STUDIES ON SEASONAL INCIDENCE AND MANAGEMENT OF POMEGRANATE FRUIT BORER, *Deudorix* (= *Virachola) isocrates* (Fab.) DURING *Hasta Bahar.*

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CERTIFICATE

This is to certify that the thesis **entitled "STUDIES ON SEASONAL INCIDENCE AND MANAGEMENT OF POMEGRANATE FRUIT BORER, *Deudorix* (= *Virachola) isocrates* (Fab.) DURING *Hasta Bahar.*"** submitted by Mrs. **VANITHA, K.,** for the Degree of **MASTER OF SCIENCE (HORTICULTURE)** in **ENTOMOLOGY**, to the University of Horticultural Sciences, Bagalkot, is a record of research work done by her, during the period of her study in this University, under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associate ship, fellowship or other similar titles.

BAGALKOT
AUGUST, 2017

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Dedicated to

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and Guide

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1. INTRODUCTION

Pomegranate (*Punica granatum* L.) is emerging as one of the commercially important fruit crop of tropical and subtropical regions of the world. The name pomegranate is derived from two latin words *Ponum* (= apple) and *granates* (= seeded). It belongs to family Lythraceae that includes one genus and two species, the other being *Punica protopunica* Balf (Socotra pomegranate) found wild in Socotra Island. In India, pomegranate is popularly known as *Anar* or *Dalima* or *Dodima*. It is thought to be indigenous to Iran, where it was first cultivated during 2000 B.C. (Evreinoffa, 1949). It spread to the Mediterranean countries and was extensively cultivated in Spain, Morocco, Egypt, Iran, Afghanistan, Arabia and Baluchistan. Its cultivation spread further to other countries like China, Japan, USA, USSR, Pakistan and India.

In India, it is regarded as a "vital cash crop", grown in an area of 1, 43, 140 ha with a production of 17,73,660 MT and average productivity of 12.39 MT (Anon., 2015a). Among the pomegranate growing states, Maharashtra is the largest producer occupying 2/3rd of total area in the country followed by Karnataka, Andhra Pradesh, Gujarat and Rajasthan. Karnataka has the distinction of cultivating pomegranate under tropical conditions with an area of 19,040 ha spread across different districts *viz.*, Vijayapura, Bagalkot, Chitradurga, Belagavi, Bengaluru, Bellari, Davangere, Gadag, Kalaburgi, Koppal, Raichur and Tumkur with an annual production of 2,04,640 tonnes (Anon., 2015b).

Area under pomegranate cultivation is increasing worldwide because of its hardy nature, wider adaptability and drought tolerance, higher yield levels with excellent keeping quality and remunerative prices in domestic as well as export market. It thrives well in dry and sub-tropics and comes up very well in soils of low fertility status as well as on saline soils. The most popular varieties suitable for processing and table purpose are Ganesh, Mridula, Arakta, Bhagwa, Kesar, G-137 and Khandar. Pomegranate is a good source of carbohydrates and minerals such as calcium, iron and sulphur. It is rich in vitamin-C and citric acid (Malhotra *et al.*, 1983). Glucose (5.46 %) and fructose (6.14 %) are the main sugars in fruits but no sucrose. The fruits of pomegranate are known to possess pharmaceutical and therapeutic properties. Sweet varieties are mildly laxative, while, sour types are good for curing inflammation of stomach and heart problems. In India, there is a common saying '*Ek Anar Sau Bimar Dur*' meaning one pomegranate cures hundred diseases. The flower buds are very useful in Ayurveda for managing bronchitis.

The bark of the stem, root and rind of the fruit are used for slimming, control of dysentery, diarrhoea and killing of tape worms (Anon., 1969). The arils of the well matured fruit are consumed raw and also in processed form like juice or concentrate, syrup and jelly. Seeds with fleshy portions of sour pomegranates are dried and marketed as '*Anardana*', which is being used as a condiment and for souring curries.

Several insect and non-insect pests are known to infest pomegranate crop (Mote *et al.,* 1992). About 47 insect species were known to attack pomegranate in India (Butani, 1976). Some prominent pests are fruit borer (*Deuodorix* (= *Virachola*) *isocrates* Fab.), fruit sucking moth (*Eudocema materna* Cramer), aphid (*Aphis punicae* Pass.), whiteflies (*Siphoninus phillyriae* Haliday), leaf eating caterpillar (*Trabala vishnou* Lefevere), shot hole borers (*Euwallacae* (= *Xyleborous*) *fornicatus* Eichoff), and *Xyleborous perforans* (Wollaston) mealybug (*Ferrisia virgata* Ckll.), thrips (*Scirtothrips dorsalis* Hood), stem borers (*Batocera rufomaculata* De Geer and *Celosterna scabrator* Fab.), scale insect (*Parasaisselia nigra* Nietn.) and mite (*Tenuipalpus punicae* P& B.). In Karnataka, area under commercial cultivation of pomegranate is steadily increasing mainly in Koppal, Chitradurga, Vijayapur, Bellari, Bagalkot, Belgavi, Davangere, Kolar, Dharwad, Tumkur, Bengaluru and Gulbarga districts. There are three main flowering seasons in a year which are locally known as *Ambe bahar* (June - August), *Mrig bahar* (October - November) and *Hasta bahar* (January - February). Therefore, this crop is most favorable for self perpetuation of the pests throughout the year.

In recent years, anar butterfly has become a major constraint in the production of quality fruits of pomegranate for domestic and export markets. Pomegranate fruit borer or pomegranate butterfly, *D. isocrates* is the most widespread, polyphagous and destructive pest with a wide range of host plants *viz*., wood apple, pomegranate, citrus, guava, litchi, aonla, apple, ber, loquat, mulberry, peach, pear, plum, sapota and tamarind (Halleppanavar, 1955; Butani, 1976; Anon., 2005). Peak incidence of the pest is noticed during August in monsoon and November- December in winter crop. It attacks the developing fruits and causes heavy losses for growers. Halleppanavar (1955) reported 100 per cent damage to pomegranate under severe epidemic conditions in Karnataka. However average, losses in the range of 40 to 90 per cent have been reported in different parts of India (Wadhi and Batra, 1969). Female butterflies of fruit borer lay eggs singly on vegetative as well as reproductive parts (bud, flower and developing fruit). On hatching, larva feeds externally and then enter into fruits and feeds internally. Pomegranate fruits with puncture caused by borer are most suitable for the entry of microorganisms responsible for rotting of fruits. Fruit borer has been considered as persistent pest in almost all pomegranate growing areas of Maharashtra and hence warrants the need to practice management based on sound scientific information. Apart from fruit borer, fruit sucking moth and thrips also cause damage to pomegranate fruits. The adults of fruit sucking moth, *E. maternal* suck the juice from half ripened fruits and cause premature fruit dropping. The thrips, *S. dorsalis* infesting pomegranate is a polyphagous pest known to cause damage to several seasonal field crops, vegetables and fruit crops. Both nymph and adult thrips feed by rasping and sucking. They lacerate the surface of developing fruit and cause deformation showing corcky appearance on surface of fruits which ultimately deteriorate the quality, fetching low price in domestic market and not acceptable for export (Praveenkumar, 2016).

Considering the potentiality of fruit borer, fruit sucking moth and thrips in damaging fruits right from flowering to harvest, it is necessary to manage these pests more effectively. Several pesticides have been reported to be effective against pests of pomegranate. However, most of them are required to be sprayed with high doses, which may pose problems of residues. In recent years, several new pesticides are available and claimed to be effective at low doses. Moreover, many of them are ecofriendly and posses novel modes of action than those of conventionally used pesticides belonging to organochlorine, organophosphate, carbamate and synthetic pyrethroid groups. So, evaluating the efficacy of such new insecticides and considering their suitability in Integrated Pest Management for managing pomegranate fruit borer, fruit sucking moth and thrips was considered essential.

Keeping the aforesaid facts in view, the present research work was carried out with the following objectives.

1. To study the seasonal incidence of fruit borer, *Deudorix isocrates* (Fab.) on pomegranate

2. To evaluate the efficacy of new insecticide molecules against pomegranate fruit borer

3. Formulation and evaluation of IPM modules for the management of pomegranate fruit borer during *Hasta bahar*

2. REVIEW OF LITERATURE

Insect pest complex occurring on pomegranate fruits, seasonal incidence and efficacy of new insecticide molecules against fruit borer and evaluation of integrated pest management modules against pomegranate fruit borers have been reviewed and presented in this chapter.

2.1 Insect pest occurring on pomegranate fruits

Pomegranate is attacked by large number of insect and non-insect pests. A list of nine insect species feeding on pomegranate in the Indian Union was published by Misra (1919). Subsequently, Ayyar (1938) reported 13 species infesting this crop in South India. Pruthi and Batra (1960), enlisted 21 insect species on pomegranate in North-West India.

In Maharashtra state, Cheema *et al.* (1954) reported that fruit borer or pomegranate butterfly (*Deudorix* (=*Virachola*) *isocrates* Fab.), bark eating caterpillar (*Indarbela quadrinotata* Wlk.) and whitefly (*Aleurodicus* spp.) are the most important pests of pomegranate. Whereas, Mathur and Singh (1960) and Butani (1979) reported 47 insect species infesting pomegranate in India. In addition, Zirpe (1966) recorded 26 insect and non-insect species infesting pomegranate in Maharashtra and reported four as economically important species *viz.*, fruit borer (*D. isocrates*), mite (*Tenuipalpus punicae* P. & B.), scale insect (*Saissetia nigra* Nietn.) and leaf eating caterpillar (*Euproctis fraterna* Moore). Mote *et al.* (1992) reported 53 insect species associated with pomegranate in Maharashtra. Although several pests are recorded, the fruit borer, bark eating caterpillar, shot hole borer, thrip, aphid, whitefly, mealy bug, scale insect and mite are recognized as important in cultivation of pomegranate (Parry and Pawar, 1988; Ghule and Dhumal, 1992; Jadhav and Ajri, 1992 and Patyal and Nath, 1993).

Ananda *et al.* (2009a) conducted a study on sucking insect and mite pests of pomegranate and their natural enemies through roving survey during 2006-07 at fortnightly interval in and around Bagalkot and revealed the association of eleven sucking insect and two mite pests. Among these, eight belonged to Hemiptera, three Thysonaptera and two Acarine pests. During roving survey, ten natural enemies (predators and parasitoids) were also encountered on sucking pests in pomegranate ecosystem. Among these, five belonged to Coleoptera, one each to Neuroptera and Hymenoptera. Three species of praying mantids were noticed as generalist predators in pomegranate ecosystem.

Ozturk and Ulusoy (2009) conducted a study on pests and natural enemies in pomegranate orchards in Turkey. They reported 100 pests belonging to 12 orders (Insecta= 8, Gastropoda, Arachnida, Aves and Mammalia) and 38 families and 64 natural enemies belonging to 7 orders (Insecta=7) and 14 families were found in pomegranate orchards in Turkey. Depending on the regions, two pests, *viz.*, *Ectomyelois ceratonia* Zell. (Lep.: Pyralidae) and *Ceratitis capitata* Wied. (Dip.: Tephritidae), are found to be the main pests and *Aphis punicae* (Hom.: Aphididae), *S. phillyreae*, *Aleurothrixus floccosus* Maskell (Hom.: Aleyrodidae), *Planococcus citri* (Risso) (Hom.: Pseudococcidae), *Zeuzera pyrina* (L.) (Lep.: Cossidae), *Carpophilus bipustulatus* Heer (Col.. Nitidulidae) and *Schistocerus bimaculatus* Ol. (Col.: Bostrychidae) are found to be other important pest problems. For natural enemies, *Chrysoperla carnea* Stephens (Neu. Chrysopidae), *Coccinella septempunctata* (L.), *Exochomus quadripustulatus* L., *Serangium montazerii* Fürsch, *Scymnus apetzi* Mulsant (Col.: Coccinellidae), *Nabis punctatus* Costa (Hem.: Nabidae), *Orius niger* Wollf. (Hem.: Anthocoridae), *Deraeocoris serenus* Doug. & Scott. (Hem.: Miridae), *Encarsia inaron* Walker (Hym.: Aphelinidae), *Episyrphus baltaetus* De Geer (Dip.: Syrphidae) and *Forficula auricularia* L. (Derm.: Forficulidae) are found to be common species in pomegranate orchards in Turkey.

Sachin *et al.* (2016) conducted a study on insect pests and their natural enemies in pomegranate. Among the borer pests, shot hole borer (*Xylosandrus compactus*) and hairy caterpillars (*Olene mendosa*, *Somena scintillans* and *Euproctis fraterna*) have been reported for the first time in pomegranate. A new species of shot hole borer, *X. compactus* was suspected to be associated with gummosis. Among sucking pests, vine mealybug, *Planococcus ficus*, cottony cushion scale, *Icerya aegyptiaca*, and brown soft scale, *Coccus hesperidium* are reported on pomegranate from Maharashtra.

2.1.1 Seasonal incidence of fruit borer on pomegranate

Aitkin (1886) noticed that pomegranate butterfly or fruit borer, *V. isocrates* was very common during December to March in Bombay and Poona regions. Mackinnon and Niceville (1896) observed it from July to September, near Mussoorie while Subramania (1921) reported the occurence of this insect during March and April in Mysore state. The pomegranate butterfly was noticed upto 4000 feet on Kumaon hills in India from July to November, while in Orissa and Dehra Dun it was found throughout the year. At Delhi, this butterfly was not common and the incidence was medium during September to November (Jandu, 1942). Lal (1952) found that fruit borer could breed throughout the year with four overlapping generations in a year. In North India, there were three distinct pomegranate bearing seasons *viz.*, *Ambebahar*. *Mrigbahar, Hast bahar*, where flowering coincides with January, July and November, respectively.

Halleppanavar (1956) recorded incidence of fruit borer throughout the year in Bombay and Karnataka, while Trehan (1956) observed more pest activity during summer in Punjab. Zirpe (1966) reported initiation of activity of fruit borer in July on *Mrigbahar* crop and was highest during second fortnight of October, while in *Ambebahar*, it began from January and it reached peak in the fortnight of May. Wadhi and Batra (1969) reported 40 to 90 per cent fruit borer damage in different parts of the country.

The pomegranate butterfly, *D. epijarbus* was reported as one of the most serious pests attacking the fruits in Himachal Pradesh (Butani, 1976 and Prasad *et al.*, 1987) and Jammu Kashmir (Zaka-ur-Rab, 1980). At Udaipur in Rajasthan, the incidence of fruit borer increased gradually from April and reached its peak during July and declined gradually afterwards (Pareek, 1982). Sinha and Roy (1984) stated that the anar butterfly, *V. isocrates* is the worst enemy of pomegranate fruits wherever pomegranate is grown.

The Anar butterfly, *D. isocrates* is an economically important and regular pest among all the butterflies. It is distributed across India and in the adjoining countries wherever pomegranate is grown. It is the most destructive pest of pomegranate fruit in the plains. The cornelian butterfly, *Deudorix epijarbas* (Moore) a closely related fruit borer species, occurs mainly in hills. Both these fruit borers limit the cultivation of pomegranate in certain areas, the former being widely distributed and predominant species (Kakar *et al.*, 1987)

Shah (1990) reported that pomegranate fruit borer was noxious pest and had inflicted damage to fruits to the extent of 40 per cent in the Andamans. Incidence of fruit borer on pomegranate was observed from September to October (Kabre and Moholkar, 1991) but, the period from July to October was favorable for its build-up (Shevale and Kaulgud, 1998) while, the period from November to February was intermediate (Shevale and Khaire, 1999). Kabre and Moholkar (1992) recorded the peak incidence of fruit borer on pomegranate during second half of March and second half of June in *Hasta* and *Ambe bahar*, respectively in Maharashtra.

Thirumurugan (1992) reported two peaks of fruit borers during June and November under different conditions. Murugan and Thirumurugan (2001) reported that severe infestation started from March onwards in pomegranate and reached to its peak in July-August and diminished during October to February.

In Solan district of Himachal Pradesh, the incidence of pomegranate butterfly increased gradually from June and reached its peak in the last week of July (Patyal and Nath, 1993) and the damage ranged from 12 to 94 per cent (Prasad *et al.*, 1987). The population dynamics of fruit borers, *V. isocrates* and *D. epijarbus* was at the ratio of 60 and 40 in Himachal Pradesh (Patyal and Nath, 1993). The incidence of fruit borer prevailed throughout the year depending on the weather conditions as reported by Angadi (1993). High relative humidity and rainfall increased the pest abundance of *V. iocrates* on pomegranate (Yadav and Pandey, 1995).

Shevale and Kaulgud (1998) observed severe incidence of pomegranate butterfly during *Mrigbahar*, showing significant positive correlation with relative humidity. The mealy bug, scale insect and whitefly were more abundant during *Ambebahar* having significant positive correlation with temperature and negative correlation with relative humidity.

In Tamil Nadu, Murugan and Thirumurugan (2001) reported that the infestation of fruit borer peaked during April to August.

Haseeb and Sharma (2007) studied the incidence and crop losses by fruit borer, *D. isocrates* in India and result indicated that the incidence of fruit borer was at its peak on cv. L-49 in the month of August in rainy crop, while in winter crop it was more during November or December. The incidence ranged from 3.0 to 38.0 per cent during these periods. Losses in fruit weight were found directly proportional to the extent of infestation by the borer.

Sunita (2012) studied the intensity of anar butterfly, *D. isocrates* for 40 standard weeks. The results revealed highest population of anar butterfly in third week of September (35.60/acre) followed by 32.22 per acre in the third week of August, 28.29 per acre in the secod week of September and 27.18 per acre in the fourth week of December. The minimum population was observed in the fourth week of November (10.79/acre). The population fluctuation showed greatest variation from September to November.

Sajad mohi-ud-din *et al.* (2015) conducted an experiment on seasonal incidence of anar butterfly and its correlation with weather parameters. According to them, the pest started its activity in the second fortnight of May and attained its peak in the second fortnight of August during 2011, as well as first fortnight of August during 2012. The maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and rainfall have showed positive and significant correlation with population build-up of the pest. Therefore, they concluded that fruit borer causes a considerable damage to pomegranate fruits and also the weather factors extended their specific impact on building- up of borer population. Apart from pomegranate the pest also cause significant damage to guava and considered as potential pest on sweet orange in India (Chhetry *et al.*, 2015)

Kulkarni *et al.* (2016) studied the influence of weather parameters on seasonal incidence of major pests of pomegranate in western Maharashtra. According to the study, *Mrigbahar* season was relatively more favorable to the infestation by fruit borer and thrips. However, incidence of aphids in *Hasta bahar* and mealy bugs and whiteflies in *Ambebahar* was high. Among different meteorological parameters, relative humidity and temperature played major role in regulating the pest population.

2.1.2 Seasonal incidence of other fruit damaging pests of pomegranate

Ananthakrishnan (1971) recorded two species of thrips (*Retithrips syriacus* Mayet and *Rhipiphorothrips cruentatus* Hood) on pomegranate. The nymph and adult of thrips could lacerate leaves and flower stalks and suck the sap that ooze out of these wounds. As a result, the leaf tips curled and dried away while flowers shed and ultimately the fruiting capacity of the plant was reduced.

In India, *S. dorsalis* on pomegranate is a common pest of chilli and pepper and hence known as a chilli thrips (Thirumurthi *et al.*, 1972). Different thrips species like *R. syriacus* feeds on leaves, and *Anaphothrips oligochaetus* Kerny, *Rama swamiahiell subnudula* Kerny, and *Scirtothrips dorsalis* Hood infest flowers and fruits of pomegranate (Butani, 1979).

Ahmed *et al.* (1987) reported losses due to *S. dorsalis* up to 50 per cent of total yield, while, Bagle (1993) reported loss of about 50 to 90 per cent fruit yield.

Incidence of *S. dorsalis* was observed on pomegranate during June to August (Bagle, 1993) and July to October (Shevale and Kaulgud, 1998).

Karuppuchamy *et al.* (1998) recorded the maximum incidence of aphid, *Aphis punicae* on pomegranate during the third week of February and March in hill area at Yercaud and plains at Namakkal in Tamil Nadu, respectively.

The occurrence of thrips and aphids was more prominent in *Mrig* and *Hasta bahar* crops, respectively (Shevale and Khaire, 1999).

Severe incidence of whitefly (*S. phillyreae*) was observed in February-April, 1999 to the extent of 60 to 65 per cent infested leaves (Balikai *et al.*, 1999). Zhang and Hu (2000) reported two generations in a year of pomegranate downy scale which is the important pest of pomegranate in China. Biradar and Shaila (2004) considered pomegranate aphid as the serious pest occurring regularly throughout the year with more abundance in winter.

Ramkumar *et al.* (2010) conducted a study on species diversity and seasonal abundance of fruit piercing moth complex in Tamil Nadu. Based on the survey made at different localities in Tamil Nadu, five species of primary fruit piercers belonging to two genera *viz.*, *Othreis materna* (L.), *O. fullonia* (Clerck), *O. homaena* Hubner, *O. salaminia* (Cram.) and *Rhytia hypermnestra* (Stoll) were found to feed on guava and citrus fruits. Among the five species, *O. materna* was the predominant piercer followed by *O. fullonia* and *O. homaena*. The species *viz.*, *O. salaminia* and *R. hypermnestra* were very less abundant in all the localities surveyed. Species richness of fruit piercing moth was higher in Periyakulam (2.173), low in Mettupalayam (1.103). The overall measure of diversity and relative abundance of fruit piercing moths was high at Periyakulam and low in Mettupalayam. The activity of *O. materna* found from the second fortnight of July to till January and *O. fullonia* and *O. homaena* was observed from the first week of September and continuing up to first forthnight of January. The larvae of *R. hypermnestra* were collected during first week of October and moth activity was recorded from the second fortnight of September.

Kotikal (2011) conducted a study on seasonal incidence of major sucking pests of pomegranate and their relation with weather parameters in India. A fixed plot survey conducted at five locations revealed the presence of pomegranate aphid (*Aphis punicae*), thrips (*R. ruentatus*; *S. dorsalis*; *Anaphothrips oligochaetus* Kerny), whiteflies (ash whitefly, *Siphoninus phillyreae* Haliday; spiralling whitefly, *Aleurodicus dispersus* Russell), mealy bug (*Planococcus lilacinus* (Cockrell)) and mites (eriopid mite, *Aceria granati* Canestrini; false spider mite, *Tenuipalpus granati* Sayed). The peak activity of pomegranate aphids was observed during the second fortnight of December. The highest infestation of thrips was noticed in the second fortnight of March. Population density of whiteflies was maximum during the second fortnight of February and the first fortnight of March. Nymphs and adults of mealy bug made early appearance during February and caused maximum damage during March and April. Incidence of mites started from January and reached a peak during the first fortnight of March.

Kulkarni *et al.* (2016) studied the influence of weather parameters on seasonal incidence of major pest of pomegranate in western Maharashtra. Occurrence of insect pests *viz.*, thrip, aphid, whitefly, mealy bug and scale insect was noticed, but the intensity of scale insects was negligible (0.01 to 0.49/twig). *Mrig bahar* season was relatively more favourable to the infestation of thrips (4.36/fruit). However, incidence of aphids (39.58/shoot) in *Hasta bahar,* and mealy bugs (5.29/fruit) and whiteflies (4.72% inf. leaves) in *Ambae bahar* was maximum (Praveenkumar, 2016).

2.1.3 Damage and economics significance of fruit damaging pests on pomegranate

Balikai *et al*. (2011) reported a total of 91 insects, six mites and one snail pest feeding on pomegranate crop in India. The most obnoxious enemy is pomegranate butterfly, *Deudorix* (=*Virachola*) *isocrates* Fab. which could destroy more than 50 per cent of fruits. Next in the order are the three species of fruit sucking moths (*Eudocima* (=*Othreis*) *fullonia* (Clerk) ; *Eudocima* (=*Othreis*) *materna* (Linn.) ; *Eudocima* (=*Othreis*) *homaena* Hub.) and two species of bark eating caterpillars (*Indarbela tetraonis* (Moore) ; *Indarbela quadrinotata* (Walker)). In the recent past, two species of pomegranate shot hole borers (*Xyleborus fornicatus* E.; *X. perforans* Wollastan) have become major pests infesting in the collar region of the plant by making innumerable pin or shot holes causing discontinuity in the conducting vessels affecting conduction of water to the upper portion of the plant. Consequently, the drying of the twigs became imminent and in severe cases the entire plant dried up. These sucking pests *viz*., whiteflies (Pomegranate whitefly, *Siphoninus phillyreae* (Haliday) ; Spiralling whitefly, *Aleurodicus dispersus* Russell) mealy bug (*Pseudococcus lilacinus* (Cockerell)) Thrips (*Rhipiphorothrips cruentatus* Hood; *Scirtothrips dorsalis* Hood; *Anaphothrips oligochaetus* Karny), aphid (*Aphis punicae*) and mites, *Aceria granati* Can. & Massal; occur during the flowering and fruiting stage of the crop and thereby reduce the vigor of the plant in addition to excretion of honeydew on the leaves and development of sooty mould on leaves and fruits.

