armigera* on leaves (0.10/plant) was recorded in last week of January. As regards *H. armigera* on capsule, first appearance of the pest was observed in last week of January when temperature and relative humidity were 21.1 °C and 50.5 per cent respectively. The pest population increased subsequently and maximum population was recorded in second week of February, during both the seasons.

First appearance of safflower caterpillar was noticed in second week of January during 1998-99 and first week of January during 1999-2000. Pest population subsequently increased and maximum population was observed from 4th week of January to 1st week of February during 1998-99 and last week of January during 1999-2000.

6.1.2 Relationship between weather parameters and pests of safflower

Minimum temperature and morning relative humidity exhibited highest positive direct effect on aphid

population during 1998-99 and 1999-2000 respectively. Maximum temperature exhibited highest negative direct effect in both the seasons. Morning relative humidity during 1998-99 and evening relative humidity during 1999-2000 exhibited significantly positive correlation with aphid population.

During 1998-99, minimum temperature and during 1999-2000, morning relative humidity exhibited highest positive direct effect on thrips population. Maximum temperature exhibited highest negative direct effect on pest population during both the seasons.

Minimum temperature and evaporation exhibited highest positive direct effect on the population of *H. armigera* on leaves during 1998-99 and 1999-2000 respectively. Maximum temperature exhibited highest negative direct effect in both the trials. Maximum temperature and evaporation exhibited non-significantly negative correlation with the population of *H. armigera* on leaves.

during 1998-99, bright sunshine hours and during 1999-2000, maximum temperature exhibited highest positive direct effect on the population of *H. armigera* on capsules. Minimum temperature exhibited significantly positive correlation with the population of *H. armigera* on capsules during both the seasons. Morning relative humidity

exhibited non-significantly negative correlation with the pest population in both the trials.

Minimum temperature and morning relative humidity exhibited highest positive direct effect on the population of safflower caterpillar during 1998-99 and 1999-2000 respectively. Maximum temperature, minimum temperature, evaporation and wind velocity showed non-significantly negative correlation with the population of safflower caterpillar.

6.2 Assessment of crop losses due to safflower pest complex

The aphid population on Lats₁ was significantly low as compared to Co-1 during both the seasons. Significantly lowest population of aphid was recorded in the plots where the crop was treated completely throughout growth period (T₃) and in the plots where crop was protected during vegetative stage (T₁). Significantly lowest population of aphids was recorded in Lats₁ with T₁ and T₃ treatment combinations in both the seasons.

Comparatively low thrip population was recorded during 1999-2000 as compared to 1998-99. Thrips population was significantly low in the plots treated throughout growth period and in the plots treated during vegetative stage in both the years.

The population of *H. armigera* on leaves was higher in variety Co-1 than in Lats₁ in both the seasons.

Significantly lowest population of the pest was recorded in the plots where the crop was treated completely throughout growth period (T_3) and in the plots where the crop was protected during vegetative stage (T_1).

Significantly lowest population of *H. armigera* on capsules was recorded in the plots where the crop was protected completely throughout growth period (T_3) and in the plots where the crop was protected during reproductive stage (T_2) during 1998-99 and 1999-2000.

Comparatively higher population of safflower caterpillar was recorded during 1999-2000 as compared to 1998-99. The treatment T_4 recorded highest population of the pest where as T_1 and T_3 were at par with each other.

Effect of treatments on biometric parameters

The height of the plants in $Lats_1$ was recorded significantly more as compared to Co-1 in both the seasons. The plant height was significantly more in the plots with T_1 , T_2 and T_3 treatments as compared to unsprayed plots throughout growth period (T_4).

Length of shoot in the variety $Lats_1$ was slightly more as compared to Co-1 in both the trials. Length of shoot was not affected significantly in T_1 , T_2 and T_3 treatments but increased significantly in the same treatments over T_4 during both the seasons.

Significant reduction in number of leaves per plant was observed in the treatment T_4 as compared to rest of the treatments. In the treatment T_3 , significant increase in number of leaves was observed over T_1 and T_2 .

Number of spines per leaf in $Lats_1$ were recorded more as compared to Co-1 in both the seasons. Number of spines pe leaf were significantly more in the treatments T_1 , T_2 and T_3 as compared to T_4 . Significant reduction in number of spines per leaf was observed in $Lats_1$ with T_4 combination.

Yield and yield components

Number of capitula pe plant were significantly more in $Lats_1$ than in Co-1 in both the trials. Significantly more number of capitula per plant were obtained from T_1 and T_3 treatments where as they were significantly reduced in T_2 and T_4 treatments in both the years.