Anithakumari *et al.* (2011) conducted a fixed plot survey at the Fruit Research Station, Sangareddy in central Telangana region during 2006 to 2008 to investigate the population dynamics of major pests of pomegranate. The major pests recorded on vegetative parts were aphids, thrips, stem borer, while fruit borer, mites and mealy bugs were recorded on reproductive parts. Fruit borer, *D. isocrates* (Fabricius) was the major pest which was constantly and regularly injurious on pomegranate during flowering and fruit set stage. Oviposition was observed on calyx and young larvae damaged the fruits from fruit set to maturity stage. The incidence of fruit borer was maximum during monsoon season (*Mrig bahar* crop). They also screened pomegranate cultivars against fruit borer. Among the five cultivars screened for fruit borer, maximum infestation was recorded in ‘Mridula’ (60%) followed by ‘Araktha’, ‘G-137’ and ‘Ganesh’ and lowest in ‘Bhagawa’ (30%). Low temperatures coupled with high humidity were congenial for the development of borer during the second fortnight of August. Incidence of thrips was observed on new flush but its severity was less. Aphids infestation was noticed on new flush as well as small fruits and the infestation was severe during August to September months. Mite damage was also noticed but with less intensity. Mealy bug infestation was more in the *hasta bahar* crop and increased with increase in temperature.

2.2 Evaluation of new insecticide molecules against pomegranate fruit borer

Sinha and Roy (1984) conducted an experiment to test the efficacy of some insecticides against butterfly, *V. isocrates* on pomegranate and found carbaryl 0.2% as most effective followed by quinalphos 0.05% and phosphamidon 0.03%.

Kabre (1986) evaluated 15 insecticides against pomegranate fruit borer and concluded that cypermethrin 0.0075 % was the most effective followed by decamethrin 0.025 % > cyfloxiate 0.03 % > fenvalerate 0.015 % > clocythrin 0.003 % > quinalphos 0.05 %.

Thirumurugan (1992) suggested the spray of cypermethrin 0.02% as effective against *V. isocrates*. Spray treatment of 0.14 per cent endosulphon was also reported to be effective in minimizing fruit damage (Dubey and Thakur, 1993). Cypermethrin 0.0075 per cent sprayed at an interval of 21 days after flowering was found effective by Kabre and Maholkar (1993). Verghese (1997) reported that infestation of the fruit borer was maximum from November- January, and two sprays of deltamethrin 0.0028 % during late rainy season or early winter resulted in excellent consistent control in both summer and rainy seasons.

Angadi (1993) reported that spraying of quinalphos 0.05%, methyl parathion 0.1%, carbaryl 0.2% and malathion 0.05% as effective against fruit borer when applied at the time of flowering and repeated at an interval of three weeks till the fruits were harvested.

Gupta and Dybey (2002) studied the bioefficacy of some insecticides against pomegranate fruit borer, *D. epijarbas*. The results revealed less infestation up to ten days of first spray, hence the treatments were non-significant. After ten days of second spray, only deltamethrin was statistically significant over control. However, after ten days of third spray, the fruit infestation was very high and all the chemical treatments were statistically superior over untreated control. Deltamethrin proved to be the most effective followed by ß-cyfluthrin and chlorpyriphos.

Wisam and Mazen (2002) studied the bionomics and control of pomegranate butterfly, *Virachola* (*Deudorix*) *livia* (Klug.). Use of malathion treatment with butter paper covering, lambda cyhalothrin treatment with bagging and dimethoate (0.045%) or deltamethrin (0.003%) with cloth were found effective against *D. isocrates* and recorded the best economic returns.

Kadam (2006) studied the performance of low dose pesticides against fruit borer and reported that emamectin benzoate 0.0022% was most effective treatment in minimizing fruit borer damage and recorded highest yield of 10.89 tonnes per ha followed by 0.0016% emamectin benzoate and 0.002% deltamethrin with the yield of 10.14 and 9.76 tonnes per ha, respectively.

Ramachandra (2007) reported that application of different chemicals like spinosad (0.018%), emamectin benzoate (0.0022%), thiodicarb (0.15%), deltamethrin (0.002%) and neem seed extract (NSE 5%) against pomegranate fruit borer, *D. isocrates*. Among these treatments the emamectin benzoate and spinosad could minimize the fruit damage to the extent of 2.37 and 3.21per cent and recorded the yield of 11.10 and 10.93 tonnes per ha, respectively. Whereas, untreated plants recorded fruit damage of 26.33 per cent with the yield of 628 tonnes per ha. Pareek (1997) reported that spraying of deltamethrin (0.002%) and carbaryl 50 WP (0.2%) in rotation at 21 days interval starting from fruit set are the most cost effective measures.

Kambrekar *et al.* (2015) conducted an experiment to evaluate new insecticides for the management of pomegranate fruit borer, *D. isocrates*. The study revealed that, emamectin benzoate 5 SG @ 0.25 g per l of water recorded highest reduction in the fruit damage at 3, 7 and 14 days followed by spinosad 45 SC @ 0.20 ml per l of water. The trees sprayed with emamectin benzoate and spinosad recorded highest quantity of marketable fruits (90.83 and 88.91 q/ha, respectively) and were statistically at par with each other.

Khan (2016) studied the biology and management of fruit borer, *D. isocrates* infesting guava. Per cent infestation reduction over control revealed that, package with field sanitation + collection of infested fruits + application of Superior® (chlorpyrifos + cypermethrin) 505 EC @ 1 ml per l of water and package consisting of field sanitation + collection of infested fruits + bagging of fruits with polythene bag gave 100 per cent control of the pest. They stated that these two packages may be used for the large scale cultivation.

Sajad Mohi-ud-din (2016) reported that, anar butterfly can be managed by spraying of dimethoate 30 EC (0.03 %) in the first fortnight of June or after initiation of fruit-setting. Three sprays of insecticides *viz.*, deltamethrin 2.8 EC (0.0028 %) or carbaryl 50 WP (0.2 %) or quinalphos 25 EC (0.06 %) or spinosad 45 SC (0.018 %) or malathion 50 EC (0.1 %) or dimethoate 30 EC (0.03 %) at 15 days interval from 2nd week of July.

Khan *et al.* (2017) conducted a study to evaluate effectiveness of chemical control against pomegranate fruit borer (*V. isocrates*). Results showed that, all the chemical applications proved significantly better than control plot. Most effective was lambda cyhalothrin which reduced the infestation level from 6.98 to 1.68 followed by methomyl (1.73), bifenthrin (2.05) and cypermethrin (2.58). Highest average infestation (8.14) was recorded in control plots.

2.2.1 Evaluation of new insecticide molecules against other fruit damaging pests of pomegranate

In an experiment conducted by Bagle (1993) in Gujarat, spraying of 0.05% monocrotophos provided effective control of thrips (*Scirtothrips dorsalis*) on pomegranate. Kadam (2006) studied the efficacy of some newly introduced pesticides against thrips on pomegranate and reported that spraying of 0.025% spinosad was most effective against infestation of thrips and also recorded highest fruit yield of about 12.6 tonnes per ha. This treatment was followed by 0.01% acetamiprid and 0.018% spinosad with the yield of about 12.4 and 12.0 tonnes per ha, respectively.

Pomegranate growers in Maharashtra always face the problems of thrips *S. dorsalis* which is polyphagous pests found infesting several cultivated crops. At international level thrips is considered as potential pest on pomegranate being responsible for deterioting the quality of fruits (Gilbert, 1986; Wang, 1994 and Karuppuchamy *et al.,* 2001b).

Ananda *et al.* (2009b) conducted a study for management of major sucking pests of pomegranate, results revealed that new generation insecticides *viz.*, thiamethoxam 25 WG @ 0.2 g and imidacloprid 200 SL @ 0.25 ml per l were most effective in controlling aphids by reducing the incidence by 85.90 and 83.54 per cent over control, respectively. These two treatments also reduced the population of thrips by 84.37 and 79.38 per cent, and white flies by 78.97 and 78.50 per cent, respectively. The combination of dimethoate 30 EC @ 1.7 ml and fish oil rosin soap @ 20 g/l proved to be effective against mealy bugs. Release of grubs of *Cryptolaemus montrouzieri* Mulsant was also effective against mealy bugs at the end of fourteen days after release.

Kambrekar *et al.* (2015) evaluated the effectiveness of cyazypyr (10% OD), against *S. dorsalis* in grapes for two fruiting seasons. Among the different doses of cyazypyr tested, cyazypyr @ 70 and 60 g *a.i* per ha has resulted in maximum reduction in the population to the extent of 97 per cent during first season and 100 per cent during second season. These doses have drastically reduced the thrips population within seven days after spray and minimized the damage caused by the pest. Cyazypyr @ 70 g *a.i* per ha has also recorded maximum berry yield of 19.38 and 20.38 tonnes per hectare followed by 60 g *a.i* per ha, which has registered 18.35 tonnes during first year and remained at par with cyazypyr @ 70 g *a.i* per ha.

2.3 Formulation and evaluation of IPM module for the management of fruit borers

Cherian (1942) recommended bagging of fruits with paper or muslin bag to prevent adult of *D. isocrates* from laying eggs on the fruits and also collection and destruction of the damaged fruits to reduce the infestation.

Shukla and Prasad (1983) conducted a study on comparative efficacy of various treatments for controlling pomegranate fruit borer, *V. isocrates* and revealed that polyethylene bagging, muslin cloth bagging and sprays of permethrin, cypermethrin (both at 0.02%), phosphamidon, monocrotophos, dimethoate, quinalphos (each at 0.05%) and dichlorovos (0.1%) were found highly effective and alternate sprays of phosphamidon and dimethoate at monthly interval can be recommended for its effective and economical control.

Thakur *et al.* (1988) conducted a survey for natural enemies of pomegranate butterfly, *D. epijarbas* in Himachal Pradesh, and reported occurrence of three egg parasitiods, *viz.*, *Anastatus sp*. nr. *kashmirensis* Mathur, *Aphelinus gossypii* Timberlake and *Telenomus cyrus* Nixon two larval parasitoids, *viz.*, *Apanteles (1) obliquae* Wilkinson and *Apanteles sp. vitripennis* group. Laboratory reared species of *Trichogramma chilonies viz., T. brasiliensis, T. exigllum, T. chilonis, T. minutum* and *T. perkinsi* did not parasitise the eggs in the laboratory as well as in the field.

Mansour *et al.* (1993) studied the effect of neem based products including neem seed extracts on predatory mites and spiders. Neem extract showed no harmful effect on benificials such as spiders, ladybird beetles and parasitiods and considered as potential component in IPM programmes.

Thakur *et al.* (1995) studied the incidence of pomegranate fruit borer, *D. epijarbas* and its natural enemies in Jammu region of Jammu & Kashmir. Mean fruit infestation was 25.33 per cent, however, infestation was lower at Kud which is located at higher altitude in comparison to Chenani and Dhrumtal. Two species of parasitoids *viz., A. kashmirensis* and *T. cyrus* were recorded parasitizing an average of 56.43 per cent eggs. Inundative releases of *Trichogramma chilonis* did not showed its establishment.

Shekharappa and Patil (1997) conducted a study on management of pomegranate fruit borer to reduce chemical pesticide load in nature. Neem based insecticides were tried using neemark in comparison with other insecticides for three years at Raichur (Karnataka). The result indicated that, malathion 50 EC at 2 ml and neemark at 5 ml per lit were found superior in reducing the incidence by recording 1.49 and 2.90 per cent fruit damage, respectively.

Singh and Singh (2000) evaluated the efficacy of different pesticides against anar butterfly, *D. isocrates*, infesting aonla, *Emblica officinalis*. Treatments comprised monocrotophos 0.05 per cent, nimol 0.50 and 1.00 per cent, nimbicidine 0.50 and 1.00 per cent, BIOLEP at 0.25 and 0.50 per cent, BIOASP at 0.25 and 0.50%, endosulfan at 0.07 per cent, muslin cloth bagging and untreated control. Both BIOLEP and BIOASP are commercial formulations of *Bacillus thuringiensis* var. *kurstaki* while, nimol and nimbicidine are commercial neem formulations. All the treatments significantly reduced the fruit damage. Bagging of fruits with muslin cloth proved to be most effective and gave total protection from the pest and produced more shining green and attractive fruits. Monocrotophos 0.05 per cent was the second most effective and economical treatment.

Release of parasitoid, *Trichogramma chilotraeae* Ishii. for the management of pomegranate fruit borer was effective in Himachal Pradesh and Karnataka. (Anon, 2001)

Karuppuchamy *et al.* (2001a) conducted a study on use of neem products and biological agents for the management of pomegranate fruit borer, *D. isocrates*. Which were found moderately effective against *D. isocrates*. They developed IPM module against the fruit borer with the components *viz.*, spraying of neem oil 3 % at the time of butterfly activity, one week later release of *T. chilonis* at 2.5 lakh parasitoids per ha, five days later spraying of monocrotophos 0.05 % as an ovicide and spraying of endosulfan 0.07 % twice, first 15 days after ovicide spray and the second 15 days thereafter, reduced the incidence of the pest to a greater extent.

Neem products such as, neem oil (3%), neem seed kernel extract (5%) and neem cake extract (5%) are moderately effective treatments against *D. isocrates*. (Anon, 2005)

Nagaraja and Ankitaguptha (2007) reported a new species of egg parasitoid, *Trichogramma manii* sp. Nov. (Hymenoptera: Trichogrammatidae) on pomegranate fruit borer, *D. isocrates* from Bangalore, India.

Biological control of pomegranate butterfly, *V. livia* was carried out by release of egg parasitoid, *Trichogramma evanescens* in Al-jabal al-akhdhar, Oman (Anon., 2009a and 2009b). Release was continued for four years and totally 300 million parasitoids were released into pomegranate orchards. The results showed low infestation during the season, where less number of eggs were collected in comparison with the previous years. The first egg sample was collected on 21st of April almost three weeks earlier than 2007 and the last egg sample was collected on the 30th of June and no eggs were found during July whereas, the last egg sample was collected on 24th July 2007. The parasitism percentage ranged from 0 to 100 per cent.

Bhut *et al.* (2013) conducted an experiment on bionomics and evaluation of different biocides against anar butterfly, *D. isocrates* infesting pomegranate and they reported that, among the nine biocides evaluated against *D. isocrate* on pomegranate, neem oil 0.5 per cent, neem seed kernel extract 5 per cent and *B. thuringiensis* @ 0.15 per cent were found more effective.

Verghese and Rashmi (2014) suggested for netting in pomegranate to protect from fruit sucking moth and also suggested to use small mesh size to protect from fruit borer, *D. isocrates*.

2.3.1 Formulation and evaluation of IPM module for the management of other fruit damaging pests of pomegranate

Neem based products including neem seed extracts showed no toxic effects on predatory mites and spiders (Mansour *et al.*, 1993). Ishaaya and Horowitz (1998) stated that the neem extract seems to have no harmful effect on benificials such as spiders, ladybird beetles and parasitiods, and considered as potential component in IPM programmes. Neem based pesticides were safe to natural enemies such as spiders, chrysopids, coccinellids (Schmutterer, 1990) and *Apanteles* spp. (Rosaiah, 2001).

Biradar and Navi (2006) studied the role of granular insecticides in the management of pomegranate sucking pest at Bijapur during 2001-02 and 2002-03. Three granular insecticides were used at different dosages. During both the years significantly higher per cent reduction in aphid population (91.4% and 88.1% during 2001-02 and 2002-03, respectively) was observed in the treatment treated with phorate 10G @ 30g per plant. The same trend was noticed in respect of thrips population also. Among the different dosages of carbofuron 3G, 100 g per plant was found most effective in reducing aphid and thrips population (97.2% & 100% reduction in aphid population during 2001-02 and 2002-03, and 90% and 100% reduction in thrips population during 2001-02 and 2002-03 respectively). Significantly higher yield was recorded in higher dosages of both the chemicals (45.25 q/ha and 46.13 q/ha in treatment carbofuron 100 g/plant during 2001-02 and 2002-03, respectively).

Kamalajayanthi *et al*. (2010) conducted a study on the possibility of managing fruit sucking moth, *Eudocima (=Othreis) materna* (L.) (Lepidoptera: Noctuidae) using feeding repellents. Results indicated that, plant oils *viz.,* jatropa, citronella, poppy, thevetia, neem and pongamia along with neem seed kernel extract were effective in preventing *E. materna* from feeding on the treated guava and pomegranate fruits. Annona oil was found to be a weak repellent.

Sawsan *et al.* (2011) evaluated the efficacy of some medicinal and ornamental plant extracts toward pomegranate aphid, *A. punicae* under laboratory conditions, *viz.*, *Aerva lanata*, *Ruta chalepensis*, *Fagonia arabica*, *Malva parviflora*, and *Calotropis procera*; were evaluated against pomegranate aphid, *A. punicae* under laboratory condition. Results indicated that the ethanol extract of *R. chalepensis* (whole plant) showed the highest repellency (75%) and mortality (79.5%) at 0.015% concentration. Followed by ethanol extract of *A. lanata* which elicited high repellent effect (60.68%) and moderate mortality percentage (55.54%) at 0.015% concentration. On the other side, water extracts of *A. lanata* caused the highest repellency (44.88%) and mortality (61.2%) at 5% concentration followed by *M. parviflora* which induced slight repellency (36.22%) and mortality (51.5%) at 5% concentration.

Bhumannavar and Viraktamath (2012) reported that genus *Eudocima* (=*Othreis*) as the dominant primary fruit piercers, accompanied by several secondary fruit feeders resulting in extensive damage to pomegranate in the south and orange in the central India. The damage was mostly observed during September to November. None of the earlier recommended methods such as catching the adult moths by hand net, smoking of the orchard in the evening, spraying the fruits with insecticides, baiting the adult moths with arsenic compounds, baggaing of the fruits, deterring the moths by the bright light source and destroying the larval host plants are adequately effective in reducing the damage caused by these insects. The egg and larval parasitoids hold good promise for the suppression of fruit piercing moths damage. Enclosing whole orchard with nylon net also advisable.

Narges *et al*. (2015) evaluated contact/fumigant toxicity of *Ferula assafoetida* (Apiaceae) essential oil against *A. punicae* in a pomegranate orchard in Karaj, Alborz province. Four treatments were used: water (control), ethanol (as oil solvent), 0.5, and 1.5 ml/L essential oil. The results showed significant differences between treatments ($p<0.001$) after 24 h. Application of 1.5 ml per l of the oil had a negative impact on aphids and caused a mortality rate of more than 70% in the population. Despite the fact that essential oils evaporate quickly in natural conditions, they could be used against sucking insect pests in the field. Complementary studies are needed to understand their effects on natural enemies such as parasitoids and predators.

Shlomo (2015) studied the efficiency of pomegranate fruit bagging as a physical protection method on pomegranate. The results suggested bagging of fruits as a good mechanical protection against serious pests. They opined that, introducing bags of the right mesh can provide better ventilation and accession of the pesticides while preventing damage by larger pests.

3. MATERIAL AND METHODS

The present investigation on 'seasonal incidence and management of pomegranate fruit borer, *Deudorix* (= *Virachola) isocrates* (Fab.) during *Hasta Bahar* was carried out during 2016-17. Field experiments were carried out at Bagalkot in Fruit Division, Sector 70 and pomegranate research plot at Main Horticulture Research and Extension Centre (MHREC), Udyanagiri, University of Horticultural Sciences (UHS), Bagalkot, Karnataka. While, the laboratory studies were carried out at Department of Entomology, College of Horticulture (COH), Bagalkot. The study area is located at a longitude of 75.7°E, latitude of 16.18°N and altitude of 533 meters above mean sea level. The detailed methodology adopted and materials used to carry out various experiments are described here under.

3.1 Seasonal incidence of fruit borer, *Deudorix isocrates* (F.) on pomegranate

3.1.1 Seasonal incidence of pomegranate fruit borer

This study was undertaken during 2016-17 in three separate fixed fields *viz.*, Main Horticulture Research and Extension Centre (MHREC), Sector 70, Bagalkot (under *Ambe bahar*), MHREC Sector 70, Bagalkot (under *Hasta bahar*) and Udyanagiri, Main campous (under *Ambe bahar*). The fields which were under *Ambe bahar* treatment were terminated (pruned) during December because of severe incidence of bacterial leaf blight, while, the field under *Hasta bahar* was continued up to fruit maturity from September 2016 to March 2017. All the three plots were under variety Bhagwa and were 3 years old and planted at 4.5 x 3.0 m spacing. Normal horticultural practices and plant protection measures against pests and diseases except fruit borer were taken up as per package of practices of UHS, Bagalkot (Anon., 2015).

3.1.2 Method of recording observations on fruit borer

Observations on incidence of fruit borer was recorded at weekly interval during fruiting seasons of pomegranate and the pest intensity was judged on the basis of damaged fruits on the pomegranate plant. Ten plants were randomly selected and were tagged to record the number of damaged fruits and healthy fruits from each plant during fruiting season. Later, the per cent fruit damage was worked out as follows.

$$\% \text{ fruit damage} = \frac{\text{No. of damaged fruits}}{\text{Total number of fruits}} \times 100$$

3.1.3 Observations on weather parameters

Observations on weather parameters *viz.*, maximum temperature, minimum temperature, morning and evening relative humidity and rain fall recorded at weekly interval were obtained from MHREC, Bagalkot (Appendix 1).

3.2 Evaluation of new insecticide molecules against pomegranate fruit borer during *Hasta bahar*

Field experiment was carried out to evaluate the efficacy of new insecticide molecules against pomegranate fruit borer and other fruit damaging pests. The experiment was carried out at Fruit Division, Sector, 70 UHS Bagalkot during 2016 in an area of 0.26 ha on three years old pomegranate crop of variety Bhagwa planted at a spacing of 4.5 × 3.0 m and was under *Hasta bahar* (pruned on Septembe 8^{th}, 2016).

Experiment was conducted in a randomized block design with eight treatments replicated thrice. The treatments consisted of six new insecticide molecules *viz.*, spinosad (Tracer 45 SC), emamectin benzoate (Proclaim 05 SG), cyazypyr (Benevia 10.26% OD), rynaxypyr (Coragen 18.5% SC), lambda cyhalothrin (Matador 4.9% CS) and azadirachtin (Neemgold 10,000 ppm) along with standard check (quinalphos 25% EC @ 2 ml/l) and untreated control (Table 1; Appendix II). Three plants were considered per replication per treatment. Treatments were imposed thrice with first spray coinciding initiation of fruit damage (5 – 10%) on 24-10-2016 and subsequent sprays were given based on fruit borer incidence *i.e.* 5-12-16 and 16-1-17. Blanket spray of imidacloprid 17.8 SL @ 0.25 ml per l was given twice at shoot development and 25% flowering stage and once by thiamethoxam 25 WG @ 0.2 g per l at fruit development stage as management against thrips. Spraying operation was carried out in non-windy hours in morning, mostly before 10 a.m. so as to avoid drift of spray treatment from target treatment plant to adjoining plants.

Table 1: Details of insecticide molecules for the management of fruit borer, *Deudorix isocrates* on pomegranate

Tr No.	Insecticides	Dosage (g or ml/l)	g *a.i*/ha
T_1	Cyazypyr 10.26 % OD	1.50 ml	76.95
T_2	Rynaxypyr 18.5% SC	0.30 ml	27.75
T_3	Spinosad 45 SC	0.25 ml	56.25
T_4	Lambda cyhalothrin 4.9% CS	0.50 ml	12.25
T_5	Emamectin benzoate 5% SG	0.25 g	6.25
T_6	Azadirachtin 10,000 ppm	1.00 ml	50000
T_7	Quinalphos 25% EC (SC*)	2.00 ml	250
T_8	Untreated control (Water spray)	-	-

*SC: Standard Check

3.2.3 Observations recorded

3.2.3.1 Fruit borer

Observations on fruit borer were recorded at day before spray (DBS) and 3, 7 and 14 days after spray. Fruit borer incidence was recorded by counting number of damaged fruits (with bored holes and dropped fruits with hole (Plate 1a & b)) and total number of fruits from each plant and was used to work out per cent fruit borer damage as shown in 3.1.2.

3.2.3.2 Fruit sucking moth and thrips

Observations on fruit sucking moth damage (Plate 1c & d) and thrips damage on fruits (plate 1e) was recorded by counting number of damaged fruits and total number of fruits per plant and later, per cent fruit damage was worked out.

3.2.3.3 Natural enemies

Natural enemies *viz.*, Coccinellids and spiders were recorded from five tagged shoots in each plant and was worked out as total number per plant.

3.2.3.4 Fruit yield

Marketable quality pomegranate fruits harvested during the season from each treatment plant were counted and weighed at each harvest and total weight of harvested fruits from each plant was taken into account to work out the fruit yield and further extrapolated to hectare basis.

3.2.3.5 Calculation of cost economics

Total cost of cultivation was worked out by adding all agronomic and plant protection costs including treatment cost. Gross return was calculated by considering the current wholesale market price for the good fruits (Rs. 80/kg). B:C ratio was worked out as mentioned below

B:C ratio = Gross return (Rs./ha) ÷ Total cost of cultivation (Rs./ha)

1a. Freshly damage on fruits by fruit borer

1b. Bored hole on fruit

1c. Fruit sucking moth damaged fruit

1d. Secondary infection on fruit sucking moth damaged fruit

1e. Thrips damage on fruits

Plate 1. Symptoms of damage on pomegranate fruits by fruit borer, fruit sucking moth and thrips

3.3 Formulation and evaluation of IPM modules for the management of pomegranate fruit borer during *Hasta bahar*

Field experiment was carried out to evaluate the formulated integrated pest management modules at MHREC, Sector 70, UHS Bagalkot during *Hasta bahar* (September 2016 to April 2017) in an area of 0.26 ha on three years old pomegranate crop of variety Bhagwa planted at a spacing of 4.5 × 3.0 m. Totally, five IPM modules were formulated based on available literature and information. The details of module components and their sequence are given in table. 2. Each module consisted of 15 plants with four intra field replications. Parasitoid release modules were separated by green shade net erected vertically one ft above crop canopy to reduce wind speed and also to confine parasitoids to released plots only (Plate 2a & b). Treatments were imposed thrice with first spray coinciding initiation of fruit damage (5 – 10%) on 22-10-2016 and subsequent sprays were given based on fruit borer incidence *i.e.* 4-12-16 and 17-1-17.

3.3.1 Release of *Trichogramma chilonis* to M_1, M_2 and M_3 modules

Tricho cards procured from National Bureau of Agricultural Insect Resources (NBAIR), Bangalore of species *Trichogramma chilonis* and strain, NBAII-MP-TRI-13 were used for these modules *viz.*, M_1: Biological IPM module, M_2: Bio-intensive IPM module and M_3: Adoptable IPM module @ 2.5 lakh per ha six times at weekly interval (40,000/release/ha). Trichocards were cut into small bits and were stapled on the lower surface of leaves in three plants which were at the centre of each module (Plate 3). Release was done during morning hours (7.30 – 8.00 am) for a twig which was less exposed to heavy sunlight.

3.3.2 Observations on fruit borer, fruit sucking moth and thrips

Observations on fruit borer, fruit sucking moth and thrips damage on fruit was recorded as explained in 3.2.3 and 3.2.4 at a day before and three, seven and fourteen days after each treatment imposition.

3.3.3 Observations on natural enemies

Observations on natural enemies *viz.*, Coccinellids and spiders were made as explained in 3.2.5 at day before and three, seven and fourteen days after each treatment imposition.

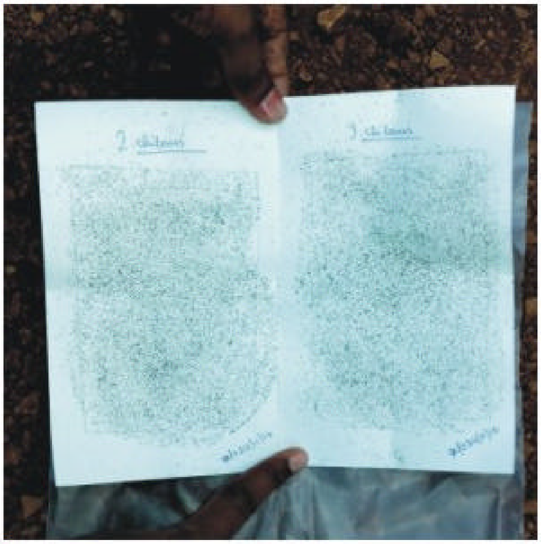
Table 2: Details of formulated IPM modules and their components used against fruit borer, *Deudorix isocrates* on pomegranate

M. No.	IPM modules	IPM Components and their sequence
M_1	Biological IPM module	Release of egg parasitoid, *Trichogramma chilonis* @ 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – Collection and destruction of affected fruits
M_2	Bio-intensive IPM module	Release of *Trichogramma chilonis* @ 2.5 lakh/ha -Azadirachtin 10000 ppm @ 1ml/l - *Bt* @ 1g/l- Collection and destruction of affected fruits
M_3	Adoptable IPM module	Release of *Trichogramma chilonis* @ 2.5 lakh/ha – Cyazypyr 10.26 % OD @ 1.50 ml/l – Spinosad 45 SC @ 0.25 ml/l – Collection and destruction of affected fruits
M_4	Chemi-intensive IPM module	Emamectin benzoate 5% SG @ 0.25 g/l – Cyazypyr 10.26 % OD @ 1.50 ml/l – Spinosad 45 SC @ 0.25 ml/l- Collection and destruction of affected fruits
M_5	Recommended Package of Practice	Malathion 50% EC @ 2.00 ml/l – Deltamethrin 25% EC @ 1.00 ml/l – Azadirachtin 1500 ppm @ 5.00 ml/l - Collection and destruction of affected fruits (RPP*)

2a. Erection of shade net wall to modules, M_1, M_2 and M_3 to prevent parasitoid movement through wind

2b. General view of insecticides treated pomegranate plot

Plate 2. Pomegranate experimental fields used for evaluation of insecticides and different IPM modules at MHREC, Bagalkot, Karnataka during *Hasta bahar,* 2016-17



3a. Trichocards, *Trichogramma chilonis*, strain NBAII-MP-TRI-13

3b. Preparation of Trichocards for release

3c. Tagging of Trichocards

3d. Tagged Trichocards

Plate 3. Preparation and tagging of Trichocards containing *Trichogramma chilonis* in IPM modules

3.3.4 Fruit yield

Fruit yield was recorded as explained in 3.2.6 separately for each module and was extrapolated to hectare basis.

3.3.5 Calculation of cost economics

Total cost of cultivation, gross return and B:C ratio was worked out as explained in 3.2.3.5.4

3.4 Statistical analysis

Data obtained from the study was subjected to suitable transformation based on nature of the data before subjecting to suitable statistical analysis.

Weekly data on incidence of fruit borer during crop growth period and weather parameters were subjected to correlation matrix analysis.

Data on per cent fruit damage obtained from new insecticides evaluation trial and IPM module evaluation trials were subjected to arc sine transformation and then were analysed with single factor ANOVA and means were compared based on CD value at 5%. The data on natural enemies from both trials were subjected to square root transformation and analysed using single factor ANOVA through *WASP* software as given by ICAR Research complex, Goa.

4. EXPERIMENTAL RESULTS

The results of investigations to study "Seasonal incidence and management of pomegranate fruit borer, *Deudorix isocrates* Fab. (Lepidoptera: Lycaenidae) during *Hasta bahar*" during the year 2016-17 at Fruit Division, Sector No. 70 and Udyanagiri, College of Horticulture, University of Horticultural Science Bagalkot are presented in this chapter separately under different headings.

4.1 Seasonal incidence of pomegranate fruit borer

Observations on incidence of fruit borer were recorded at a weekly interval in an experimental plot of three-years-old pomegranate variety, 'Bhagwa'.

4.1.1 Incidence of pomegranate fruit borer

Pomegranate fruit borer composed of only one species, *D. isocrates* laid whitish, sculptured eggs singly on calyx of flowers, young fruit or developing fruit. The young ones after hatching bored into fruit and fed on arils of tender fruit. The larvae completed development inside fruit. The grown up larvae is brownish, white, with prominent tubercules and whitish spots pupated inside or outside the fruit (Plate 4). The larvae is capable of damaging more than one fruit their by can cause significant yield loss.

4.1.2 Seasonal incidence of fruit borer during *Hasta bahar*

The weekly data on per cent fruit borer damage for the period from September 2016 to March 2017 is presented in Table 3. Fruit borer damage was relatively higher during *Ambe bahar i.e.,* 61.10 and 59.10 per cent damage in Udyanagiri and Fruit division plots, respectively. In the present study, incidence of fruit borer was highest during first fortnight of September. While, during *Hasta bahar* in Fruit division the highest incidence recorded was 15.33 per cent during first week of February and declined after wards.

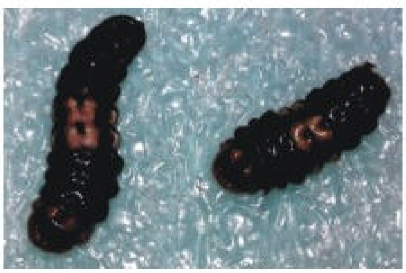
However, the incidence of fruit borer was noticed throughout the period from September to March. The peak incidence of fruit borer was recorded during September first week (35 standard week (SW) and was 60.10%) followed by 36 SW

Table 3: Seasonal incidence of pomegranate fruit borer, *Deudorix isocrates* during *Hasta bahar* and *Ambe bahar* of 2016-17

Month	Standard week	Fruit borer damage (%)			
		Udyanagiri (*Ambe bahar*)	Fruit Division (*Ambe bahar*)	Fruit Division (*Hasta bahar*)	Mean
September- 2016	35	61.10	59.10	-	60.10
	36	8.84	19.60	-	14.22
	37	8.15	8.88	-	8.51
	38	9.00	8.15	-	8.57
October- 2016	39	9.00	9.65	-	9.32
	40	8.15	9.12	-	8.63
	41	7.34	8.67	-	8.00
	42	8.00	8.00	-	8.00
November - 2016	43	4.91	8.54	-	6.72
	44	4.00	7.92	-	5.96
	45	4.51	7.67	-	6.09
	46	5.00	7.75	-	6.37
December - 2016	47	4.40	8.54	-	6.47
	48	4.10	7.92	-	6.01
	49	4.31	7.67	-	5.99
	50	3.00	7.75	-	5.37
January - 2017	51	-	-	13.20	13.20
	52	-	-	10.04	10.04
	1	-	-	13.73	13.73
	2	-	-	12.33	12.33
	3	-	-	15.33	15.33
February- 2017	4	-	-	7.33	7.33
	5	-	-	7.07	7.07
	6	-	-	9.91	9.91
March - 2017	7	-	-	8.67	8.67
	8	-	-	12.00	12.00
	9	-	-	10.43	10.43
	10	-	-	3.37	3.37

4a. Eggs of fruit borer on calyx

4b. Egg of fruit borer on fruit

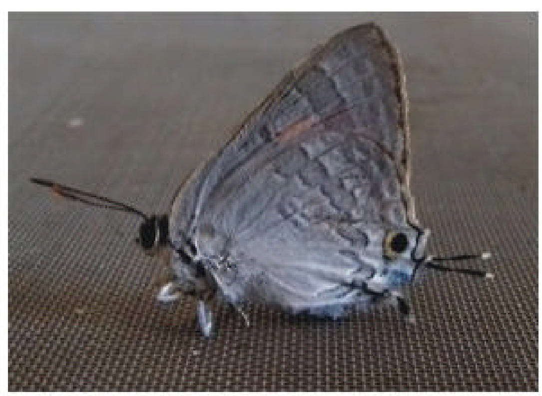


4c. Larvae of pomegranate fruit borer

4d. Pupa of fruit borer (Dorsal view)

4e. Pupae of fruit borer (Ventral view)

4f. Pomegranate fruit borer adults



4g. Pomegranate fruit borer adult in resting posture

Plate 4. Different developmental stages of pomegranate fruit borer, *Deudorix isocrates*

(14.22%). Subsequently, fruit borer incidence declined during October to December and the incidence ranged from 5.37 to 9.32 per cent. Infestation of pomegranate fruit borer increased steadily from January and reached its peak in the month of February (15.33%) first week (3rd SW). Incidence declined from February onwards and reached lowest of 3.37 per cent during fourth week of March (10th SW).

4.1.3 Correlation between weather parameters and incidence of *D. isocrates*

The weekly incidence of fruit borer (*D. isocrates*) was correlated with various weather parameters *viz.*, maximum temperature, minimum temperature, morning and evening relative humidity and rainfall and presented in Table 4.

The simple correlation studies during fruiting period revealed that, the incidence of fruit borer did not show significant correlation with any of the weather parameters. However, correlation of pest incidence was positive and non-significant with minimum temperature (r = 0.162), morning and evening relative humidity (r = 0.111) and rainfall (r = 0.002). On the other hand, correlation was negative and non-significant with maximum temperature (r = -0.049) and rainy days per week (r = -0.004).

4.2 Evaluation of the efficacy of new insecticide molecules against pomegranate fruit borer

Bio-efficacy of some selected new insecticides was studied against pomegranate fruit borer (*Deudorix isocrates*) and other fruit infesting pests *viz.*, fruit sucking moth (*Eudocima materna*) and thrips (*Scirtothrips dorsalis*) by conducting field trials at Fruit Division, Sector 70 of UHS, Bagalkot during *Hasta bahar*. Treatments were imposed thrice at an interval of 20 - 30 days based on incidence from October to January.

4.2.1 Efficacy of new insecticides against fruit borer

Effectiveness of insecticide against fruit borer, *D. isocrates* was evaluated on the basis of fruit damage recorded at a day before spray and 3, 7 and 14 days after each spray (DAS) and the results are presented in Table 5.

Table 4: Correlation analysis between fruit damage due to *Deudorix isocrates* and weather parameter during *Hasta bahar,* 2016-17

Weather parameter	**Correlation coefficient (r) values for fruit borer damage (%)**	**Statistical Significance**		
		Cal. T value	**Table T value**	**Significance @ 5 %**
Max. Temp (°C)	-0.049	0.218	2.056	NS
Min. Temp. (°C)	0.162	0.876	2.056	NS
Mrng. RH (%)	0.111	0.561	2.056	NS
Evng. RH (%)	0.111	0.561	2.056	NS
Rainfall (mm)	0.002	0.039	2.056	NS
Rainy days/week	-0.004	0.031	2.056	NS

Mrng. RH : Morning Relative Humidity
Evng. RH: Evening Relative Humidity

Table 5: Efficacy of different insecticides against pomegranate fruit borer, *Deudorix isocrates* during *Hasta bahar*, 2016-17

Tr. No.	Treatments	Dosage (ml or g/l)	Fruit borer damage (%)															Reduction in fruit borer damage over UTC (%)
				1st spray				2nd spray				3rd spray						
			1 DBS	3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean	Average		
T_1	Cyazypyr 10.26% OD	1.50 ml	9.93 (18.37)	8.77^{ab} (17.22)	6.63^{b} (14.92)	3.67^{b} (11.04)	6.36^{a} (14.60)	0.67^{a} (4.68)	0.83^{a} (5.24)	0.00^{a} (0.00)	0.50^{a} (4.05)	0.67^{a} (4.68)	0.83^{a} (5.23)	0.67^{b} (4.68)	0.72^{a} (4.88)	2.51^{a} (7.78)		78.85
T_2	Rynaxypyr 18.5% SC	0.30 ml	10.97 (19.34)	7.70^{a} (16.11)	5.17^{a} (13.14)	2.62a (9.31)	5.16^{a} (13.13)	0.67^{a} (4.68)	0.67^{a} (4.68)	0.00^{a} (0.00)	0.44^{a} (3.82)	0.67^{a} (4.68)	1.12^{b} (6.07)	0.04^{a} (1.19)	0.61^{a} (4.48)	2.07^{a} (7.14)		82.56
T_3	Spinosad 45 SC	0.25 ml	9.81 (18.25)	10.37^{b} (18.78)	7.73^{bc} (16.15)	8.00^{c} (16.43)	8.70^{b} (17.15)	2.67^{b} (9.40)	1.67^{b} (7.42)	0.00^{a} (0.00)	1.44^{b} (6.90)	2.33^{bc} (8.79)	2.13^{c} (8.40)	1.67^{bc} (7.42)	2.04^{bc} (8.22)	4.06^{b} (10.76)		65.79
T_4	Lambda cyhalothrin 4.9% CS	0.50 ml	10.67 (19.07)	9.87^{b} (18.31)	8.87^{de} (17.32)	10.00^{d} (18.43)	9.58^{bc} (18.03)	2.67^{b} (9.40)	4.05^{cd} (11.61)	3.00^{c} (9.97)	3.24^{c} (10.37)	1.33^{ab} (6.63)	1.00^{ab} (5.74)	2.27^{d} (8.66)	1.53^{b} (7.11)	4.78^{bc} (11.84)		59.73
T_5	Emamectin benzoate 5% SG	0.25 g	11.97 (20.24)	13.57^{c} (21.61)	10.4^{ef} (18.81)	4.33^{b} (12.01)	9.43^{b} (17.89)	2.83^{b} (9.69)	7.67^{e} (16.07)	2.67^{c} (9.40)	4.39^{d} (12.09)	1.67^{b} (7.42)	4.00^{e} (11.54)	3.20^{d} (10.30)	2.96^{c} (9.90)	5.59^{c} (13.29)		52.90
T_6	Azadirachtin 10,000 ppm	1.00 ml	11.50 (19.82)	13.07^{c} (21.19)	11.33^{f} (19.67)	8.33^{c} (16.78)	10.91^{cd} (19.29)	3.17^{b} (10.25)	2.93^{c} (9.86)	0.67^{b} (4.68)	2.26^{bc} (8.64)	6.67^{d} (14.96)	5.53^{f} (13.61)	1.97^{c} (8.06)	4.72^{d} (12.55)	5.96^{d} (13.49)		49.78
T_7	Quinalphos 25% EC (SC)	2.00 ml	10.44 (18.85)	9.80^{b} (18.24)	8.47^{cd} (16.92)	9.16^{cd} (17.61)	9.14^{b} (17.60)	4.00^{b} (11.54)	4.67^{d} (12.48)	4.83^{d} (12.70)	4.50^{d} (12.25)	2.60^{c} (9.28)	2.97^{d} (9.92)	3.57^{d} (10.89)	3.04^{d} (10.05)	5.56^{cd} (13.30)		53.15
T_8	Untreated control (Water spray)	-	9.13 (17.59)	13.20^{c} (21.30)	10.04^{e} (18.48)	13.73^{e} (21.75)	12.33^{d} (20.55)	15.33^{c} (23.05)	7.33^{e} (15.71)	7.07^{e} (15.42)	9.91^{e} (18.35)	8.67^{e} (17.12)	12.00^{g} (20.27)	19.43^{e} (26.16)	13.37^{e} (21.44)	11.87^{e} (20.12)		-
S.Em. ±			-	0.66	0.52	0.51	0.56	0.80	0.45	0.63	0.54	0.60	0.40	0.96	0.65	0.58		
C.D. at 5%			NS	1.98	1.58	1.54	1.702	2.42	1.36	1.09	1.62	1.80	1.20	2.90	1.97	1.76		
C.V. (%)				5.94	5.35	5.78	5.671	13.50	7.501	8.218	9.74	11.27	6.90	17.31	11.83	9.08		

DBS: Day Before Spray
DAS: Days After Spray
UTC: Untreated Control
NS : Non Significant

SC: Standard Check
Figures in the parentheses are arc sin transformed values
Figures with same alphabetical superscripts are statistically non-significant

4.2.1.1 At first spray

Fruit damage in untreated pomegranate plants ranged from 9.13 to 13.73 per cent with a mean of 12.33 per cent during the observation period. All the treatments were significantly superior over untreated control in minimizing the fruit damage. At 3 DAS, rynaxypyr 18.5% SC @ 0.30 ml recorded significantly lowest fruit damage (7.70%) which was at par with cyazypyr 10.26 % OD @ 1.50 ml per l(8.77%). The next best treatments were, quinalphos 25% EC @ 2.00 ml (9.80%), lambda cyhalothrin 4.9% CS @ 0.50 ml (9.87%) and spinosad 45 SC @ 0.25 ml per l (10.37%) and were statistically at par with each other. At 7 DAS, rynaxypyr 18.5% SC recorded significantly lowest fruit damage (5.17%) and was statistically superior over all other treatments. The next best treatments were, cyazypyr 10.26% OD and spinosad 45 SC which recorded 6.63 and 7.73 per cent fruit damage, respectively. At 14 DAS, rynaxypyr 18.5% SC recorded significantly lowest fruit damage (2.62%) and was statistically superior over all other treatments. The next best treatment were, cyazypyr 10.26% OD and emamectin benzoate 5% SG @ 0.25 g per l, which recorded 3.67 and 4.33 per cent fruit damage, respectively. Whereas, spinosad 45 SC, azadirachtin 10,000 ppm @ 1.00 ml per l, and quinalphos 25% EC @ 2.00 ml per l recorded significantly higher fruit borer damage of 8.00, 8.33 and 9.16 per cent, respectively.

Across the different treatments, the mean fruit borer damage in rynaxypyr and cyazypyr was significantly lowest (5.16 and 6.36%) followed by spinosad, quinalphos, emamectin benzoate and lambda cyhalothrin with a mean fruit damage of 8.70, 9.14, 9.43 and 9.58 per cent, respectively.

4.2.1.2 At second spray

The data obtained on fruit damage due to fruit borer in the field trial are given in Table 5. Fruit damage in untreated pomegranate plants ranged from 7.07 to 15.33 per cent with a mean of 9.91 per cent during observation period. All treatments were significantly superior over untreated control in recording lower fruit damage. At 3 DAS, rynaxypyr 18.5% SC @ 0.30 ml and cyazypyr 10.26% OD @ 1.50 ml per l recorded significantly the lowest fruit damage of 0.67 per cent each and were statistically at par with each other. The next best treatments were spinosad 45 SC @

0.25 ml (2.67%), lambda cyhalothrin 4.9 CS @ 0.50 ml (2.67%), emamectin benzoate 5% SG @ 0.25 g (2.83%), azadirachtin 10,000 ppm @ 1.00 ml (3.17%) and quinalphos 25% EC @ 2.00 ml per l. (4.00%) and were statistically at par with each other. At 7 DAS, similar trend was recorded where, rynaxypyr 18.5% SC and cyazypyr 10.2% OD recorded significantly lowest fruit damage (0.67 and 0.83% respectively) At 14 DAS, spinosad 45 SC, rynaxypyr 18.5% SC and cyazypyr 10.26% OD recorded no fruit damage (0.00 %) and were statistically superior over all other treatments followed by azadirachtin 10000 ppm (0.67%). The next best treatments were emamectin benzoate 5% SG and lambda cyhalothrin 4.9% CS which recorded moderate fruit borer damage (2.67 and 3.00 %, respectively). Standard check, quinalphos 25% EC @ 2.00 ml per l was inferior and recorded significantly higher fruit damage (4.83%).

Among seven tested pesticides, rynaxypyr and cyazypyr were effective in controlling fruit borer damage (0.44% and 0.50%, respectively), followed by spinosad and azadirachtin which were next best treatments with 1.44 and 2.26 per cent fruit damage, respectively. Whereas, lambda cyhalothrin, emamectin benzoate and quinalphos recorded higher per cent fruit damage of 3.24, 4.39 and 4.50 per cent, respectively.