During 1998-99 and 1999-2000, significant reduction was observed in the treatment T_4 as compared to rest of the treatments. In the treatment T_3 , significant increase in number of seeds per capsule was observed over T_1 and T_2 .

Significantly increased safflower seed yield in $Lats_1$ was recorded than that of Co-1 in both the years. In both the seasons, the treatment T_1 and T_3 recorded

significantly higher yield of safflower over T_2 and T_4 . Likewise the yield in T_2 was also increased significantly as compared to T_4 in both the trials. Significant reduction was found in yield of safflower, corresponding to the combination of treatment T_4 followed by T_2 with Co-1 in 1998-99 as well as in 1999-2000.

6.2.1 Crop losses due to safflower pest complex.

Effect on biometric parameters

Sucking pest complex reduced the plant height by 3.98 and 7.20 per cent in $Lats_1$ and Co-1 during 1998-99 while 4.46 and 8.00 per cent during 1999-2000 respectively. *H. armigera* caused 1.40 and 1.16 per cent reduction in the height of Co-1 while the height of $Lats_1$ was not much affected during the same period. Safflower caterpillar reduced the plant height by 0.38 and 0.40 per cent in $Lats_1$ while 0.46 and 0.50 per cent in Co-1.

The reduction in length of shoot due to sucking pest complex was 2.72 and 5.38 per cent in $Lats_1$ and Co-1. Due to infestation of *H. armigera* 0.54 per cent and 0.48 per cent reduction in $Lats_1$ during first and second season was noted. Due to safflower caterpillar 0.29 and 0.32 per cent reduction in $Lats_1$ and 0.33 and 0.35 per cent reduction in Co-1 was noticed in first and second season respectively.

Sucking pest complex reduced number of leaves per plant by 2.00 and 2.58 per cent in Lats₁ and 1.98 and 2.76 in Co-1 during 1998-99 and 1999-2000. Per cent reduction in number of leaves per plant was less in Lats₁ as compared to Co-1 due to *H. armigera*. Safflower caterpillar reduced more number of leaves in Co-1 than in Lats₁.

Reduction in number of spines per leaf due to sucking pest complex in Lats₁ was nil while 1.52 and 1.20 per cent in Co-1 during 1998-99 and 1999-2000 respectively. The effect of *H. armigera* on number of spines was nil in Lats₁ and 0.06 per cent in Co-1. Influence of safflower caterpillar on number of spines per leaf was not observed in Lats₁ while 0.16 per cent in Co-1.

Effect on yield and yield components

The reduction in number of capitula of Lats₁ was 8.42 and 8.68 per cent while 10.94 and 11.36 per cent in Co-1 due to sucking pest complex. *H. armigera* caused 1.34 and 1.66 per cent reduction in capitula in Lats₁ while 2.94 and 3.00 per cent in Co-1. Very low response was obtained in reducing number of capitula due to the infestation of safflower caterpillar.

Sucking pest complex reduced the number of seeds per capsule by 7.98 and 8.32 per cent in Lats₁ and 10.20 and 10.84 per cent in Co-1. During 1998-99 and 1999-2000, 3.00 and 3.16 per cent reduction in number of seeds was

observed in Lats₁ while 3.74 and 4.12 per cent in Co-1 during the same period. Very low response was obtained in reducing number of seeds per capsule due to safflower caterpillar.

The losses to the tune of 17.35 and 18.46 per cent were recorded in Lats₁ and 23.36 and 24.40 per cent in Co-1 during 1998-99 and 1999-2000 respectively. The effect of *H. armigera* infestation was comparatively less in yield of Lats₁ and Co-1 in both the seasons. During 1998-99, 5.38 per cent loss in yield of Lats₁ and 8.58 per cent loss in yield of Co-1 was recorded. Lats₁ recorded 1.72 and 1.86 per cent loss due to safflower caterpillar during 1998-99 and 1999-2000 respectively.

6.3 Management of safflower pest complex through botanical insecticides

Lowest population of aphid was recorded in methyl demeton 0.05 per cent spray T₇) and was significantly superior over rest of the treatments. Among the botanicals, nimbicidin 0.5 per cent (T₁), bioneem 0.3 per cent (T₂) and neemark 1.0 per cent (T₅) were found promising in reducing the pest population. significant differences were not observed between the treatments T₁ and T₅, T₅ and T₉, T₆ and T₄ during 1998-99 and T₂, T₃ and T₆ during 1999-2000 respectively.