4.2.1.3 At third spray

Fruit damage during third spray in untreated pomegranate plants ranged from 8.67 to 19.43 per cent with a mean of 13.37 per cent. All treatments were significantly superior over untreated control in recording lower fruit damage. At 3 DAS, rynaxypyr 18.5% SC @ 0.30 ml recorded significantly lowest fruit damage (0.67%) which was at par with cyazypyr 10.26% OD @ 1.50 ml (0.67%) and lambda cyhalothrin 4.9% CS @ (1.33%) The next best treatments were, emamectin benzoate 5% SG @ 0.25 g (1.67%), spinosad 45 SC @ 0.25 ml (2.33%), lambda cyhalothrin 4.9% CS @ 0.5 ml (2.67%) and quinalphos 25% EC @ 2.00 ml per l (2.60%) which recorded lower of fruit borer damage. At 7 DAS, cyazypyr 10.26% OD @ 1.50 ml (0.83%) recorded significantly lowest fruit damage which was at par with lambda cyhalothrin 4.9% CS (1.00%) followed by rynaxypyr 18.5% SC @ 0.30 ml (1.12%) and were statistically superior over all other treatments. At 14 DAS, rynaxypyr 18.5% SC recorded significantly lowest fruit damage (0.04%) and the next best treatments were cyazypyr

10.26% OD (0.67%) and spinosad 45 SC (1.67%) while, azadirachtin 10,000 ppm, lambda cyhalothrin 4.9% CS and emamectin benzoate 5% SG were moderately effective and recorded significantly higher fruit damage (1.97, 2.27 and 3.20%, respectively).

Among seven insecticides, rynaxypyr and cyazypyr were found effective in controlling fruit borer damage (0.61 and 0.67% respectively) and followed by lambda cyhalothrin and spinosad as second best treatments with 1.53 and 2.04 per cent fruit damage, respectively. Whereas, azadirachtin and quinalphos were inferior with 4.72 and 3.04 per cent fruit damage, respectively.

4.2.1.4 Per cent reduction in fruit damage

Rynaxypyr 18.5% SC @ 0.30 ml per l recorded highest per cent reduction in fruit borer damage over untreated control (82.56), it was closely followed by cyazypyr 10.26% OD @ 1.50 ml per l (78.85) and spinosad 45 SC @ 0.25 ml per l (65.79). Whereas, spinosad 45 SC @ 0.25 ml per l (65.79), lambda cyhalothrin 4.9% CS @ 0.5 ml per l (56.73), quinalphos 25% EC @ 2.00 ml (53.15) and emamectin benzoate 5% SG @ 0.25 g per l (52.90) showed lower per cent reduction. Azadirachtin 10000 ppm @ 1.00 ml per l recorded least per cent reduction in fruit damage (49.78).

4.2.2 Efficacy of new insecticides against fruit sucking moths

Effectiveness of new insecticides on the incidence of fruit sucking moth was assessed based on its damage (sunken brownish spot with small holes) at a day before and 3, 7 and 14 days after each spray (DAS) and results presented in Table 6.

4.2.2.1 At first spray

Fruit sucking moth damage in untreated pomegranate plants ranged from 6.53 to 22.00 per cent with a mean of 14. 18 per cent during first spray observation period. All treatments were significantly superior over untreated control in recording lower fruit damage. At 3 DAS, rynaxypyr 18.5% SC @ 0.30 ml recorded significantly lowest fruit damage (3.33%) and the next best treatments were spinosad 45 SC @ 0.25 ml, lambda cyhalothrin 4.9% CS @ 0.5 ml and emamectin benzoate 5% SG @ 0.25 g which were statistically at par with each other (3.78, 4.00 and 4.13% fruit

Table 6: Efficacy of different insecticides against pomegranate fruit sucking moth during *Hasta bahar*, 2016-17

Tr. No.	Treatments	Dosage (ml or g/l)	Fruit sucking moth damage (%)										Reduction in fruit sucking moth damage over UTC (%)
			1 DBS	1st spray				2nd spray				Average	
				3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean		
T_1	Cyazypyr 10.26% OD	1.50 ml	10.05 (18.48)	4.67^{c} (12.048)	2.03^{b} (8.20)	1.47^{a} (6.96)	2.72^{ab} (9.50)	1.73^{ab} (7.57)	1.41^{ab} (6.81)	1.00^{a} (5.75)	1.38^{a} (6.75)	2.05^{ab} (8.12)	78.02
T_2	Rynaxypyr 18.5% SC	0.30 ml	9.61 (18.06)	3.33^{a} (10.52)	0.92^{a} (5.49)	1.17^{a} (6.21)	1.81^{a} (7.72)	1.47^{a} (6.96)	1.04^{a} (5.84)	1.35^{ab} (6.67)	1.28^{a} (6.51)	1.55^{a} (7.12)	83.38
T_3	Spinosad 45 SC	0.25 ml	10.27 (18.69)	3.78^{b} (11.21)	2.79^{bc} (9.61)	5.50^{ef} (13.56)	4.02^{c} (11.57)	2.20^{b} (8.53)	1.00^{a} (5.74)	1.00^{a} (5.74)	1.40^{a} (6.80)	2.71bc (9.18)	70.95
T_4	Lambda cyhalothrin 4.9% CS	0.50 ml	10.80 (19.19)	4.00^{b} (11.54)	6.33^{e} (14.58)	3.87^{cd} (11.34)	4.73^{c} (12.57)	1.67^{a} (7.42)	1.67^{b} (7.42)	2.40^{c} (8.91)	1.91^{ab} (7.95)	3.32^{cd} (10.26)	64.41
T_5	Emamectin benzoate 5% SG	0.25 g	10.13 (18.56)	4.13^{bc} (11.73)	3.57^{cd} (10.89)	2.21^{b} (8.54)	3.30^{b} (10.47)	1.33^{a} (6.63)	1.01^{a} (5.76)	1.67^{b} (7.42)	1.34^{a} (6.64)	2.32^{b} (8.55)	75.13
T_6	Azadirachtin 10,000 ppm	1.00 ml	9.10 (17.56)	12.69^{e} (20.87)	6.23^{e} (14.45)	4.60^{de} (12.38)	7.84^{e} (16.26)	3.67^{c} (11.04)	1.00^{a} (5.74)	2.40^{c} (8.91)	2.36^{b} (8.83)	5.10^{e} (12.54)	45.33
T_7	Quinalphos 25% EC (SC)	2.00 ml	10.33 (18.75)	10.06^{d} (18.50)	4.33^{d} (12.01)	3.03^{c} (10.03)	5.81^{d} (13.95)	4.33^{c} (12.01)	1.70^{b} (7.49)	1.23^{a} (6.38)	2.42^{b} (8.95)	4.12^{de} (11.45)	55.84
T_8	Untreated control (Water spray)	-	7.21 (15.57)	14.00^{e} (21.97)	22.00^{f} (27.97)	6.53^{f} (14.81)	14.18^{f} (22.12)	5.23^{f} (13.22)	5.20^{c} (13.18)	3.00^{c} (9.97)	4.48^{c} (12.22)	9.33f (17.17)	-
S.Em. ±			-	0.48	0.62	0.49	0.53	0.57	0.40	0.46	0.48	0.43	
C.D. at 5%			NS	1.46	1.86	1.47	1.60	1.73	1.21	1.40	1.45	1.30	
C.V. (%)				5.65	8.28	8.05	7.33	10.82	9.63	10.70	10.40	7.94	

DBS: Day Before Spray
DAS: Days After Spray
UTC: Untreated Control
NS : Non Significant

SC: Standard Check
Figures in the parentheses are arc sin transformed values
Figures with same alphabetical superscripts are statistically non-significant

damage, respectively). Whereas, cyazypyr 10.26% OD @ 1.50 ml per l recorded moderate fruit damage. Treatments like, quinalphos 25% EC @ 2.00 ml and azadirachtin 10000 ppm @ 1.00 ml per l recorded higher damage of fruit sucking moth with 10.06 and 12.69 per cent, respectively. At 7 DAS, similar trend with respect to performance of insecticides was noticed with rynaxypyr 18.5% SC recording significantly lowest fruit damage (0.92%) and was statistically superior over all other treatments. At 14 DAS, rynaxypyr 18.5% SC recorded significantly lowest fruit damage (1.17%) and which was statistically at par with cyazypyr 10.26% OD @ 1.50 ml (1.47%) but significantly superior over all other treatments. Next best treatment was emamectin benzoate 5% SG @ 0.25 g (2.21%). While, standard check, quinalphos 25% EC @ 2.00 ml (3.03%), lambda cyhalothrin 4.9% CS @ 0.5 ml (3.87%) and azadirachtin 10000 ppm @ 1.00 ml per l were statistically inferior and recorded higher fruit sucking moth damage (3.03, 3.87 and 4.60% respectively).

However, among seven test insecticides, the mean fruit sucking moth damage after first spray was significantly lowest and statistically at par in rynaxypyr and cyazypyr (1.81 and 2.72%, respectively) followed by emamectin benzoate (3.30%). Spinosad, lambda cyhalothrin, quinalphos and azadirachtin were moderately effective in managing fruit sucking moth damage (4.02, 4.73, 5.81 and 7.84%, respectively).

4.2.2.2 At second spray

Fruit sucking moth damage in untreated pomegranate plants ranged from 3.00 to 5.23 per cent with a mean of 4.48 per cent during second spray period. All treatments were significantly superior over untreated control in recording lower fruit damage. At 3 DAS, emamectin benzoate 5% SG, rynaxypyr 18.5% SC, lambda cyhalothrin 4.9% CS and cyazypyr 10.26% OD have recorded significantly lower fruit sucking moth damage (1.33, 1.47, 1.67 and 1.73%, respectively) and were statistically at par with each other followed by spinosad 45 SC (2.20%), azadirachtin 10000 ppm (3.67%) and quinalphos 25% EC (4.33%) which were next best treatments. At 7 DAS, azadirachtin 10000 ppm, spinosad 45 SC, emamectin benzoate 5% SG and rynaxypyr 18.5% SC have recorded significantly lower fruit damage (1.00, 1.00, 1.01 and 1.04%, respectively) and were at par with each other, but statistically superior over all other treatments. Further, the next best treatments were, cyazypyr 10.26% OD, lambda cyhalothrin 4.9% CS and standard check, quinalphos

25% EC (1.41, 1.67 and 1.70% fruit sucking moth damage, respectively) and were at par with each other. At 14 DAS, spinosad 45 SC, cyazypyr 10.26% OD and quinalphos 25% EC recorded significantly lowest fruit damage of 1.00, 1.00 and 1.23 per cent and were statistically superior over all other treatments. The next best treatment was rynaxypyr 18.5% SC (1.35%) it was at par with emamectin benzoate 5% SG (1.67%). Lambda cyhalothrin 4.9% CS (2.40%) and azadirachtin 10000 ppm (2.40%) were moderately effective against the pest.

Among the seven test insecticides, rynaxypyr and cyazypyr were effective in controlling fruit sucking moth damage (1.55 and 2.05%, respectively.) whereas, emamectin benzoate (2.32%), spinosad (2.71%) and lambda cyhalothrin (3.32%) were next best treatments. Azadirachtin and quinalphos recorded higher per cent fruit damage of 4.12 and 5.10 per cent, respectively.

4.2.2.3 Per cent reduction in fruit sucking moth damage.

Rynaxypyr 18.5% SC @ 0.30 ml per l recorded highest per cent reduction in fruit damage over untreated control (83.38%), it was closely followed by cyazypyr 10.26% OD @ 1.50 ml (78.02%), emamectin benzoate 5% SG @ 0.25 g (75.13%) and spinosad 45 SC @ 0.25 ml (70.95%). Whereas, lambda cyhalothrin 4.9% CS @ 0.5ml (64. 41%), quinalphos 25% EC @ 2.00 ml (55.84%) and azadirachtin 10000 ppm @ 1.00 ml (45.3%) recorded lower per cent reduction in fruit sucking moth damage over untreated control.

4.2.3 Efficacy of new insecticides against pomegranate thrips

Bio-efficacy of new insecticides were assessed against thrips, *Scirtothrips dorsalis* by comparing per cent fruit damage (appearance of thrips scab as whitish corky lines or patches on fruits) at a day before and 3, 7, 14 days after each spray and results are presented in Table 7.

4.2.3.1 At first spray

Thrips damage on fruits in untreated pomegranate plants ranged from 3.60 to 12.37 per cent with a mean of 6.61 per cent during first spray observation period. All treatments were significantly superior over untreated control in recording lower fruit

Table 7: Efficacy of different insecticides against pomegranate thrips during *Hasta bahar*, 2016-17

Tr. No.	Treatments	Dosage (ml or g/l)	Thrips damage on fruits (%)													Average	Reduction in thrips damage on fruits over UTC (%)
				1st spray				2nd spray				3rd spray					
			1 DBS	3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean		
T_1	Cyazypyr 10.26% OD	1.50 ml	9.24 (17.70)	5.53^{a} (13.61)	0.36^{a} (3.42)	0.34^{a} (3.34)	2.08^{a} (8.29)	0.06^{a} (1.36)	0.02^{a} (0.74)	1.07^{a} (5.93)	0.38^{a} (3.53)	5.80^{a} (13.94)	1.17^{a} (6.20)	1.47^{a} (6.96)	2.81^{a} (9.65)	1.76^{a} (7.61)	81.66
T_2	Rynaxypyr 18.5% SC	0.30 ml	9.00 (17.46)	8.20^{b} (16.64)	2.73^{b} (9.52)	4.03^{d} (11.59)	4.99^{b} (12.91)	1.10^{c} (6.02)	1.20^{b} (6.29)	3.67^{c} (11.04)	1.99^{b} (8.11)	6.67^{ab} (14.96)	3.33^{b} (10.52)	4.00^{c} (11.54)	4.67^{b} (12.48)	3.88^{b} (11.36)	59.58
T_3	Spinosad 45 SC	0.25 ml	11.56 (19.88)	11.10^{b} (19.46)	2.79^{b} (9.61)	3.50^{c} (10.78)	5.80^{b} (13.93)	1.67^{cd} (7.42)	1.67^{b} (7.42)	2.80^{b} (9.63)	2.04^{b} (8.22)	10.33^{c} (18.75)	5.10^{d} (13.05)	5.00^{d} (12.92)	6.81^{d} (15.13)	4.88^{bc} (12.77)	49.16
T_4	Lambda cyhalothrin 4.9% CS	0.50 ml	10.62 (19.02)	9.98^{b} (18.42)	2.57^{b} (9.22)	3.01^{c} (9.99)	5.18^{b} (13.16)	2.00^{d} (8.13)	1.77^{b} (7.64)	2.40^{b} (8.91)	2.06^{b} (8.24)	6.43^{a} (14.69)	4.23^{c} (11.87)	8.33^{e} (16.78)	6.33^{d} (14.58)	4.52^{b} (12.28)	52.91
T_5	Emamectin benzoate 5% SG	0.25 g	11.97 (20.24)	10.16^{b} (18.59)	3.07^{b} (10.09)	2.93^{c} (9.86)	5.39^{b} (13.42)	0.46^{b} (3.89)	1.67^{b} (7.42)	4.00^{c} (11.54)	2.04^{b} (8.22)	9.93^{c} (18.37)	5.67^{d} (13.77)	2.67^{b} (9.40)	6.09^{c} (14.29)	4.51^{b} (12.26)	53.02
T_6	Azadirachtin 10,000 ppm	1.00 ml	10.59 (18.99)	11.92^{bc} (20.20)	3.12^{b} (10.17)	2.67^{c} (9.40)	5.90^{bc} (14.06)	2.00^{d} (8.13)	1.93^{b} (7.99)	4.23^{c} (11.87)	2.72^{b} (9.50)	13.43^{d} (21.50)	6.07^{d} (14.26)	12.00^{f} (20.27)	10.50^{e} (18.91)	6.37^{c} (14.62)	33.64
T_7	Quinalphos 25% EC (SC)	2.00 ml	11.01 (19.38)	9.12^{b} (17.58)	2.80^{b} (9.63)	1.63^{b} (7.34)	4.52^{b} (12.27)	1.43^{c} (6.86)	2.00^{b} (8.13)	3.53^{bc} (10.83)	2.32^{b} (8.76)	7.83^{b} (16.25)	2.67^{b} (9.40)	4.80^{cd} (12.66)	5.10^{b} (13.05)	3.98^{b} (11.51)	58.54
T_8	Untreated control (Water spray)	-	9.99 (18.42)	12.37c (20.59)	3.60^{b} (10.94)	3.87^{cd} (11.34)	6.61^{c} (14.90)	6.00^{e} (14.18)	4.50^{c} (12.25)	6.98^{d} (15.32)	5.83^{c} (13.97)	16.83^{d} (24.22)	12.43^{e} (20.65)	19.87^{g} (26.47)	16.38^{f} (23.87)	9.60^{d} (18.05)	-
S.Em. ±			-	0.95	0.59	0.65	0.73	0.59	0.74	0.50	0.61	0.53	0.61	0.45	0.46	0.60	
C.D. at 5%			NS	2.85	1.79	1.97	2.20	1.78	2.22	1.50	1.84	1.61	1.84	1.35	1.39	1.81	
C.V. (%)				9.00	11.40	12.42	10.90	14.73	17.73	8.09	13.52	5.17	8.47	5.31	5.63	10.00	

DBS: Day Before Spray
DAS: Days After Spray
UTC: Untreated Control
NS : Non significant

SC: Standard Check
Figures in the parentheses are arc sin transformed values
Figures with same alphabetical superscripts are statistically non-significant

damage due to thrips. At 3 DAS, cyazypyr 10.26% @ 1.50 ml recorded significantly lowest fruit damage (5.53%) and the next best treatments were, rynaxypyr 18.5% SC @ 0.30 ml, quinalphos 25% EC @ 2.00 ml, lambda cyhalothrin 4.9% CS @ 0.50 ml, emamectin benzoate 5% SG @ 0.25 g and spinosad 45 SC @ 0.25 ml which were at par with each other (8.20, 9.12, 9.98, 10.16 and 11.10%, respectively). Azadirachtin 10000 ppm @ 1.00 ml (11.92%) recorded significantly higher thrips damage and was at par with untreated control. At 7 DAS, cyazypyr 10.26% OD recorded significantly the lowest fruit damage (0.36%). While, lambda cyhalothrin 4.9% CS (2.57%), rynaxypyr 18.5% SC (2.73%), spinosad 45 SC (2.79%) and quinalphos 25% EC (2.80%) were next best treatments. At 14 DAS, cyazypyr 10.26% OD recorded significantly lowest fruit damage (0.34%). While other treatments *viz.*, azadirachtin 10000 ppm, emamectin benzoate 5% SG, lambda cyhalothrin 4.9% CS and spinosad 45 SC have recorded moderate level of fruit damage due to thrips (2.67, 2.93, 3.01 and 3.50%, respectively).

Among seven insecticides, the mean thrips damage on pomegranate fruits after first spray was significantly lowest in cyazypyr 10.26% OD (2.08%) and the next best treatments were quinalphos 25% EC (4.52%), rynaxypyr 18.5% SC (4.99%), lambda cyhalothrin 4.9% CS (5.18%), emamectin benzoate 5% SG (5.39%), spinosad (5.80%) and azadirachtin 10000 ppm (5.90%) which were moderately effective against thrips.

4.2.3.2 At second spray

In untreated pomegranate plants fruit damage due to thrips ranged from 4.50 to 6.98 per cent with a mean of 5.83 per cent during second spray observation period. All treatments were significantly superior over untreated control in recording lower per cent fruit damage due to thrips. At 3 DAS, cyazypyr 10.26% OD @ 1.50 ml recorded significantly lowest fruit damage (0.06%) followed by emamectin benzoate 5% SG @ 0.25 g (0.46%) as second best treatment. Rynaxypyr 18.5% SC @ 0.30 ml, quinalphos 25% EC @ 2.00 ml and spinosad 45 SC @ 0.25 ml have recorded moderate level of fruit damage (1.10, 1.43 and 1.67%, respectively) and statistically at par with each other. Lambda cyhalothrin 4.9% CS @ 0.5 ml (2.00%) and azadirachtin 10000 ppm @ 1.00 ml (2.00%) have recorded higher fruit damage. At 7 DAS, cyazypyr 10.26% OD @ 1.50 ml recorded significantly lowest fruit damage (0.02%) and remaining treatments *viz*., rynaxypyr 18.5% @ 0.30 ml (1.20%), spinosad 45 SC @ 0.25ml (1.67%), emamectin benzoate 5% SG @ 0.25 g (1.67%), azadirachtin 10000 ppm @ 1.00 ml (1.93%) and quinalphos 25% EC @ 2.00 ml (2.00%) were next best treatments recorded fruit damage significantly less than untreated control (4.50%). At 14 DAS, cyazypyr 10.26% OD @ 1.50 ml (1.07%) was significantly superior than all other treatments, Lambda cyhalothrin 4.9% CS @ 0.5ml (2.40%), spinosad 4.5% SC @ 0.25ml (2.80) and quinalphos 25% EC @ 2.00 ml (3.53%) were next best treatments.

Mean thrips incidence after second spray indicated that, among seven insecticides, cyazypyr was most effective in controlling thrips damage (0.38%) followed by rynaxypyr, spinosad, emamectin benzoate, lambda cyhalothrin, quinalphos and azadirachtin (1.99, 2.04, 2.04, 2.06, 2.32 and 2.72% thrips damaged fruits, respectively).

4.2.3.3 At third spray

Thrips damage on fruits in untreated pomegranate plants ranged from 12.43 to 19.87 per cent with a mean of 16.38 per cent after third spray observation period. All treatments were significantly superior over untreated control in minimizing the fruit damage due to thrips. At 3 DAS, cyazypyr 10.26% OD recorded significantly lowest fruit damage (5.80%) which was at par with lambda cyhalothrin 4.9% CS (6.43%) and rynaxypyr 18.5% SC (6.67%). The next best treatment was quinalphos 25% EC (7.83%). Whereas, emamectin benzoate 5% SG (9.93%) and spinosad 45 SC (10.33%) recorded moderate reduction of thrips damage. At 7 DAS, the trend was similar with cyazypyr 10.26% OD recording lowest fruit damage (1.17%) and was significantly superior over all other treatments. At 14 DAS, cyazypyr 10.26% OD recorded significantly lowest fruit damage (1.47%) followed by emamectin benzoate 5% SG (2.67%) while, rynaxypyr 45 SC (4.00%) was third best treatment followed by quinalphos 25% EC which was moderately effective against thrips (4.80% fruit damage) and was intern at par with spinosad 45 SC (5.00%) Whereas, lambda cyhalothrin 4.9% CS and azadirachtin 10,000 ppm recorded higher fruit damage (8.33 and 12.00%, respectively), and found less effective against thrips.

As indicated in table-7, mean thrips damage on fruits after third spray, among seven test insecticides, cyazypyr was effective in controlling fruit damage due to thrips (2.81%). Further, rynaxypyr and quinalphos have come up as next best treatments (4.67 and 5.10%, respectively).

4.2.3.4 Per cent reduction in fruit damage due to thrips.

Cyazypyr 10.26% OD @ 1.50 ml recorded highest per cent reduction in thrips damage on fruit over untreated control (81.66%) which was followed by rynaxypyr 18.5% SC @ 0.30 ml (59.58%), quinalphos 25% EC @ 2.00 ml, emamectin benzoate 5% SG @ 0.25 g and lambda cyhalothrin 4.9% CS @ 0.50 ml (58.54, 53.02 and 52.91%, respectively). Spinosad 45 SC @ 0.25 ml and azadirachtin 10000 ppm @ 1.00 ml recorded 49.16 and 33.64 per cent reduction in thrips damage over untreated control, respectively.

4.2.5 Impact of new insecticide molecules on the population of natural enemies

Effect of evaluated insecticides on the abundance of natural enemies *viz.,* spiders and coccinellids in pomegranate was studied during the *Hasta bahar* 2016-17. Observations on natural enemies were recorded a day before and 3, 7 and 14 days after each spray and presented in Table 8

4.2.5.1 Safety of new insecticide molecules to natural enemies at first spray

The population of natural enemies (spiders and coccinellids) in untreated plot ranged from 0.00 to 0.33 per plant with a mean of 0.22 per plant. However, predatory population showed non-significant differences among different treatments at all observation periods during first spray.

4.2.5.2 Population of natural enemies at second spray

The population of natural enemies (spiders and cic cinellids) in untreated plots ranged from 0.33 to 1.67 per plant with a mean of 0.89 per plant during second spray observation period. However, natural enemies population showed non-significant difference among different treatments at all observation perio ds during second spray.