Among the conventional insecticides, methyl demeton 0.05 per cent spray (T₉) followed by endosulphan 0.05 per cent (T₉) and among the botanicals, nimbicidin 0.5 per cent (T₁) followed by bioneem 0.3 per cent (T₂) were found superior for the control of thrips on safflower.

Population of *H. armigera* on leaves was found to be nil in the plots treated with conventional insecticides during both the trials. But as regards the neem based products, neemark 1.0 per cent (T₅) was most superior followed by bioneem 0.3 per cent (T₃). There were no significant differences between the treatments T₂, T₃, T₄ and T₆.

Population of *H. armigera* on capsules was found to be nil in treatment with methyl demeton 0.05 per cent (T₇), thiamethoxam 0.01 per cent (T₈) and endosulphan 0.05 per cent (T₉). These three treatment were significantly superior over all neem based products but were at par with each other in both the seasons. However, among neem based products tested, the plots treated with bioneem 0.3 per cent (T₂) and neemark 1.0 per cent (T₅) were found promising.

During 1998-99 as well as 1999-2000, lowest population of safflower caterpillar was recorded in methyl demeton 0.05 per cent spray (T₇) and was at par with endosulphan 0.05 per cent (T₉). Among the botanicals,

bioneem 0.3 per cent (T_2), castor oil 1.0 per cent (T_4) and neemark 1.0 per cent (T_5) were found promising in reducing the pest population.

As regards yield of safflower, all the insecticidal treatments were significantly superior over control in both the seasons. Highest yield of safflower was recorded in methyl demeton 0.05 per cent spray (T_7) and was significantly superior over rest of the treatments except endosulphan 0.05 per cent (T_9). There were no significant differences between the treatments T_3 , T_4 and T_6 .

Highest number of capitulas per plant were recorded in methyl demeton 0.05 per cent spray (T_7) followed by endosulphan 0.05 per cent (T_9) and thiamethoxam 0.01 per cent (T_8). All the chemical insecticides were significantly superior over the plant originated insecticides.

Highest grain weight per plant was observed in methyl demeton 0.05 per cent (T_7) and was significantly superior over rest of the treatments except endosulphan 0.05 per cent (T_9). There were no significant differences between the treatments T_4 and T_6 in both the trials.

During both the seasons, weight of 100 seeds was highest in methyl demeton 0.05 per cent spray (T_7) followed by endosulphan 0.05 per cent spray (T_9) and thiamethoxam 0.01 per cent (T_8). There were no significant differences

between the treatments T_2 , T_3 , T_4 , T_5 and T_6 during both the trials.

Over all, It can be concluded that the conventional insecticides were superior over all the botanicals in reducing the infestation of pests. However among botanicals, nimbicidin 0.5 per cent (T_1), bioneem 0.3 per cent (T_2) and neemark 1.0 per cent (T_5) were observed promising and can be included confidently in controlling the important key pests of safflower. They will also help in reducing extra pressure increasing on environment due to insecticides and assist in implementation of IPM concept.

6.4 Screening of various varieties of safflower for aphid resistance

Data on screening of safflower cultivars against *Uroleucon sonchi* for their tolerance/susceptibility revealed that, out of the 20 entries screened, only Lats₁ was found to be highly tolerant. The 8 entries viz., CTV₃₀ x Lats₁, A₁, GMU-7868, PBNS-12, PBNS-11, F₄F₅NO-62, GMU-1787 and Sel-48 were observed to be tolerant. While GMU-7047, S₄ x Lats₂, PBNS-51, PBNS-10, LASF-29, A₁ x 19-185 and Sharda were moderately tolerant. These entries namely HUS-305, PSF₁₄ and Sel-4 were susceptible to aphid. The only one cultivar, Co-1 was highly susceptible to aphid.

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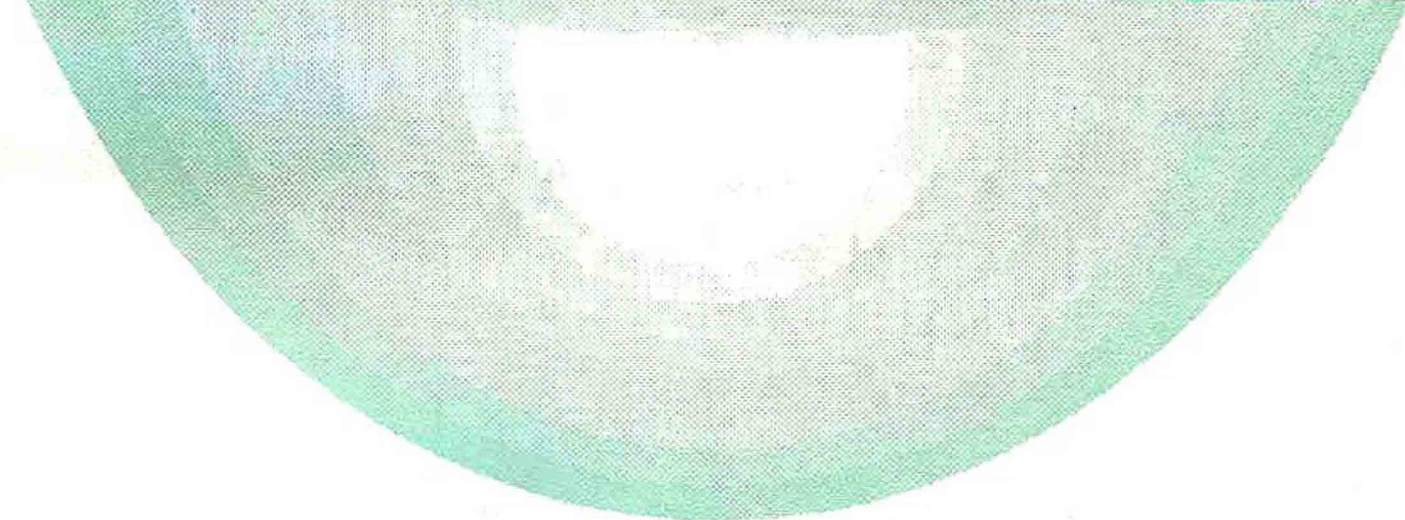
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APPENDIX



APPENDIX - I

Weekly average meteorological data during 1998-99.

Month	Meteo. week	Rainfall (mm)	Temp. (°C)		Humidity (%)	
			Max.	Min.	A.M.	P.M.
November	44	4.6	29.5	19.6	84	56
	45	22.0	29.8	19.6	78	38
	46	0.0	30.8	20.5	75	41
	47	0.0	29.3	15.4	78	37
December	48	0.0	29.6	13.0	77	29
	49	0.0	29.0	10.5	74	27
	50	0.0	29.5	8.8	76	28
	51	0.0	28.0	8.7	77	30
	52	0.0	27.8	7.9	78	28
January	1	0.0	28.0	7.8	80	31
	2	0.0	26.2	6.9	71	30
	3	0.0	28.7	9.0	78	29
	4	0.0	30.5	11.0	74	28
February	5	9.0	30.5	11.7	74	27
	6	0.0	30.5	15.6	83	38
	7	0.0	32.0	14.7	77	36
	8	0.0	34.5	14.7	66	38
March	9	0.0	35.5	15.8	69	29
	10	0.0	36.2	16.5	60	28
	11	0.0	36.7	17.8	51	24
	12	0.0	37.4	18.0	47	24
April	13	0.0	39.5	18.0	47	17
	14	0.0	40.3	19.7	46	14

APPENDIX - II

Weekly average meteorological data during 1999-2000.

Month	Meteo. week	Rainfall (mm)	Temp. (°C)		Humidity (%)	
			Max.	Min.	A.M.	P.M.
November	44	0.0	28.4	18.8	85	58
	45	0.0	32.5	15.3	74	37
	46	0.0	31.3	11.6	74	32
	47	0.0	28.6	10.0	75	24
December	48	0.0	29.6	9.4	75	25
	49	0.0	28.7	10.9	76	35
	50	0.0	27.0	8.1	81	29
	51	0.0	27.6	6.4	79	26
	52	0.0	29.0	10.7	75	29
January	1	0.0	28.0	8.0	76	25
	2	0.0	29.7	10.0	73	30
	3	0.0	31.2	13.5	75	35
	4	0.0	30.6	11.4	76	27
February	5	9.0	31.2	10.7	74	35
	6	0.0	30.5	12.6	72	33
	7	0.0	31.0	14.0	68	43
	8	0.0	30.7	13.2	77	51
March	9	0.0	31.8	13.4	72	28
	10	0.0	34.5	13.2	62	25
	11	0.0	32.6	12.8	70	30
	12	0.0	32.8	14.0	64	26
April	13	0.0	33.2	14.2	68	28
	14	0.0	34.0	15.0	69	30