Table 8: Population of natural enemies in insecticides treated pomegranate field during *Hasta bahar*, 2016-17

Tr. No.	Treatments	Dosage (ml or g/l)	Population of natural enemies/plant														
			1 DBS	1st spray				2nd spray				3rd spray				Average
				3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean	
T_1	Cyazypyr 10.26% OD	1.50 ml	0.33 (0.91)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.67 (0.99)	0.00 (0.70)	0.67 (0.99)	0.44 (0.95)	1.33^{ab} (1.34)	0.33^{bc} (0.87)	0.33 (0.87)	0.84^{b} (1.14)	0.64^{b} (0.76)
T_2	Rynaxypyr 18.5% SC	0. 30 ml	0.44 (0.95)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.33 (0.87)	0.00 (0.70)	0.67 (0.99)	0.33 (0.89)	0.67^{bc} (0.99)	0.33^{bc} (0.87)	1.33 (1.34)	0.48^{bc} (0.97)	0.40^{b} (0.62)
T_3	Spinosad 45 SC	0.25 ml	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.67 (0.99)	0.00 (0.70)	1.67 (1.35)	0.78 (1.08)	0.00^{c} (0.70)	0.00^{c} (0.70)	0.33 (0.87)	0.24^{c} (0.85)	0.51^{b} (0.65)
T_4	Lambda cyhalothrin 4.9% CS	0.50 ml	0.22 (0.83)	0.33 (0.87)	0.00 (0.70)	0.00 (0.70)	0.11 (0.77)	0.67 (0.99)	0.00 (0.70)	0.67 (0.99)	0.44 (0.95)	0.00^{c} (0.70)	0.67^{abc} (1.05)	0.67 (0.99)	0.51^{bc} (0.97)	0.48^{b} (0.68)
T_5	Emamectin benzoate 5% SG	0.25 g	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.67 (0.99)	0.22 (0.83)	0.00 (0.70)	0.00 (0.70)	0.33 (0.87)	0.11 (0.77)	0.00^{c} (0.70)	0.00^{c} (0.70)	0.33 (0.87)	0.32^{bc} (0.89)	0.21^{bc} (0.39)
T_6	Azadirachtin 10,000 ppm	1.00 ml	0.22 (0.83)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.67 (1.35)	0.00 (0.70)	0.56 (0.96)	0.67^{bc} (0.99)	1.00^{ab} (1.17)	1.33 (1.28)	0.87^{b} (1.16)	0.71^{ab} (0.80)
T_7	Quinalphos 25% EC (SC)	2.00 ml	0.00 (0.70)	0.33 (0.87)	0.00 (0.70)	0.00 (0.70)	0.11 (0.77)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00^{c} (0.70)	0.00^{c} (0.70)	0.00 (0.70)	0.10^{c} (0.76)	0.05^{c} (0.19)
T_8	Untreated control (Water spray)	-	0.44 (0.96)	0.33 (0.87)	0.33 (0.87)	0.00 (0.70)	0.22 (0.84)	0.33 (0.87)	1.67 (1.38)	0.67 (0.99)	0.89 (1.15)	2.33^{a} (1.65)	1.67^{a} (1.46)	1.33 (1.34)	2.08^{a} (1.60)	1.49^{a} (1.21)
S.Em. ±			-	-	-	-	-	-	-	-	-	0.20	0.14	-	0.09	0.13
C.D. at 5%			NS	NS	NS	NS	NS	NS	NS	NS	NS	0.60	0.43	NS	0.29	0.41
C.V. (%)												34.2	26.23		15.94	15.73

DBS: Day Before Spray
DAS: Days After Spray
NS : Non Significant

SC: Standard Check
Figures in the parentheses are square root transformed values
Figures with same alphabetical superscripts are statistically non-significant

4.2.5.3 Population of natural enemies at third spray

The population of natural enemies (spiders and coccinellids) during third spray observation period ranged from 1.33 to 2.33 per plant with a mean of 2.08 per plant on untreated plants. The natural enemy population at 3 DAS showed significant variation among different treatments. Natural enemy population in untreated plot was significantly highest (2.33/plant) and was statistically at par with cyazypyr 10.26% OD (1.33/plant). While, all other treatments were at par with each other (population ranged from 0.00 to 0.67/plant) and inferior than untreated control. At 7 DAS, significantly highest natural enemy population was recorded in untreated control (1.67/plant) and was at par with azadirachtin 10000 ppm and lambda cyhalothrin 4.9% SC (1.00 and 0.67/plant, respectively). While, all other treatments were at par with each other (population ranged from 0 to 0.33/plant). But, the natural enemy population at 14 DAS was non-significant across different treatments.

The average natural enemy population showed significant variation among different treatments. The population was significantly highest in untreated control (1.49/plant) and was statistically at par with azadirachtin 10000 ppm (0.71/plant). The next safest treatments were, cyazypyr 10.26% OD, spinosad 45 SC, lambda cyhalothrin 4.9 CS and rynaxypyr 18.5% SC which recorded natural enemy population of 0.64, 0.51, 0.48 and 0.40 per plant, respectively. While, rest of the treatments were not safer to natural enemies.

4.2.6 Efficacy of new insecticide molecules on pomegranate fruit yield

4.2.6.1 Number of marketable fruits per plant

Number of pomegranate fruits were significantly highest in plots treated with cyazypyr 10.26% OD @ 1.50 ml (73.67/plant) followed by rynaxypyr 18.5% SC @ 0.30 ml (69.33/plant). The next best treatment were, spinosad 45 SC @ 0.25 ml and emamectin benzoate 5% SG @ 0.25 g which were statistically at par with each other (65.33 and 64.33/plant, respectively). The other treatments *viz.,* lambda cyhalothrin 4.9% CS @ 0.50 ml and azadirachtin 10000 PPM @ 1.00 ml per l were at par with each other and recorded 64.33 and 58.00 marketable fruits per plant. Number of fruit were significantly lowest in quinalphos 25% EC @ 2.00 ml (55.00/plant) followed by untreated control (32.33/plant) (Table 9) (Plate 5).

5a. Fruit quality in T_1: Cyazypyr 10.26% OD

5b. Fruit quality in T_2: Rynaxypyr 18.5% SC

5c. Fruit quality in T_8: Untreated control

Plate 5. Quality of pomegranate fruits in different insecticide treated plots

4.2.6.2 Weight of fruits per plants

Significantly highest pomegranate fruit weight was obtained in plot treated with cyazypyr 10.26% OD @ 1.50 ml (18.23kg/plant), the next best treatment was rynaxypyr 18.5% SC @ 0.30 ml (16.13kg/plant) which was statistically at par with emamectin benzoate 5% SG @ 0.25 g (14.60 kg/plant) and the latter was intern at par with spinosad 45 SC @ 0.25 ml (13.40 kg/plant). While, lambda cyhalothrin 4.9% CS @ 0.5 ml, azadirachtin 10000 ppm @ 1.00 ml and quinalphos 25% EC @ 2.00 ml were inferior and statistically at par with each other and recorded fruit yield of 11.43, 11.40 and 11.33 kg per plant. Fruit weight was significantly lowest in untreated control (8.03 kg/plant) (Table 9).

4.2.6.3 Fruit yield

Significantly highest pomegranate fruit yield was obtained in plot treated with cyazypyr 10.26% OD @ 1.50 ml (12.16t/ha), the next best treatment was rynaxypyr 18.5% SC @ 0.30 ml (10.76t/ha) and was statistically at par with emamectin benzoate 5% SG @ 0.25 g (9.73 t/ha) and the latter intern was at par with spinosad 45 SC @ 0.25 ml (8.93 t/ha). While, lambda cyhalothrin 4.9% CS @ 0.5 ml and azadirachtin 10000 ppm @ 1.00 ml, quinalphos 25% EC @ 2.00 ml were inferior and statistically at par with each other and recorded fruit yield of 7.62, 7.60 and 7.56 tonnes per ha, respectively. Fruit yield was significantly lowest in untreated control (5.36 t/ha) (Table 9).

4.2.7 Economics of new insecticide molecules on pomegranate during *Hatsa Bahar*, 2016-17

The economics of each pesticide treatment was worked out based on yield of marketable quality fruits obtained in experiment during the year 2016-17 as presented in Table 10. In untreated plot, the gross returns from pomegranate yield was Rs. 4,28,800 per ha. Among evaluated pesticides, maximum gross income was obtained in plants protected with three sprays of cyazypyr 10.26 % OD (Rs. 9,72,800/ha), followed by rynaxypyr 18.5% SC (Rs. 8,60,800/ha) and emamectin benzoate 5% SG (Rs. 7,78,400/ha) the next treatments in descending order were spinosad 45 SC (Rs. 7,14,400/ha), lambda cyhalotrin 4.9% CS (Rs. 6,09,600/ha) and quinalphos 25% EC

Table 9: Performance of new insecticides on pomegranate fruit yield during *Hasta bahar*, 2016-17

Tr. No.	Treatments	Marketable fruits (No./plant)	Fruit weight (kg/plant)	Fruit yield (t/ha)
T_1	Cyazypyr 10.26 % OD	73.67[a]	18.23[a]	12.16[a]
T_2	Rynaxypyr 18.5% SC	69.33[b]	16.13[b]	10.76[b]
T_3	Spinosad 45 SC	65.33[c]	13.40[cd]	8.93[cd]
T_4	Lambda cyhalothrin 4.9% CS	58.33[d]	11.43[de]	7.62[de]
T_5	Emamectin benzoate 5% SG	64.33[c]	14.60[bc]	9.73[bc]
T_6	Azadirachtin 10,000 ppm	58.00[d]	11.40[de]	7.60[de]
T_7	Quina lphos 25% EC (SC*)	55.00[d]	11.33[e]	7.56[e]
T_8	Untreated control	32.33[e]	8.03[f]	5.36[f]
	S.Em. ±	1.32	0.67	0.44
	C.D. at 5%	3.96	2.01	1.34
	C.V. (%)	3.80	8.81	8.82

*SC: Standard Check

Table 10: Economics of new insecticides in pomegranate during *Hasta bahar,* 2016-17

Tr. No.	Treatments	Fruit yield (t/ha)	Gross return (Rs./ha)	Total cost of cultivation (Rs./ha)	Treatment cost (Rs./ha)	Net returns (Rs./ha)	B:C ratio
T_1	Cyazypyr 10.26 % OD	12.16	972800	231700	19200	741100	4.20
T_2	Rynaxypyr 18.5% SC	10.76	860800	221935	9435	638865	3.88
T_3	Spinosad 45 SC	8.93	714400	219550	7050	494850	3.25
T_4	Lambda cyhalothrin 4.9% CS	7.62	609600	214210	1710	395390	2.85
T_5	Emamectin benzoate 5% SG	9.73	778400	215837	3337	562563	3.61
T_6	Azadirachtin 10,000 ppm	7.60	608000	214862	2362	393138	2.83
T_7	Quinalphos 25% EC (SC)	7.56	604800	215170	2670	389630	2.81
T_8	Untreated control	5.36	428800	212500	-	216300	2.02

Market price of fruits : Rs. 80/kg
Cost of the chemicals furnished in the Appendix II

(Rs. 6,04,800/ha). Whereas, azadirachtin 10,000 ppm and untreated control plots have recorded lowest gross income of Rs. 6,04,800 and Rs. 4,28,800, respectively.

Net returns indicated that, treatment of cyazypyr, rynaxypyr and emamectin benzoate provided maximum profit of Rs. 7,41,100, Rs. 6,38,865 and Rs. 5,62,563 per ha, respectively, followed by the treatment of spinosad (Rs. 4,94,850/ha), lambda cyhalothrin (Rs. 3,95,390/ha) and quinalphos (Rs. 3,89,630/ha) Net gain was relatively less in treatments of azadirachtin (Rs. 3,93,138/ha) and untreated control (Rs. 2,16,300/ha).

Benefit cost (B:C ratio) was worked out for each pesticide treatment, in which, cyazypyr provided highest B:C ratio of 4.20. While, B:C ratio in rynaxypyr and emamectin benzoate were 3.88 and 3.61, respectively. Whereas, spinosad, lambda cyhalothrin, azadirachtin and quinalphos have recorded 3.25, 2.85, 2.83 and 2.81 respectively. Relatively low B:C ratio of 2.02 was resulted in un-treated control.

4.3 Formulation and evaluation of IPM modules for the management of pomegranate fruit borer

Five integrated pest management modules (IPM modules) including recommended package of practices (RPP) of UHS, Bagalkot were evaluated against fruit borer, fruit sucking moths and thrips by recording their efficacy at 3, 7 and 14 days after treatment imposition (DAT) period.

4.3.1 Evaluation of IPM modules against pomegranate fruit borer

The data obtained on efficacy of IPM modules against fruit damage due to fruit borer in the field trial are given in Table 11.

4.3.1.1 At first treatment

At 3 DAT, module 4 *i.e.*, spray of emamectin benzoate @ 0.25 g/l - cyazypyr @ 1.50 ml/l - spinosad @ 0.25 ml/l - collection and destruction of affected fruit by fruit borer recorded significantly lowest fruit damage (2.15%) which was statistically at par with M_5 (Malathion @ 2.00 ml/l – deltamethrin @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits (RPP)) (2.78%).

Table 11 : Performance of different IPM modules against pomegranate fruit borer, *Deudorix isocrates* during *Hasta bahar*, 2016-17

M. No.	IPM modules	Fruit borer damage (%)													
		1st Treatment					2nd Treatment				3rd Treatment				Average
		1 DBT	3 DAT	7 DAT	14 DAT	Mean	3 DAT	7 DAT	14 DAT	Mean	3 DAT	7 DAT	14 DAT	Mean	
M_1	Biological IPM module	5.81 (13.95)	4.23^{c} (11.86)	2.58^{b} (9.23)	2.25^{d} (8.63)	3.02^{c} (10.00)	2.50^{c} (9.10)	4.48^{b} (12.21)	4.93^{c} (12.82)	3.97^{d} (11.49)	0.50^{b} (4.05)	2.25^{c} (8.63)	0.64^{c} (4.58)	1.13^{d} (6.10)	2.70^{b} (9.46)
M_2	Bio-intensive IPM module	5.49 (13.55)	4.48^{c} (12.21)	3.05^{c} (10.06)	1.98^{cd} (8.08)	3.17^{c} (10.25)	4.28^{d} (11.93)	3.75^{b} (11.17)	1.50^{b} (7.03)	3.18^{c} (10.26)	0.33^{a} (3.27)	0.83^{b} (5.21)	0.50^{b} (4.05)	0.55^{b} (4.25)	2.30^{b} (8.72)
M_3	Adoptable IPM module	4.67 (12.48)	$3.50b^{c}$ (10.77)	2.35^{b} (8.82)	1.40^{b} (6.80)	2.42^{b} (8.94)	0.48^{a} (3.95)	0.44^{a} (3.80)	0.33a (3.27)	0.35^{a} (3.37)	0.38^{ab} (3.51)	0.01^{a} (0.57)	0.30^{a} (3.14)	0.23^{a} (2.74)	1.00^{a} (5.73)
M_4	Chemi-intensive IPM module	4.75 (12.59)	2.15^{a} (8.43)	0.68^{a} (4.73)	0.88^{a} (5.37)	1.24^{a} (6.38)	1.00^{b} (5.74)	1.99^{a} (8.11)	0.88^{a} (5.37)	1.29^{b} (6.52)	0.50^{b} (4.05)	0.78^{b} (5.05)	0.75^{d} (4.97)	0.68^{c} (4.71)	1.07^{a} (5.93)
M_5	Recommended Package of Practice	5.22 (13.21)	2.78^{ab} (9.59)	2.47^{b} (9.03)	1.85^{c} (7.82)	2.36^{b} (8.84)	3.08^{cd} (10.10)	5.15^{b} (13.12)	1.75^{b} (7.60)	3.33^{cd} (10.51)	0.51^{b} (4.11)	3.20^{d} (10.30)	1.00^{e} (5.74)	1.57^{e} (7.20)	2.42^{b} (8.95)
S.Em. ±		-	0.52	0.27	0.20	0.33	0.46	0.67	0.29	0.47	0.20	0.13	0.07	0.13	0.31
C.D. at 5%		NS	1.57	0.82	0.60	0.99	1.40	2.02	0.87	1.43	0.61	0.39	0.23	0.41	0.94
C.V. (%)			9.71	6.37	5.32	7.13	11.31	13.65	7.89	10.95	10.55	4.31	13.98	12.94	10.34

DBT : Day Before Treatment
DAT: Days After Treatment
NS: Non significant

Figures in the parenthesis are arc sin transformed values
Figures with same alphabetical superscripts are statistically non-significant

The next best module was M_3 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) (3.50%), which intern was statistically at par with M_1 (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) (4.23%) and M_2 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l - collection and destruction of affected fruits) (4.48%). At 7 DAT, M_4 recorded significantly lowest fruit damage (0.68%) and the next best modules were M_3, M_5 and M_1 which recorded 2.35, 2.47 and 2.58 per cent fruit damage, respectively. Whereas, M_2 recorded higher fruit damage (3.05%). At 14 DAT, M_4 recorded significantly lowest fruit damage (0.88%) and was statistically superior over all other modules. The next best module was M_3 with 1.40 per cent fruit damage. Whereas, M_5 (1.85%) was statistically at par with M_2 (1.98%). While, M_1 recorded highest fruit borer damage of 2.25 per cent.

The mean per cent fruit infestation by fruit borer during first treatment imposition indicated that, among five modules, M_4 was effective in recording significantly lowest fruit borer damage (1.24%) and the next best modules were, M_5 and M_3 which were statistically at par with each other respect to fruit borer damage (2.36 and 2.42 %, respectively). Modules M_1 and M_2 were statistically inferior in reducing the fruit damage (3.02 and 3.17%, respectively).

4.3.1.2 At second treatment

Fruit damage due to fruit borer during second treatment period is given in table 11. At 3 DAT, M_3 recorded significantly lowest fruit borer damage (0.48%). The next best treatment was M_4 with 1.0 per cent fruit damage. At 7 DAT, M_3 recorded significantly lowest fruit damage (0.44%) and it was at par with M_4 (1.99%). Whereas, M_2 (3.75%), M_1 (4.48%) and M_5 (5.15%) recorded highest fruit damage and were at par with each other. At 14 DAT, M_3 recorded significantly lowest fruit damage (0.33%) and it was statistically at par with M_4 (0.88%) but significantly superior over all other modules. The next effective modules were M_2 (1.50%) and M_5 (1.75%) which were at par with each other. Whereas, M_1 a recorded significantly higher fruit borer damage of 4.93 per cent.

The mean per cent fruit damage by fruit borer during second treatment imposition indicated that, among five modules, M_3 was effective in controlling fruit borer damage (0.35%) and second best module was M_4 with 1.29 per cent fruit damage. Whereas, M_2, M_5 and M_1 were moderately effective in reducing the fruit borer damage (3.18, 3.33 and 3.97%, respectively).

4.3.1.3 At third treatment

Fruit damage due to fruit borer recorded during third treatment are given in Table 11. At 3 DAT, module 2 and module 3 recorded significantly lower fruit damage (0.33 and 0.38%, respectively) which were at par with each other. The other modules *viz.,* M_1 (0.50%) M_4 (0.50%) and M_5 (0.51%) were statistically at par with each other. At 7 DAT, M_3 recorded significantly lowest fruit damage (0.01%) and significantly superior then all other modules. The next best modules were, M_4 (0.78%) and M_2 (0.83%) which were at par with each other. At 14 DAT, module M_3 recorded significantly lowest fruit damage (0.30%) and was statistically superior over all other modules. The next effective module was M_2 (0.50%). Whereas, M_1, M_4 and M_5 were moderately effective and recorded 0.64, 0.75, and 1.00 per cent fruit damage, respectively.

Mean fruit damage during third treatment imposition indicated that, among five modules, M_3 was effective in controlling fruit borer damage (0.23%) followed by module M_2 which recorded 0.55 per cent fruit damage. While, M_4 was next best module in recording fruit borer damage (0.68%).

4.3.1.4 Average fruit borer damage

In integrated pest management modules treatment, the average fruit borer damage was significantly lower in M_3 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) and M_4 (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) were statistically superior over al other modules and recorded 1.00 and 1.07 per cent fruit borer damage, respectively. Remaining three modules *viz.,* M_2 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l- collection and destruction of affected fruits),

M_5 (Malathion @ 2.00 ml/l – deltamethrin @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) and M_1 (Release of egg parasitoid, *Trichogramma chilonis* at 2.50 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits.) have recorded moderate level of fruit borer damage with 2.30, 2.42 and 2.70 per cent, respectively.

4.3.2 Evaluation of IPM modules against pomegranate fruit sucking moth

4.3.2.1 At first treatment

Fruit damage due to fruit sucking moth was assessed in different IPM modules during *Hasta bahar* and the results obtained are given in Table 12. At 3 DAT, module 4 (M_4) recorded significantly lowest fruit damage by fruit sucking moth (0.30%). The next best modules was M_1 which was statistically at par with M_2 and recorded 1.08 and 1.25 per cent fruit damage, respectively. M_5 and M_3 recorded significantly higher fruit damage of 1.78 and 2.53 per cent respectively. At 7 DAT, M_3 and M_4 recorded significantly lower fruit damage (0.49, 0.68%, respectively) and were statistically at par with each other. Whereas, M_2 and M_5 were next best modules in recording fruit damage of 1.25 and 1.65 per cent, respectively, and were at par with each other. At 14 DAT, M_4, M_5 and M_3 recorded significantly lower fruit damage (0.88, 1.10 and 1.20%, respectively) and were statistically at par with each other and significantly superior than other modules. While, M_1 was recorded as the next best module with 2.13 per cent fruit damage followed by M_2 with 3.20 per cent fruit damage.

The mean per cent fruit sucking moth damage during first treatment imposition period showed that, among the five modules, M_4 (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and distraction of affected fruits) was effective in controlling fruit sucking moth damage (0.62%) followed by M_3 (Relesase of *Trichogramma chilonis* @ 2.5 lakh – cyazypyr 10.26% OD @ 1.50 ml/l - spinosad 45 SC @ 0.25 ml/l - collection and distruction of affected fruits), M_5 (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l - azadirachtin 1500 ppm @ 5.00 ml/l - collection and distruction of affected fruits) and M_2 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l - collection and destruction of affected fruits) and were statistically at par with each other in recording fruit sucking

Table 12: Performance of different IPM modules against pomegranate fruit sucking moth during *Hasta bahar*, 2016-17

M. No.	IPM modules	Fruit sucking moth damage (%)													
		1st Treatment					2nd Treatment				3rd Treatment				Average
		1 DBT	**3 DAT**	**7 DAT**	**14 DAT**	**Mean**	**3 DAT**	**7 DAT**	**14 DAT**	**Mean**	**3 DAT**	**7 DAT**	**14 DAT**	**Mean**	
M_1	Biological IPM module	2.21 (8.55)	1.08^{b} (5.95)	3.00^{c} (9.97)	2.13^{b} (8.38)	2.07^{c} (8.27)	3.33^{b} (10.51)	3.98^{c} (11.50)	3.75^{d} (11.17)	3.68^{c} (11.06)	5.78^{c} (13.90)	0.50^{b} (4.05)	1.28^{b} (6.48)	2.52^{c} (9.13)	2.76^{c} (9.56)
M_2	Bio-intensive IPM module	2.42 (8.94)	1.25^{bc} (6.42)	1.25^{b} (6.42)	3.20^{c} (10.30)	1.90^{bc} (7.92)	4.50^{c} (12.25)	3.20^{bc} (10.30)	3.19^{cd} (10.28)	3.63^{c} (10.98)	1.38^{b} (6.73)	1.25^{c} (6.42)	1.50^{b} (7.03)	1.38^{b} (6.73)	2.30^{bc} (8.73)
M_3	Adoptable IPM module	2.53 (9.14)	2.53^{d} (9.14)	0.49^{a} (4.01)	1.20^{a} (6.29)	1.41^{b} (6.81)	1.80^{a} (7.71)	1.90^{a} (7.92)	0.88^{b} (5.37)	1.53^{a} (7.09)	0.90^{a} (5.44)	0.25^{a} (2.87)	0.01^{a} (0.57)	0.39^{a} (3.57)	1.11^{a} (6.04)
M_4	Chemi-intensive IPM module	2.31 (8.74)	0.30^{a} (3.14)	0.68^{a} (4.72)	0.88^{a} (5.37)	0.62^{a} (4.51)	1.75^{a} (7.60)	2.25^{a} (8.63)	0.01^{a} (0.57)	1.34^{a} (6.64)	1.00^{a} (5.74)	0.50^{b} (4.05)	0.01^{a} (0.57)	0.50^{a} (4.07)	0.82^{a} (5.19)
M_5	Recommended Package of Practice	2.44 (8.99)	1.78^{c} (7.66)	1.65^{b} (7.38)	1.10^{a} (6.02)	1.51^{b} (7.05)	3.25^{b} (10.39)	2.51^{ab} (9.12)	2.33^{c} (8.77)	2.70^{b} (9.45)	1.25^{ab} (6.42)	1.40^{c} (6.80)	1.20^{b} (6.29)	1.28^{b} (6.50)	1.83^{b} (7.77)
S.Em. ±		-	0.49	0.47	0.44	0.46	0.16	0.43	0.56	0.44	0.41	0.17	0.26	0.34	0.41
C.D. at 5%		NS	1.47	1.42	1.33	1.40	1.01	1.29	1.70	1.33	1.24	1.05	0.79	1.02	1.25
C.V. (%)			14.90	14.20	11.90	13.66	6.79	8.93	15.42	10.38	10.59	14.18	12.29	12.35	12.13

DBT: Day Before Treatment
DAT: Days After Treatment
NS: Non Significant

Figures in the parenthesis are arc sin transformed values
Figures with same alphabetical superscripts are statistically non-significant

moth damage of 1.14, 1.51 and 1.90 per cent, respectively. Whereas, M_1 (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) was significantly less effective in reducing the fruit sucking moth damage (2.07%).

4.3.2.2 At second treatment

At 3 DAT, module 4 recorded significantly lowest fruit sucking moth damage (1.75%) and it was statistically at par with M_3 (1.80%). The next best module was M_5 (3.25%) which was statistically at par with M_1 (3.33%). Whereas, M_2 recorded significantly higher fruit sucking moth damage with 4.50 per cent. At 7 DAT, fruit sucking moth damage was statistically at par with each other in M_3, M_4 and M_5 with 1.90, 2.25 and 2.51 per cent fruit damage, respectively. At 14 DAT, M_4 recorded significantly lowest fruit damage (0.01%) which was significantly superior over all other modules. M_3 was the next best module with 0.88 per cent fruit damage. Whereas, M_5 and M_2 were moderate in their action to reduce fruit damage and recorded 2.33 and 3.19 per cent fruit damage, respectively. M_1 recorded significantly highest fruit sucking moth damage of 3.75 per cent.

The mean fruit sucking moth damage during second treatment showed that, among five modules, M_4 (Emamectin benzoate @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l- collection and destruction of affected fruits) and M_3 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26 % OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) were effective in controlling fruit sucking moth damage and were statistically at par with each other (1.34 and 1.53%, respectively). The next best module was M_5 (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l - azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits (RPP).) (2.70%) followed by M_2- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l - collection and destruction of affected fruits) and M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) which recorded higher fruit sucking moth damage with 3.63 and 3.08 per cent and they were statistically at par with each other.

4.3.2.3 At third treatment

Fruit sucking moth damage during third treatment was given in Table 12. At 3 DAT, module 3 recorded significantly lowest fruit damage (0.90%) and it was statistically at par with M_4 (1.00%) and M_5 (1.25%). The next best module was M_2 (1.38%). Whereas, M_1 recorded significantly highest fruit sucking moth damage of 5.78 per cent. At 7 DAT, M_3 recorded significantly lowest fruit damage (0.25%). Whereas, M_4 and M_1 were next best modules in controlling fruit damage with 0.50 per cent each. At 14 DAT, M_4 and M_3 recorded significantly lowest fruit damage (0.01% each) which were statistically superior over all other modules. Whereas, M_5, M_1 and M_5 were moderate in controlling fruit sucking moth with 1.20, 1.28 and 1.50 per cent fruit damage, respectively.

The mean fruit sucking moth damage during third treatment period was recorded and result indicated that, among five modules, M_3- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26 OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) was effective in controlling fruit sucking moth damage (0.39%) and was statistically at par with M_4 (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) (0.50%). The next best module was M_5- (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits (RPP)) (1.28%) and M_2 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - Azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l- Collection and destruction of affected fruits) (1.38%). Whereas, M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) recorded significantly higher fruit damage (2.52%).

4.3.2.4 Average fruit sucking moth damage

The average fruit sucking moth damage among five modules, (Table 12), indicated that, M_4 (Emamectin benzoate @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) and M_3 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% @ 1.50 ml/l

– spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) were statistically at par and significantly superior over remaining three modules with 0.82 and 1.11 per cent fruit damage, respectively. Remaining three modules *viz.*, M_5 (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l - azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) and M_2 (release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - Bt @ 1g/l- collection and destruction of affected fruits.) were next best and recorded moderate fruit sucking moth damage of 1.83 and 2.30 per cent, respectively. Whereas, M_1 (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) recorded significantly higher fruit damage (2.76%).

4.3.3 Evaluation of IPM modules against pomegranate thrips

Performance of different IPM modules on pomegranate thrips was recorded as per cent fruit damage at 3, 7 and 14 DAT during three treatment imposition periods and are presented in Table 13.

4.3.3.1 At first treatment

The fruit damage by thrips at 3 DAT indicated that, module 4 was best with significantly lowest fruit damage (3.25%). The next best module was M_5 (5.25%), followed by M_3 (8.07%) which recorded moderate thrips damage. Whereas, module 1 and module 2 recorded moderate thrips damage with 12.50 and 14.50 per cent, respectively. At 7 DAT, M_3 recorded significantly lowest thrips damage (0.75%). Whereas, M_4 and M_5 were next best modules with 2.60 and 2.75 per cent thrips damage, respectively. At 14 DAT, module 3 recorded significantly lowest fruit damage due to thrips (1.38%) which was statistically superior over other modules, while, M_1 and M_2 recorded moderate level of thrips damage (1.53 and 2.01%). Among all the modules, module 4 recorded highest thrips damage of 3.50 per cent.

The mean thrips damage on fruits during first treatment indicated that, among the five modules, M_4 (Emamectin benzoate 5% SG @ 0.25 g/l - cyazypyr 10.26% OD @ 1.50 ml/l - spinosad 45 SC @ 0.25 ml/l - collection and distruction of affected fruits) M_5 and M_3 were effective in controlling thrips damage (3.12, 3.42 and 3.61%, respectively) and were statistically at par with each other. The next best modules were

Table 13: Performance of different IPM modules against pomegranate thrips during *Hasta bahar*, 2016-17

M. No.	IPM modules	Thrips damage on fruits (%)													
			1st Treatment				2nd Treatment				3rd Treatment				Average
		1 DBT	3 DAT	7 DAT	14 DAT	Mean	3 DAT	7 DAT	14 DAT	Mean	3 DAT	7 DAT	14 DAT	Mean	
M_1	Biological IPM module	12.69 (20.87)	12.50^{d} (20.70)	5.25^{d} (13.25)	1.53^{ab} (7.09)	6.43^{b} (14.68)	3.75^{d} (11.17)	7.75^{e} (16.16)	4.48^{c} (12.21)	5.33^{e} (13.34)	11.50^{c} (19.82)	14.20^{c} (22.14)	15.75^{c} (23.38)	13.82^{e} (21.82)	8.52^{d} (16.97)
M_2	Bio-intensive IPM module	12.78 (20.95)	14.50^{e} (22.38)	3.40^{c} (10.63)	2.03^{bc} (8.18)	6.64^{b} (14.93)	3.00^{c} (9.97)	4.50^{d} (12.25)	2.63^{b} (9.32)	3.38^{d} (10.59)	14.75^{d} (22.59)	9.75^{b} (18.19)	7.25^{b} (15.62)	10.58^{d} (18.98)	6.87^{c} (15.19)
M_3	Adoptable IPM module	10.03 (18.46)	8.70^{c} (17.15)	0.75^{a} (4.97)	1.38^{a} (6.73)	3.61^{a} (10.95)	1.25^{a} (6.42)	0.01^{a} (0.57)	1.45^{a} (6.92)	0.90^{a} (5.45)	3.55^{a} (10.86)	5.00^{a} (12.92)	3.00^{a} (9.97)	3.85^{b} (11.32)	2.79^{a} (9.61)
M_4	Chemi-intensive IPM module	10.75 (19.14)	3.25^{a} (10.39)	2.60^{b} (9.28)	3.50^{d} (10.78)	3.12^{a} (10.17)	2.00^{b} (8.13)	0.75^{b} (4.97)	1.73^{ab} (7.55)	1.49^{b} (7.02)	3.78^{a} (11.20)	3.95^{a} (11.46)	2.13^{a} (8.38)	3.28^{a} (10.44)	2.63^{a} (9.33)
M_5	Recommended Package of Practice	10.39 (18.80)	5.25^{b} (13.25)	2.75^{bc} (9.55)	2.25^{c} (8.63)	3.42^{a} (10.65)	1.48^{a} (6.98)	2.50^{c} (9.10)	2.75^{b} (9.55)	2.24^{c} (8.61)	7.50^{b} (15.89)	4.50^{a} (12.25)	6.00^{b} (14.18)	6.00^{c} (14.18)	3.89^{b} (11.37)
S.Em. ±		-	0.86	0.40	0.39	0.40	0.19	0.47	0.72	0.46	0.42	0.36	0.84	0.27	0.38
C.D. at 5%		NS	2.58	1.22	2.00	1.21	0.58	1.43	2.19	1.40	1.28	1.90	2.54	0.83	1.15
C.V. (%)			10.03	8.31	9.40	7.49	16.47	10.84	15.69	14.33	5.19	8.06	11.62	3.48	8.43

DBT: Day Before Treatment
DAT: Days After Treatment
NS: Non Significant

Figures in the parenthesis are arc sin transformed values
Figures with same alphabetical superscripts are statistically non-significant

M_1 (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) and M_2 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - Bt @ 1.00 g/l - collection and destruction of affected fruits) which recorded higher thrips damage of 6.43 and 6.64 per cent, respectively.

4.3.3.2 At second treatment

Data obtained on fruit damage due to thrips in the field trial are given in Table 13. At 3 DAT, module 3 recorded significantly lowest fruit damage (1.25%) and it was statistically at par with module 5 (1.48%) but significantly superior over all other modules. The next best module was M_4 (2.00%). While, module 2 and module 1 were less effective (3.00 and 3.75%, respectively). At 7 DAT, module 3 recorded significantly lowest fruit damage (0.01%). Whereas, module 4 was next best with 0.75 per cent thrip damage. Module 2 and module 1 recorded significantly higher fruit damage of 4.50 and 7.75 per cent, respectively. At 14 DAT, module 3 recorded significantly lowest fruit damage (1.45%) which was statistically at par with module 4 (1.73%) and significantly superior over all other. Whereas, module 2 and module 5 were the next best with 2.63 and 2.75 per cent thrips damage, respectively.

The mean thrips damage on fruits during second treatment period indicated that, among five modules, M_3- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) recorded significantly lowest fruit damage of 0.90 per cent while, M_4 (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad @ 0.25 ml/l - collection and destruction of affected fruits) was next best module with 1.49 per cent thrips damage. M_5- (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) was moderate in recording thrips damage on fruits (2.24%). Whereas, M_2- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - aazadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l- collection and destruction of affected fruits) and M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) was statistically inferior in recording thrips damage (3.38 and 5.33%, respectively).

4.3.3.3 At third treatment

Data obtained on fruit damage due to thrips in the field trial are given in Table 13. At 3 DAT, M_3 and M_4 recorded significantly lower fruit damage (3.55 and 3.78%, respectively) and were statistically superior over all other modules. The next best module was M_5 (7.50%). Whereas, M_1 and M_2 recorded significantly higher thrips damage on fruits with 11.50 and 14.75 per cent, respectively. At 7 DAT, M_4 recorded significantly lowest fruit damage (3.95%). This was statistically at par with M_5 and M_3 with fruit damage of 4.50 and 5.00 per cent, respectively. At 14 DAT, M_4 recorded significantly lowest fruit damage (2.13%) which was statistically at par with M_3 (3.00%) but significantly superior than other modules. Next best modules were M_5 and M_2, which recorded moderate level of fruit damage with 6.00 and 7.25 per cent, respectively.

Among five modules the mean thrips damage in M_4 (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26 OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l- collection and destruction of affected fruits) was significantly lowest (3.28%). M_3- (Release of *Trichogramma chilonis* @ 2.50 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) was the next best with 3.85 per cent thrips damage. Among all the modules, M_1 (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) recorded significantly highest thrips damage on fruit (13.82%).

4.3.3.4 Average thrips damage on fruits

After completion of three IPM treatment impositions, average thrips damage on fruits was significantly lowest in M_4- (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l - spinosad @ 0.25 ml/l - collection and destruction of affected fruits) and M_3- (Release of *Trichograma chilonis* @ 2.5 lakh – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) and were statistically at par with each other with 2.63 and 2.79 per cent fruit damage, respectively. M_5- (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) was next best module in controlling thrips damage

(3.89%). While, M_2- (Release of *Trichograma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l- collection and destruction of affected fruits) and M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) recorded higher thrips damage of 6.87 and 8.52 per cent, respectively.

4.3.4 Impact of different IPM modules on natural enemy population

Effect of different IPM modules on the abundance of natural enemies on pomegranate was studied during the *Hasta bahar* 2016-17. Observations on natural enemies *viz.*, Coccinellids and spiders were recorded from five tagged shoots per plant at day before spray and 3, 7 and 14 days after each treatment were averaged as numbers per plant and results are presented in Table 14.

4.3.4.1 Safety of IPM modules to natural enemies after first treatment

The population of natural enemies in module M_1 ranged from 0 to 0.75 per plant during first spray with a mean of 0.33 per plant. The population of natural enemies at 3, 7 and 14 DAS was non-significant among treatments. The mean natural enemy population showed non-significant results with natural enemies ranging from 0.17 to 0.50 per plant.

4.3.4.2 Population of natural enemies after second treatment

The population of natural enemies in module M_1 ranged from 0.25 to 0.75 per plant during second spray with a mean of 0.42 per plant. The population of natural enemies at 3, 7 and 14 DAS was non-significant among treatments. The mean natural enemy population showed non-significant ranged from 0.17 to 0.42 per plant.

4.3.4.3 Population of natural enemies after third treatment

Natural enemy population during third spray observation period ranged from 0.00 to 1.55 per plant with a mean of 0.50 per plant. The natural enemy population showed non-significance at 3 and 7 DAS. However, population at 14 DAS showed significantly highest population in M_1 (1.50/plant) which was statistically at par with M_2 (0.85/plant) and were statistically superior than other modules.

Table 14: Population of natural enemies in different IPM modules on pomegranate during *Hasta bahar*, 2016-17

M. No.	IPM modules	Population of coccinellids and spiders (No./plant)													
		1st Treatment					2nd Treatment				3rd Treatment				Average
		1 DBT	3 DAT	7 DAT	14 DAT	Mean	3 DAT	7 DAT	14 DAT	Mean	3 DAT	7 DAT	14 DAT	Mean	
M_1	Biological IPM module	0.58 (1.01)	0.75 (1.05)	0.00 (0.70)	0.25 (0.83)	0.33 (0.88)	0.25 (0.85)	0.75 (1.05)	0.25 (0.85)	0.42 (0.93)	0.65 (0.96)	1.55 (1.31)	1.50^{a} (1.36)	1.08 (1.25)	0.61 (1.05)
M_2	Bio-intensive IPM module	0.25 (0.85)	0.5 (0.96)	0.25 (0.83)	0.75 (1.05)	0.50 (0.98)	0.25 (0.85)	0.50 (0.98)	0.50 (0.98)	0.42 (0.95)	0.90 (0.96)	0.65 (0.92)	0.85^{ab} (1.05)	0.58 (1.01)	0.50 (0.99)
M_3	Adoptable IPM module	0.50 (0.97)	0.25 (0.83)	0.00 (0.70)	0.25 (0.83)	0.17 (0.80)	0.25 (0.85)	0.25 (0.85)	0.50 (0.98)	0.33 (0.89)	0.90 (0.96)	0.2 (0.83)	0.65^{b} (0.92)	0.42 (0.91)	0.31 (0.88)
M_4	Chemi-intensive IPM module	0.25 (0.85)	0.25 (0.83)	0.25 (0.83)	0.25 (0.83)	0.25 (0.86)	0.00 (0.70)	0.25 (0.85)	0.25 (0.85)	0.17 (0.80)	0.40 (0.96)	0.65 (0.96)	0.00^{b} (0.70)	0.33 (0.90)	0.25 (0.86)
M_5	Recommended Package of Practice	0.33 (0.90)	0.00 (0.70)	0.25 (0.83)	0.50 (0.92)	0.25 (0.83)	0.00 (0.70)	0.50 (0.98)	0.25 (0.85)	0.25 (0.85)	0.65 (0.96)	1.55 (1.18)	0.00^{b} (0.70)	0.50 (0.98)	0.33 (0.90)
S.Em. ±			-	-	-	-	-	-	-	-	-	-	0.14	-	-
C.D. at 5%			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.43	NS	NS
C.V. (%)													29.90		

DBT: Day Before Treatment
DAT: Days After Treatment
NS: Non Significant

Figures in the parenthesis are square root transformed values
Figures with same alphabetical superscripts are statistically non-significant

The average natural enemy population showed non-significant variation among different modules. Natural enemy population ranged from 0.25 and 0.61 per plant across the treatments.

4.3.5 Performance of different IPM modules on pomegranate fruit yield

4.3.5.1 Number of marketable fruits

Number of marketable pomegranate fruits were significantly higher in M_3 - (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) (73.75/plant) and M_4- (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26 OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l- collection and destruction of affected fruits) (68.00/plant) which were statistically at par with each other. The next best module was, M_5 - (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) (59.75/plant) and was statistically at par with M_2- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1g/l - collection and destruction of affected fruits) (54.50/plant). Whereas, M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) recorded least number of good fruits per plant (44.00/plant) (Table 15 and Plate 6).

4.3.5.2 Weight of fruits

Significantly higher pomegranate fruit weight per plant was obtained in module M_4 (23.25 kg/plant) which was statistically at par with M_3 (21.08 kg/plant). While, next best modules were M_5 and M_2 which were statistically at par with each other (16.55 and 15.25 kg/plant, respectively).Whereas, M_1- recorded significantly lowest fruit weight (12.60 kg/plant) (Table 15).

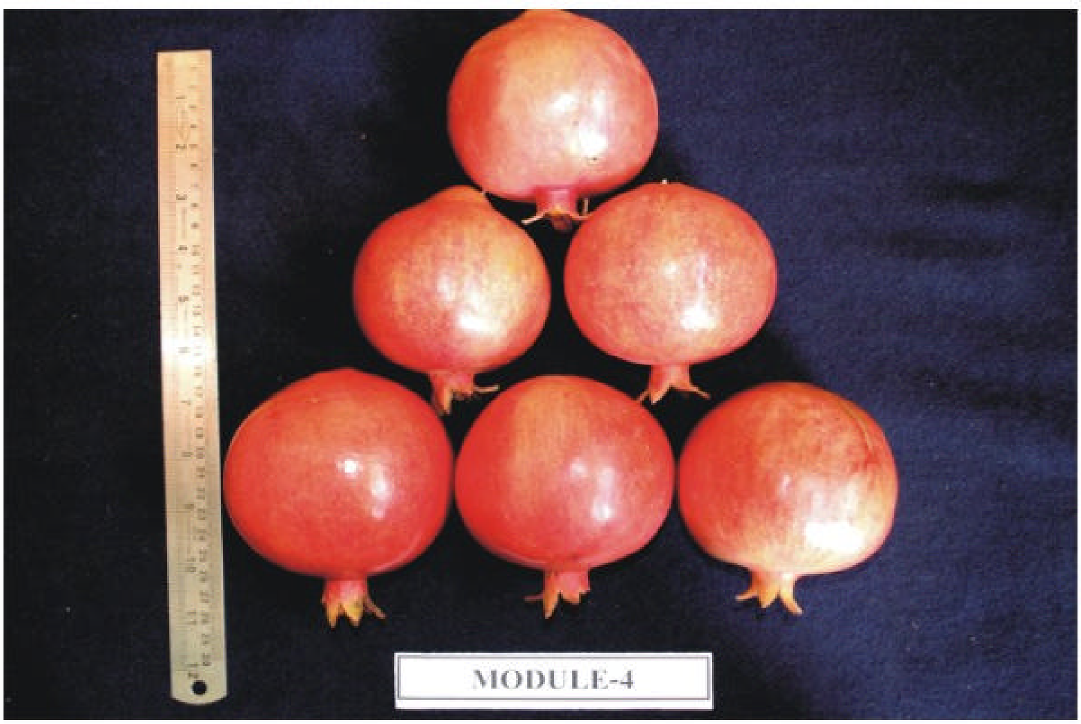
4.3.5.3 Fruit yield

Pomegranate fruit yield was significantly highest in M_4 (15.50 t/ha) which was statistically at par with M_3- (14.05 t/ha). While, next best modules were in M_5 and M_2

Table 15: Performance of different IPM modules on pomegranate fruit yield during *Hasta bahar*, 2016-17

M. No.	IPM modules	Marketable fruits (No./plant)	Fruit weight (kg/plant)	Fruit yield (t/ha)
M_1	Biological IPM module	44.00[d]	12.60[c]	8.40[c]
M_2	Bio-intensive IPM module	54.50[cd]	15.25[bc]	10.17[bc]
M_3	Adoptable IPM module	73.75[a]	21.08[a]	14.05[a]
M_4	Chemi-intensive IPM module	68.00[ab]	23.25[a]	15.50[a]
M_5	Recommended Package of Practice	59.75[bc]	16.55[b]	11.03[b]
S.Em. ±		3.81	1.27	0.85
C.D. at 5 %		11.40	3.82	2.55
C.V. (%)		12.33	13.99	13.99

6a. Fruit quality in Module 3: Adoptable IPM module



6b. Fruit quality in Module 4: Chemi-intensive IPM module

Plate 6. Quality of pomegranate fruits in different IPM module plots

which were statistically at par with each other (11.03 and 10.17 t/ha, respectively). Whereas, M_1- recorded significantly lowest fruit yield (8.40 t/ha) (Table 15).

4.3.6 Economics of different modules in pomegranate during *Hasta bahar*

The economics of each IPM module was worked out based on yield of marketable quality fruits and expenditure made in each module and presented in Table 16. Among evaluated modules maximum gross income of Rs. 12,40,000 per ha was obtained in M_4 module (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits). The next best module was M_3- (Release of *Trichograma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) with gross returns of Rs. 11,24,000 per ha while, a recommended package, M_5 (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) recorded Rs. 8,82,400 per ha of gross returns. Next modules in order of superiority were M_2- (Release of *Trichograma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l - collection and destruction of affected fruits) and M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) with gross returns of Rs. 8,13,600 and 6,72,000 per ha, respectively.

Net returns indicated that, modules like M_3 and M_4 provided maximum net profit of Rs. 10,85,491 and Rs.10,16,268 per ha, respectively followed by M_5 (Rs. 6,67,375/ha) M_2 (Rs. 5,98,212/ha) and M_1 (Rs. 4,56,200/ha).

Benefit cost ratio (B:C) was worked out for each modules, in which M_4 provided highest B:C ratio of 5.54 followed by M_3 (5.01) while, BC ratio obtained in modules, M_5 and M_2 were 4.10 and 3.77, respectively. Relatively low B:C ratio of 3.11 was recorded in M_1 module.

Table 16: Economics of different IPM modules in pomegranate during *Hasta bahar*, 2016-17

M. No.	IPM modules	Fruit yield (t/ha)	Gross return (Rs./ha)	Total cost of cultivation (Rs./ha)	Treatment cost (Rs./ha)	Net returns (Rs./ha)	B:C ratio
M_1	Biological IPM module	8.40	672000	215800	3300	456200	3.11
M_2	Bio-intensive IPM module	10.17	813600	215388	2888	598212	3.77
M_3	Adoptable IPM module	14.05	1124000	223969	11469	1085491	5.01
M_4	Chemi-intensive IPM module	15.50	1240000	223732	11232	1016268	5.54
M_5	Recommended Package of Practice	11.03	882400	215025	2525	667375	4.10

Market price for fruits @ Rs. 80/kg
Cost of each component of IPM modules is furnished in the Appendix II

5. DISCUSSION

Results of different experiments conducted under the investigation entitled "seasonal incidence and management of pomegranate fruit borer, *Deudorix isocrates* (Fab.) during *Hasta bahar*" are discussed here under. The experiments under this investigation were carried out in the Fruit Division, MHREC, University of Horticultural Sciences, Bagalkot and Udyanagiri, College of Horticulture, UHS Bagalkot, during 2016-17.

5.1 Seasonal incidence of fruit borer, *Deudorix isocrates* on pomegranate

5.1.1 Seasonal incidence of pomegranate fruit borer

The pomegranate fruit borer, *D. isocrates* was noticed from fruit initiation period of pomegranate plants from September 2016 to March 2017 (during *Ambe bahr* and *Hasta bahar* periods), in which occurrence ranged from 3.37 to 60.10 per cent. First peak incidence was noticed in the September 2016 (60.10%) and second peak during third week of January fallowed by first week of February and second week of March (13.73, 15.33 and 12.00%, respectively) (Fig. 1). While, fruit borer incidence from October to December was moderate ranging from 9.32 to 5.37 per cent. This is in confirmation with the findings of Shevale and Kaulgud (1998) who reported that the period from July to October was favorable for pomegranate fruit borer build up. However, the fruit borer incidence from November to February was intermediate (Shevale and Khaire, 1999). This incidence period corresponds with *Hasta bahar* in Karnataka. However, results are also partly in confirmation with the reports of Kabre and Moholkar (1991) who observed the incidence of fruit borer on pomegranate from September to October. This indicated that, the fruit borer incidence may be relatively higher during September to October corresponding with *Ambe bahar* period. The second peak incidence noticed during January to March period in the present study corresponds to *Hasta baha* period, which is in agreement with Kabre and Moholkar (1992) who reported that the peak incidence of fruit borer on pomegranate during second fortnight of March and second half of June in *Hasta bahar* from Maharastra.

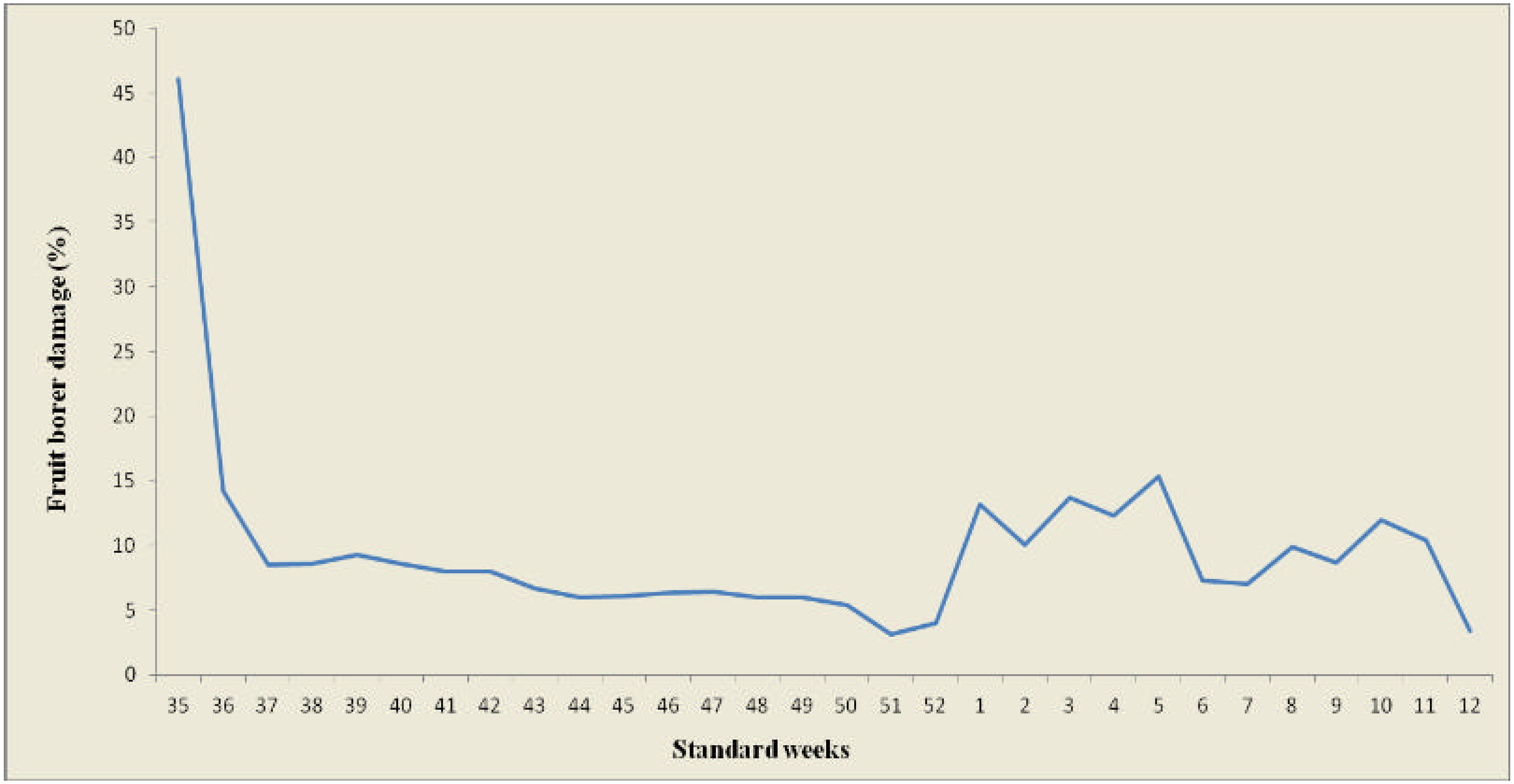


Fig. 1. Seasonal incidence of pomegranate fruit borerduring *Hasta bahar,* 2016-17

In the present study, seasonal incidence was recorded from three pomegranate fields two were under *Ambe bahar* (pruned during February to March) and other was under *Hasta bahar* (pruned during September to October). From the present findings, it is evident that, probably fruit borer attacks young developing fruits with relatively higher infestation during *Ambe bahar* compared to *Hasta bahar* season.

5.1.2 Correlation studies between weather parameters and per cent fruit infestation by *Deudorix isocrates*

The correlation studies between per cent fruit infestation by *D. isocrates* and weather parameter *viz.*, maximum and minimum temperature, morning and evening relative humidity, rainfall and rainy days, prevailed during the actual weeks were done to know the impact of weather parameters on the incidence of *D. isocrates*.

Incidence of *D. isocrates* showed a non-significant and negative relationship with maximum temperature and rainy days and non-significant, positive relationship with other parameters. During November to February the un-favorable weather parameter like moderate temperature, maximum relative humidity and no rainfall resulted in the less development and multiplication of fruit borer. However, the present study indicated less influence of weather parameters on fruit borer incidence and is contradictory to the results of Kulkarni *et al*. (2016) who reported meteorological parameters *viz.*, relative humidity and temperature playing major role in regulating the pest population.

5.2 Efficacy of new insecticide molecules for the management of pomegranate fruit borer

Results of the experiment on the management of pomegranate fruit borer during *Hasta bahar* of 2016-17 revealed that, all the insecticides were significantly superior over untreated control in suppressing the incidence of fruit borer.

The average fruit borer incidence during three sprays of rynaxypyr 18.5% SC @ 0.3 ml and cyazypyr 10.26% OD @ 1.5 ml per l are at par with each other with respect to fruit damage (2.07 and 2.51% respectively) and were significantly superior over other treatments. The next best treatments were, spinosad 45 SC @ 0.25 ml per l and lambda cyhalothrin 4.9% CS @ 0.5 ml per l which have recorded 4.06 and 4.78

per cent fruit borer damage respectively. Quinalphos 25% EC @ 2 ml (a standard check), emamectin benzoate 5% SG @ 0.25 g and azadirachtin 10000 ppm @ 1 ml per l were less effective but significantly superior than untreated control (Fig. 2).

The data recorded at fourteen days after first, second and third spray showed that, the treatments rynaxypyr 18.5% SC @ 0.3 ml per l and cyazypyr 10.26% OD @ 1.5 ml per l were consistently superior in suppressing the fruit borer incidence followed by spinosad 45 SC @ 0.25 ml per l, lambda cyhalothrin 4.9% CS @ 0.5 ml per l and emamectin benzoate 5% SG @ 0.25 g per l and were statistically at par with each other but, superior over standard check, quinalphos 25% EC and azadirachtin 10000 ppm which intern were statistically at par with each other and superior over un-treated control.

It is evident from the result that, the mean per cent of fruit borer damage was significantly lowest in rynaxypyr 18.5% SC 0.3 ml per l and cyazypyr 10.26% OD 1.5 ml per l treated plots compared to other treatments. The results are in agreement with Rashwan (2013) who reported rynaxypyr as very effective against lepidopteran pests by acting on rynodine receptors of muscle system.

In the present findings, next best treatments in reducing fruit borer incidence were spinosad, emamectin benzoate and lambda cyhalothrin. These result are in conformity with the report of Ramachandra (2007) who stated that application of emamectin benzoate (0.0022%) and spinosad (0.018%) could minimize the fruit borer damage. Spraying of lambda cyhalothrin a pyrethroid with bagging of fruits found effective against *D. isocrates* (Wisma and Mazen, 2002). Moustafa *et al.* (2016) also reported that spinosad and emamectin benzoate as promising alternatives to conventional insecticides for the management of lepidopteran pest successfully.

Standard and conventional insecticide, quinalphos and a botanical product, azadirachtin were less effective in controlling the fruit borer damage. These result are in conformity with Sinha and Roy (1984) who reported that quinalphos @ 0.05% was next best treatment after carbaryl @ 0.2%. Kabre (1986) concluded that quinalphos 0.05 % was less effective when compare to other treatments.

Considering these results, it appears that pomegranate fields sprayed with insecticides like rynaxypyr and cyazypyr have recorded lower fruit borer damage.

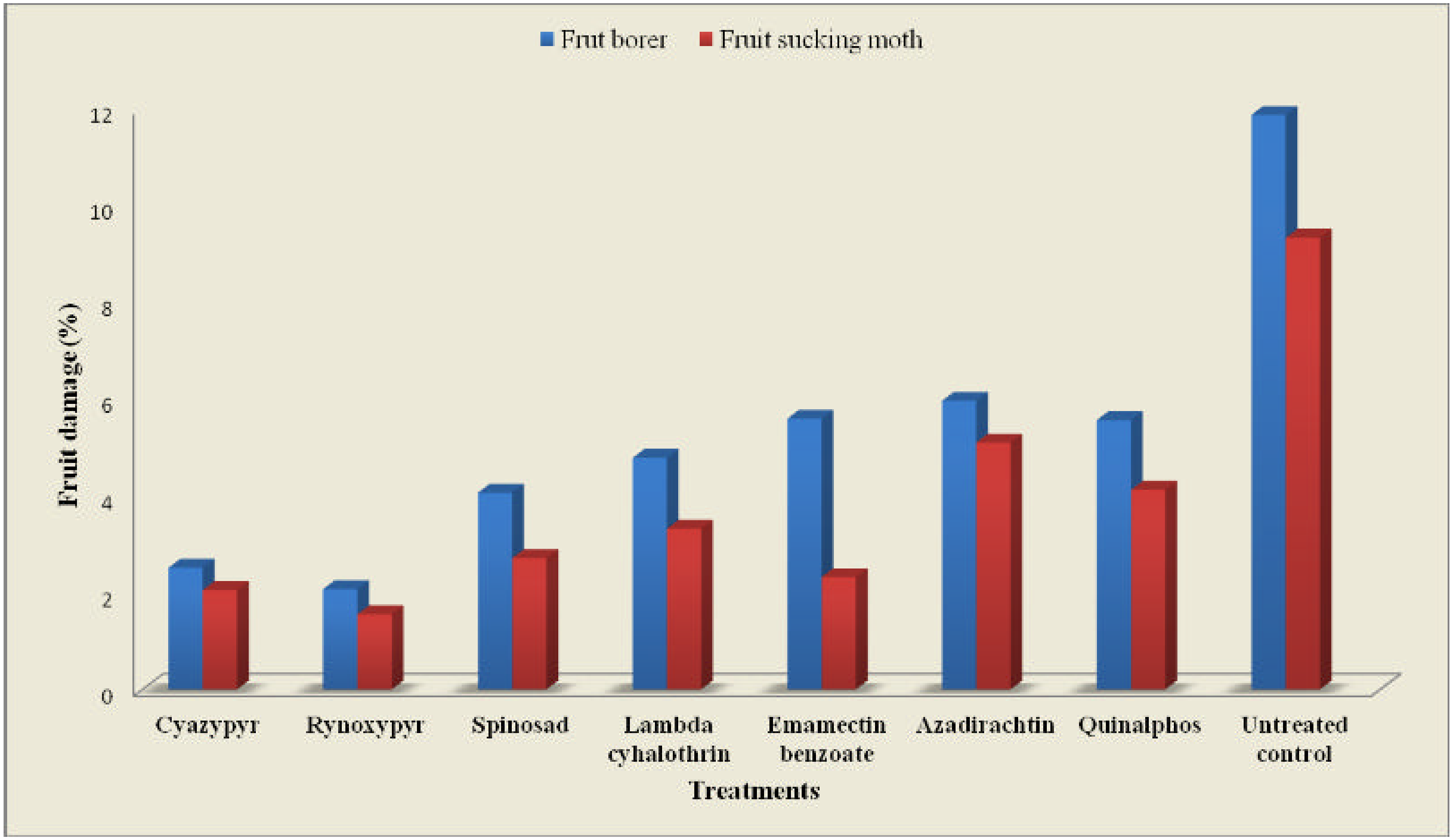


Fig. 2. Efficacy of new insecticides against fruit borer and fruit sucking moth on pomegranate during *Hasta bahar*, 2016-17

Further, both the chemicals belongs to diamide group of insecticides and kills the insects by depletion of muscle cells, causing impaired muscle regulation, paralysis and ultimate death of insect (Cordova *et al.,* 2006) Further, the need based sprays on pomegranate with rynaxypyr or cyazypyr thrice at an interval of 20 - 25 days during fruit initiation to fruit development stage may be necessary to keep the population at low levels.

5.2.1 Efficacy of new insecticide molecules against pomegranate fruit sucking moth

Results of the experiment on the management of pomegranate fruit sucking moth during *Hasta bahar* of 2016-17 reveled that, all the insecticides were significantly superior over untreated control in suppressing the damage of fruit sucking moth.

During second and third treatment periods pomegranate fruit sucking moth damage was significantly lowest in rynaxypyr 18.5% SC @ 0.3 ml and cyazypyr 10.26% OD @ 1.5 ml per l and were significantly superior over other treatments and recorded an average of 1.55 and 2.05 per cent fruit damage, respectively. The next best treatments were, emamectin benzoate 5% SG @ 0.25 g, spinosad 45 SC @ 0.25 ml and lambda cyhalothrin 4.9% CS @ 0.5 ml per l, which have recorded 2.32, 2.71 and 3.32 per cent fruit damage, respectively. While, quinalphos 25% EC @ 2 ml and azadirachtin 10000 ppm @ 1 ml per l were less effective but significantly superior than untreated control (Fig.2).

The data recorded at fourteen days after second and third sprays showed that treatments *viz.,* rynaxypyr 18.5% SC and cyazypyr 10.26% OD were consistent in suppressing the damage of fruit sucking moth followed by emamectin benzoate 5% SG, spinosad 45 SC and lambda cyhalothrin 4.9% CS. While, standard check, quinalphos 25% EC and azadirachtin 10000 ppm were statistically at par with each other and superior over un-treated control.

It is evident from the result that, the mean fruit sucking moth damage was significantly lowest in rynaxypyr and cyazypyr treated plots as compared to other treatments. The results are in accordance with Temple *et al.* (2009) reported high toxicity of rynaxypyr to lepidopteran insects. The laboratory bioassay studies also indicated rynaxypyr treated diet showing lowest LC_{50} value ranging from 0.02 to 0.009 ppm.

In the present findings, next best treatments in reducing fruit sucking moth were spinosad, emamectin benzoate and lambda cyhalothrin. These results are in conformity with the report of Abro *et al.* (2013) who reported significant level of control with spinosad and lambda cyhalothrin against lepidopteron insect pests. Bengochea *et al.* (2014) also reported effectiveness of emamectin benzoate against last instar larvae of lepdopteran insects. Insecticides like quinalphos and azadirachtin were less effective in controlling the fruit sucking moth damage. These results are in conformity with the Ojha *et al.* (2017) who evaluated azadirachtin and quinalphos against lepidopteron pest and concluded that both the chemicals were moderate in managing lepidopteran pests.

5.2.3 Efficacy of new insecticide molecules against thrips

Result of the experiment on efficacy of newer molecules of insecticides against pomegranate thrips during *Hasta bahar* of 2016-17 reveled that, all the insecticides were significantly superior over untreated control in reducing the thrips damage.

Average thrips damage on fruits during treatment imposition periods indicated that, spray of cyazypyr 10.26% OD @ 1.5 ml per l was significantly superior and recorded an average of 1.76 per cent damage and the next best treatments were, rynaxypyr 18.5% SC @ 0.3 ml, quinalphos 25 EC @ 2 ml, emamectin benzoate 5% SG @ 0.25 g and lambda cyhalothrin 4.9% CS @ 0.50 ml per l which have recorded 3.88, 3.98, 4.51 and 4.52 per cent thrips damage on fruits, respectively. Spinosad 45 SC @ 0.25 ml and azadirachtin 10000 ppm @ 1 ml were less effective (4.88 and 6.37% thrips damage, respectively) but significantly superior than untreated control.

The data recorded at fourteen days after first, second and third spray showed that, treatment cyazypyr 10.26% OD @ 1.5 ml was consistent in suppressing the damage by thrips. Whereas, rynaxypyr 18.5% SC @ 0.30 ml, quinalphos 25% EC @ 2.00 ml, emamectin benzoate 5% SG @ 0.25 g and lambda cyhalothrin 4.9% CS @

0.50 ml per l were less effective in reducing thrips damage on fruits and were statistically at par with each other and superior over spinosad 45 SC @ 0.25 ml, azadirachtin 10000 ppm @ 1.00 ml and un-treated control.

It is evident from the result that, the mean per cent incidence of thrips was significantly lowest in cyazypyr treated plots compared to other treatments. The result is in close agreement with Kambrekar *et al*. (2015) who reported cyazypyr @ 60 g *a.i* per ha as most optimum dose and resulted in maximum reduction in the thrips population in grape.

In the present findings, all other treatments *viz.*, rynaxypyr, quinalphos, emamectin benzoate, lambda cyhalothrin recorded moderate level of thrips incidence while, spinosad was less effective against thrips. These results are in conformity with the results of Jadhao *et al*. (2016) who reported spinosad as a moderately effective insecticide in reducing the thrips population in chilli. Spinosad, belonging to spionosyns group and green labelled molecule has shown tremendous efficacy against lepidopteran pests, but however, few studies have also shown it to be effective against sucking pests like thrips.

In the present study, azadirachtin 10,000 ppm @ 1.00 ml was found less effective in reducing thrips population on pomegranate. These results are in close conformity with the findings of Bhargava and Bhatnagar (2005) and Suresh *et al*. (2006) who reported nimbicidine was less effective in controlling the thrips population as compared to chemical insecticides. However, it is evident that, azadirachtin 10,000 ppm unlike the earlier neem formulation with less azadirachtin concentration could able to reduce thrips damage up to 60 per cent on fruiting bodies. So, it can be explored as an alternative to rotate with chemical insecticides in pomegranate.

Considering these results, it can be recommended that, pomegranate field showing both the incidence of fruit borer and thrips can be managed by spraying with a broad spectrum diamide insecticide, cyazypyr 10.26% OD @ 1.5 ml per l during fruit initiation and fruit development stage.

5.2.4 Impact of new insecticide molecules on natural enemies in pomegranate

Abundance of natural enemies *viz.,* coccinellids and spiders on treated and untreated pomegranate plants has shown that certain insecticides are proven to be safer to natural enemies. The natural enemy population was significantly highest in untreated control (1.49/plant) which was statistically at par with azadirachtin 10000 ppm (0.71/plant). The next safest treatments in order were, cyazypyr 10.26% OD, spinosad 45 SC, lambda cyhalothrin 4.9% CS and rynaxypyr 18.5% SC which recorded natural enemies population of 0.64, 0.51, 0.48 and 0.40 per plant, respectively. While, rest of the treatments were not safer to coccinellids and spiders. These results are in conformity with the report of Mansour *et al.* (1993) who reported neem extract showing no harmful effect on beneficials such as spiders, ladybird beetles and parasitoids.

5.2.5 Performance of new insecticide molecules on fruit yield of pomegranate during *Hasta abahr*

Significantly highest fruit yield of 12.16 tonnes per ha was recorded in cyazypyr 10.26% OD @ 1.50 ml which was statistically at par with rynaxypyr 18.5% SC @ 0.3 ml (10.76 t/ha). These results are in conformity with Kambrekar *et al.* (2015), who reported that cyazypyr recorded highest fruit yield in grapes. Next best treatments in recording highest fruit yield were, emamectin benzoate 5% SG @ 0.25 g (9.73 t/ha), spinosad 45 SC @ 0.25 ml (8.93 t/ha) and lambda cyhalothrin 4.9% CS @ 0.50 ml (7.62 t/ha). The present findings are in line with Kadam (2006) who reported highest yield in plots sprayed with spinosad The treatments, quinalphos (7.56 t/ha) and azadirachtin 10,000 ppm (7.60 t/ha) were at par with each other in fruit yield in the present study. Cyazypyr, a broad spectrum insecticide both against lepidopteron pests and sucking pests has contributed for higher marketable fruit yield (Fig. 3).

5.2.6 Economics of the management of fruit borer on pomegranate

The highest gross return was obtained from the cyazypyr 10.26% OD treated plot (Rs. 9,72,800/ha). The next best treatments in terms of gross return were

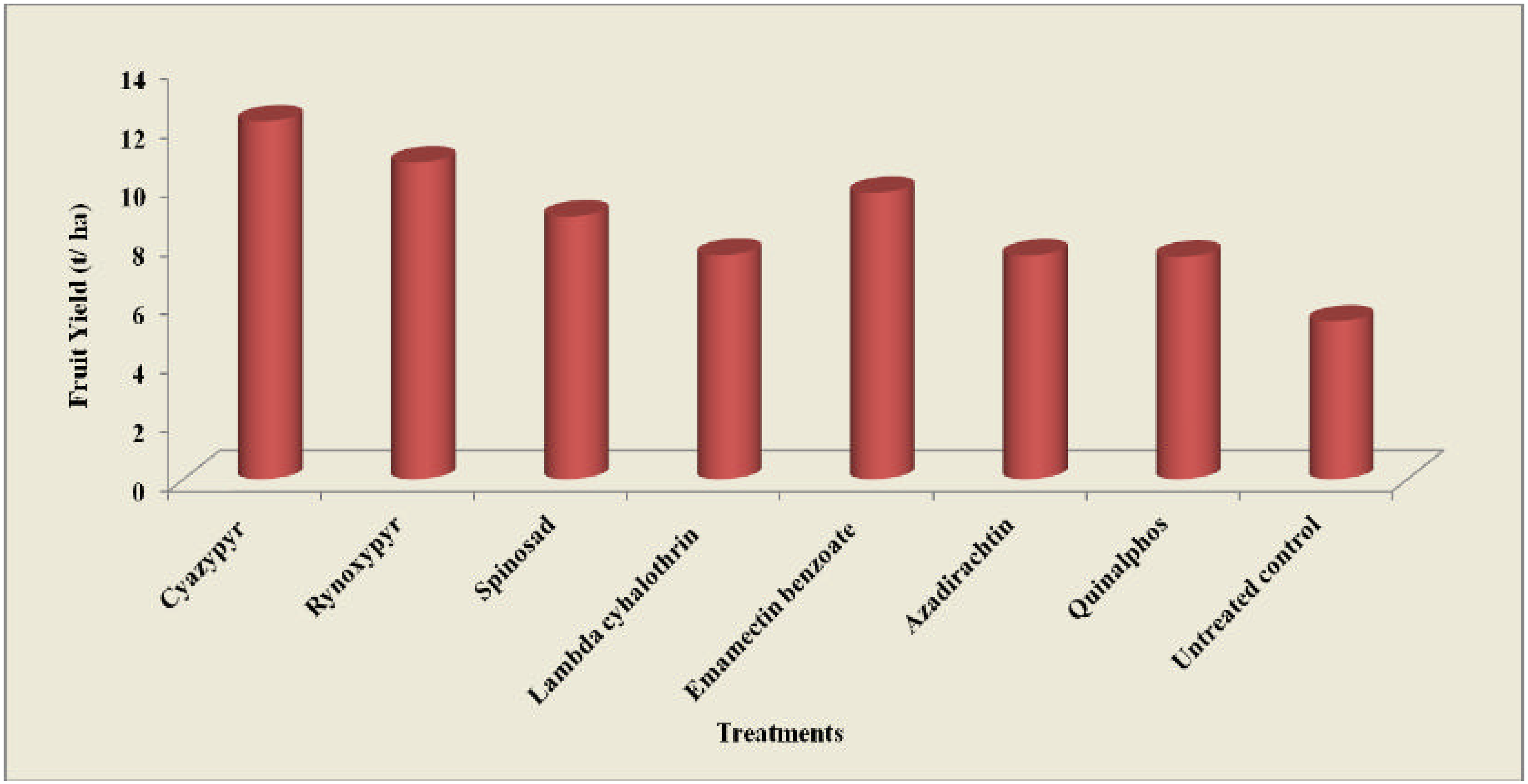


Fig. 3. Fruit yield of pomegranate in different insecticides treated plots during *Hasta bahar*, 2016-17

rynaxypyr 18.5% SC (Rs. 8,60,800/ha) followed by emamectin benzoate 5% SG (Rs. 7,78,400/ha), spinosad 45 SC (Rs. 7,14,400/ha), lambda cyhalotrin 4.9% CS (Rs. 6,09,600/ha), quinalphos 25% EC (Rs. 6,04,800/ha), and azadirachtin 10,000 ppm (Rs. 6,08,000/ha).

Net returns indicated that treatments of cyazypyr, rynaxypyr and emamectin benzoate provided maximum net profit of Rs. 7,41,100; Rs. 6,38,865 and Rs. 5,62,563 per ha, respectively followed by the treatment of spinosad (Rs. 4,94,850/ha), lambda cyhalothrin (Rs. 3,95,390/ha) and quinalphos (Rs. 3,89,630/ha). Net gain was relatively less in treatments of azadirachtin (Rs. 3,93,138/ha) and untreated control (Rs. 2,16,300/ha).

Benefit cost ratio (B:C ratio) was worked out for each insecticidal treatment, in which three sprays of cyazypyr provided highest B:C ratio of 4.20. However, such ratio obtained in other insecticide treatments like rynaxypyr, emamectin benzoate, spinosad was 3.88, 3.61 and 3.25, respectively. Whereas, lambda cyhalothrin, azadirachtin and quinalphos recorded B:C ratio of 2.85, 2.83 and 2.81, respectively. Relatively low B:C ratio of 2.02 was resulted in untreated control.

Rynaxypyr being a diamide systemic insecticide with yellow label can be recommended as cost effective treatment. However, cyazypyr being another diamide insecticide with broad spectrum activity and with green label can be a best alternative for fruit borer as well as thrips management on pomegranate. In addition, azadirachtin 10000 ppm may be one of the best options under organic cultivation of pomegranate or to rotate with chemical insecticides.

5.3 Formulation and evaluation of IPM modules for the management of pomegranate fruit borers

Result of the experiment on the management of pomegranate fruit borer during *Hasta bahar* of 2016-17 reveled that, all the IPM modules were significantly superior over M_1 in suppressing the incidence of fruit borer.

The average fruit borer damage in different IPM modules indicated that, M_4: Chemi-intensive IPM module (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.5 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) and M_3: Adoptable IPM module (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) were statistically at par and significantly superior over remaining three modules with 1.00 and 1.07 per cent fruit borer damage, respectively. Remaining three modules *viz.*, M_2: Biointensive IPM module (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1 ml/l - *Bt* @ 1 g/l - collection and destruction of affected fruits), M_5: Recommended package of practices (Melathion 50% EC @ 2.00 ml/l – deltamethrin @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) and M_1: Biological IPM module (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits.) were next best and recorded moderate fruit borer damage of 2.30, 2.42 and 2.70 per cent, respectively and were at par with each other.

The data recorded at fourteen days after first, second and third treatment imposition showed that, M_3 and M_4 were consistent in suppressing the population of fruit borer followed by M_2, M_4 and M_1 and the latter three were statistically at par with each other.

It is evident from the results that, the mean per cent of fruit borer damage was significantly lowest in M_3 and M_4 modules compared to other modules. The results are in accordance with Singh (2015) who reported that, egg parasitoid *T. chilonis* as most useful for inundative release against lepidopteron pests and chemicals like chlorantraniliprol, cyazypyr and spinosad were effective against lepidopterans.

In the present findings, next best modules were M_2, M_5 and M_1 in reducing fruit borer incidence. These results are in conformity with the report of Kahramanoglu and Usanmaz (2013) that biological insecticide, spinosad, as most effective treatment fallowed by *B. thuringiensis*. Similarly, Singh and Singh (2000) reported that *B. thuringiensis* is an effective control agent for the *Deudorix livia*. However, as Rehman *et al*, (2014) reported deltamethrin an alpho-cyana pyrethriod insececticide is currently extensively used insecticide in pest control.

Considering these result, it can be recommended that M_3- (Release of *Trichogramma chilonis* @ 2.5 lakh – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45

SC @ 0.25 ml/l – collection and destruction of affected fruits) and M_4- (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.5 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) as most promising modules because they contain egg parasitoid, followed by most effective diamide and spionosyns group of insecticides offer effective control against lepidopteran pests (Cordova *et al.*, 2006). Even the bio-intensive IPM module has been proved next best to RPP which is purely a chemical insecticide based recommendation (Fig. 4).

5.3.1 Evaluation IPM modules for the management of pomegranate fruit sucking moth

Result of the evaluation of IPM modules for the management of pomegranate fruit sucking moth during *Hasta bahar* of 2016-17 reveled that, all the IPM modules were significantly superior over module 1 in suppressing the population of fruit sucking moth.

The average fruit sucking moth damage indicated that, M_4- (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.5 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits.) and M_3- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) were statistically at par and significantly superior over remaining two modules with 0.82 and 1.11 per cent fruit damage, respectively. Remaining three modules *viz.*, M_5- (Malathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) and M_2- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - Bt @ 1.00 g/l - collection and destruction of affected fruits) were next best and recorded moderate fruit sucking moth damage with 1.83 and 2.30 per cent, respectively. Whereas, M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits) recorded significantly higher fruit damage (2.76%).

The data recorded at fourteen days after first, second and third treatment imposition showed that M_4 and M_3 were consistent in suppressing the damage fruit sucking moth followed by M_5 and M_2. While, M_1 recorded significantly less reduction of fruit sucking moth damage.

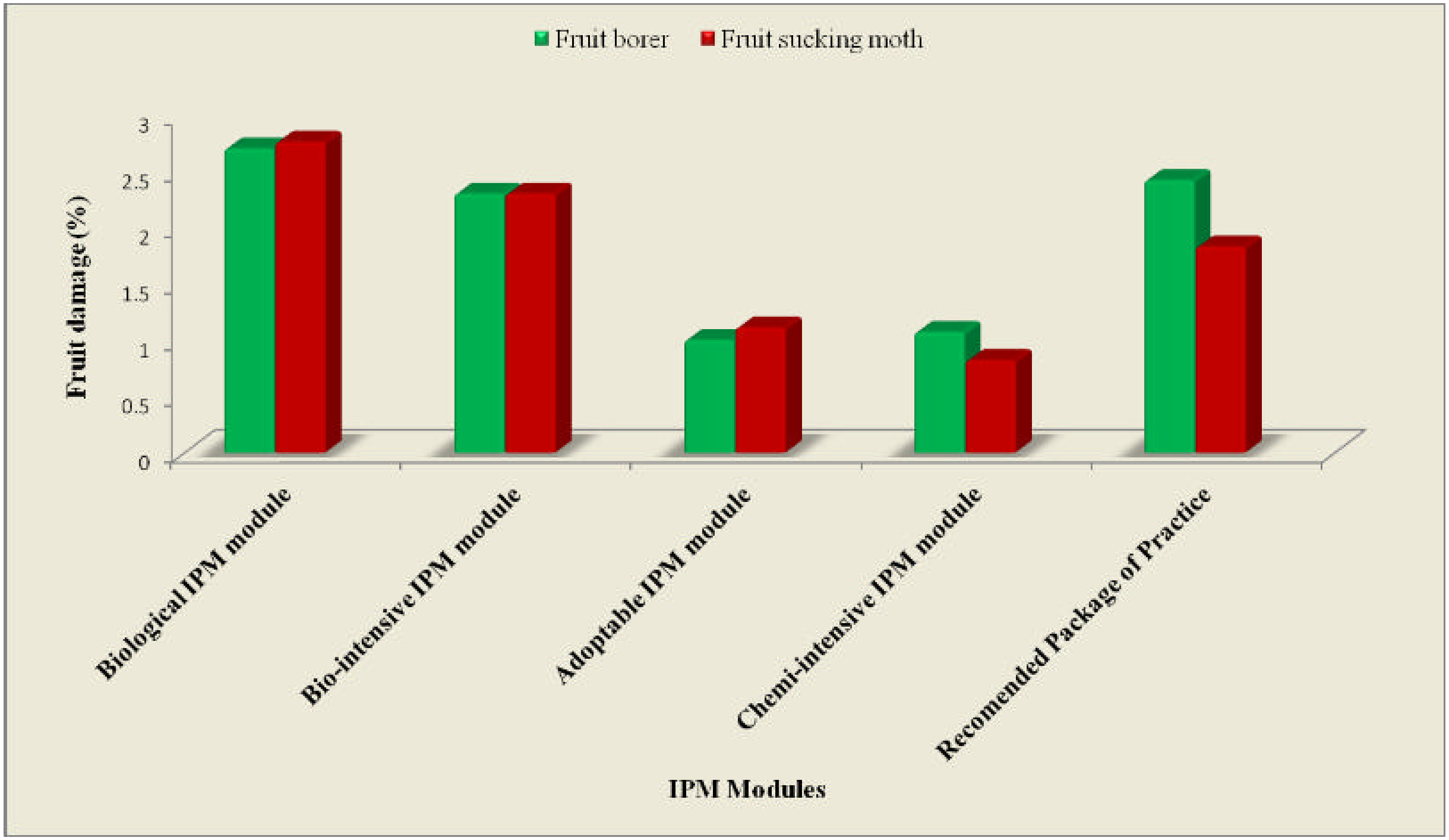


Fig. 4. Fruit borer and fruit sucking moth damage in different IPM modules in pomegranate during *Hasta bahar*, 2016-17

It is evident from the result that, the mean fruit sucking moth damage was significantly lowest in M_4 and M_3 IPM modules compared to other modules. The result are in accordance with Bhumannavar and Viraktamath (2012) who reported that spraying the fruits with insecticides is quite adequate in reducing the damage caused by fruit sucking moth.

In the present findings, next best modules were M_5 and M_2 in reducing fruit sucking moth damage and while, Module1 was less effective in controlling the fruit sucking moth damage. These results are in conformity with the report of Kamalajayanthi *et al*. (2010) who reported that azadirachtin was less effective in repelling the fruit sucking moth (Fig. 4).

5.3.2 Evaluation of IPM modules against pomegranate thrips

Result of the experiment on the management of pomegranate thrips during *Hasta bahar* of 2016-17 reveled that, all the IPM modules were significantly superior over module 1 in suppressing the damage of pomegranate thrips.

The average thrips incidence on fruits indicated that, damage on fruits was significantly lowest in M_4- (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.5 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) and M_3- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) were statistically at par with each other with 2.63 and 2.79 per cent fruit damage, respectively. M_5- (Melathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l – azadirachtin 1500 ppm @ 5.00 ml/l - collection and destruction of affected fruits) was next best module in controlling thrips damage (3.89%). While, M_2- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1.00 ml/l - *Bt* @ 1.00 g/l - collection and destruction of affected fruits) and M_1- (Release of egg parasitoid, *Trichogramma chilonis* at 2.5 lakh/ha at six times at weekly interval (40,000/release/ha) – collection and destruction of affected fruits.) recorded higher thrips damage of 6.87 and 8.52 per cent on fruits, respectively.

The data recorded at fourteen days after first, second and third treatment imposition showed that module 4 and module 3 were consistent in suppressing the incidence of thrips on fruits followed by M_5. Whereas, M_2 and M_1 recorded significantly lower reduction of thrips damage.

It is evident from the result that, the mean per cent of thrips damage was significantly lowest in M_4 and M_3 IPM modules compared to other modules which may be because of presence of broad spectrum, cyazypyr. The results are in agreement with Wagh *et al.* (2017) who reported that novel insecticides (spinosad, emamectin benzoate) found effective even against sucking pests also.

In the present findings, next best module was M_5 which reduced thrips damage moderately followed by M_2 and M_1 which were less effective in controlling the thrips damage.

Considering these result, it can be recommended that modules like M_4 (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) and M_3 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) are most appropriate modules for lowering thrips damage to a moderate level. These modules contain egg parasitoid, diamide and spionosyns group of insecticides and kills the insects of both chewing and biting and sucking insect pests (Cordova *et al.*, 2006) from the fruit initiation to fruit development phase of the crop.

5.3.3 Impact of different IPM modules on natural enemies

Abundance of natural enemies *viz.*, coccinellids and spiders was assessed in different IPM modules. Among the different IPM modules, natural enemiey count from module 1 was about 0.61 per plant which was significantly superior over all other modules. The population of natural enemies was significantly highest in module 1 and module 2 (0.61 and 0.50%, respectively). The next safest modules were, M_5, M_3 and M_4 which recorded natural enemy population of 0.33, 0.31 and 0.25 per plant, respectively. These results are in conformity with the report of Singh *et al.* (2016) who reported that novel groups of insecticides could be efficiently incorporated into the integrated pest management (IPM) programmes because they are reasonably compatible with the natural enemies.

5.3.4 Performance of different IPM modules on fruit yield of pomegranate during *Hasta bahar*

Significantly highest fruit yield of 15.50 tonnes per ha was recorded in M_4 which was statistically at par with M_3 (14.05t/ha). Next best treatments in recording highest fruit yield were, M_5 (11.03t/ha) and M_2 (10.17t/ha) and were intern at par with each other. The M_1 (8.40 t/ha) was less effective and recorded lower fruit yield in the present study. These results are conformed with Singh (2015) who reported that use of *Trichogramma chilonis* Ishii along with chlorantraniliprol, cyazypyr and spinosad to record higher fruit yield (Fig. 5).

5.3.5 Economics of IPM management of fruit borer on pomegranate

The highest gross return was obtained from the M_4 (Rs. 12,40,000/ha). The next best module in terms of gross return was M_3 (Rs. 11,24,000/ha) followed by M_5 (Rs. 8,82,400/ha). While, M_1 and M_2 recorded less grass returns (Rs. 6,72,000 and 8,13,600/ha, respectively).

Net returns indicated that modules M_4, recorded highest net profit of Rs. 10,16,268 per ha, followed by, M_3 and M_5 which recorded net returns of Rs. 10,85,491 and Rs. 6,67,375 per ha, respectively.

Benefit cost ratio (BC ratio) was worked out for each module, in which M_4 provided highest BC ratio of 5.54. However, such ratio obtained in modules, M_3 and M_5 was 5.01 and 4.10, respectively. Relatively low B:C ratio of 3.77 and 3.11 was resulted in M_2 and M_1, respectively. So, release of *Trichogramma chilonis* (egg parasitoid) at weekly interval during flower initiation and fruit initiation periods followed by spraying of cyazypyr, rynaxypyr or spinosad during fruit development not only yield higher marketable fruits but also registered higher net returns. However, pomegranate being an export oriented crop, tolerate no deterioration in fruit quality. So, for harvesting quality marketable fruits and to obtain higher BC ratio, it is advisable to go for Chemi-intencive IPM module or Adoptable IPM modules.

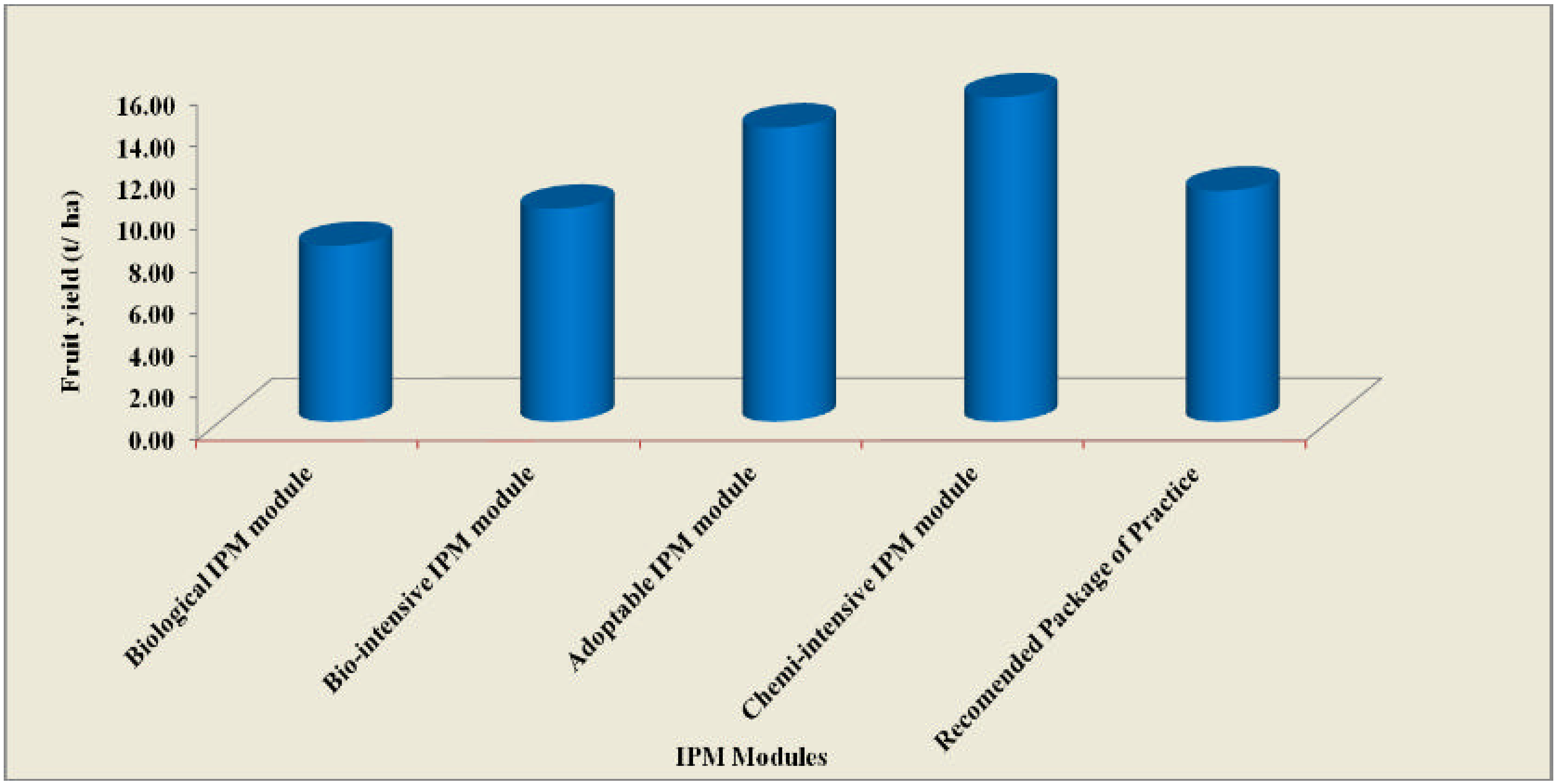


Fig. 5. Pomegranate fruit yield in different IPM modules during *Hasta bahar*, 2016-17

5.4 Future line of work

1. Study on bio-ecology of pomegranate fruit borer in different *bahars* in different agro-ecological regions.

2. Exploration of effective natural enemies associated with fruit borer and fruit sucking moth in pomegranate growing regions.

3. Development of semio-chemical based trapping technology for monitoring of fruit borer and fruit sucking moth incidence.

4. Standardization of repellent and oviposition deterrents for managing fruit borer and fruit sucking moth at early stage of infestation

6. SUMMARY AND CONCLUSIONS

The investigations on seasonal incidence and management of fruit borer, *Deudorix isocrates* Fab. (Lepidoptera: Lycaenidae) during *Hasta bahar*” on pomegranate were undertaken in Bagalkot during 2016-17. The results of the investigations are summarized in this chapter.

Seasonal incidence of pomegranate fruit borer from September 2016 to March 2017 on pomegranate under *Ambe* and *Hasta bahar* treatment revealed two peaks with major peak during September first week (60.10%) followed by first week of February (15.33%). Fruit borer infestation was declined during October to December (9.65 - 7.75%). Infestation of pomegranate fruit borer increased steadily further and reached its peak in the month of February, coinciding *Hasta bahar* crop. The peak occurrence of fruit borer was largely attributed to seasonal influence and fruit development stage rather than weather parameters.

Management of pomegranate fruit borer with spraying of rynaxypyr 18.5% SC @ 0.30 ml per l or cyazypyr 10.26 % OD @ 1.50 ml per l three times from fruit initiation to fruit maturity was most effective in reducing fruit borer, fruit sucking moth as well as thrips infestation on flower buds and fruits and considered moderately safer to the natural enemies.

Cyazypyr 10.26% OD @ 1.50 ml per l recorded significantly the highest fruit yield (12.16 t/ha) and lowest fruit borer damage of 2.51 per cent followed by rynaxypyr 18.5% SC @ 0.30 ml per l (10.76 t/ha and 2.07%, respectively). The next best treatments were emamectin benzoate 5% SG. @ 0.25 g per l and spinosad 45 SC @ 0.25 ml per l in terms of fruit yield (9.73 and 8.93 t/ha, respectively) and fruit damage (5.59 and 4.06%, respectively). Spraying of cyazypyr 10.26% OD @ 1.50 ml per l recorded highest net returns of Rs. 7,41,100 per ha followed by rynaxypyr 18.5% SC @ 0.30 ml (Rs. 6,38,865/ha) and emamectin benzoate 5% SG @ 0.25 g (Rs. 5,62,563/ha). In terms of benefit cost ratio, cyazypyr 10.26% OD @ 1.50 ml per l proved best (4.20) followed by rynaxypyr 18.5% SC @ 0.30 ml per l (3.88).

So, spraying of a green labeled anthranilic diamide insecticides, cyazypyr 10.26% OD @ 1.50 ml or rynaxypyr 18.5% SC may be recommended for the management of fruit borer on pomegranate to harvest higher quality fruits and better economic benefits.

Among the different IPM modules tested for management of pomegranate fruit borer, M_3 (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) and M_4- (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) were most effective in reducing fruit borer, fruit sucking moth and thrips infestation on flower buds and fruits and also considered moderately safer to the natural enemies.

Module M_4 - (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.5 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) recorded significantly highest fruit yield (15.50 t/ha) and lowest fruit borer damage 1.07 per cent followed by M_3 - (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits.) (14.05 t/ha and 1.00%, respectively). The next best IPM modules were, M_5- (Melathion 50% EC @ 2.00 ml/l – deltamethrin 25% EC @ 1.00 ml/l - azadirachtin 1500 ppm @ 5.00 ml/l- collection and destruction of affected fruits (RPP)) and M_2- (Release of *Trichogramma chilonis* @ 2.5 lakh/ha - azadirachtin 10000 ppm @ 1ml/l - *Bt* @ 1g/l - collection and destruction of affected fruits) in terms of fruit yield (11.03 and 10.17 t/ha, respectively) and fruit borer damage (2.42 and 2.30%, respectively). IPM module M_3 recorded highest net returns of Rs. 10,85,491 per ha followed by M_4 (Rs. 10,16,268/ha) and M_5 (Rs. 6,67,375/ha). However, in terms of benefit cost ratio, M_4 proved best (5.54) followed M_3 (5.01).

So, IPM modules with egg parasitoid, anthranilic diamide insecticide and spionosyns group of insecticides followed in Adoptable IPM module (M_3) or Chemi-intensive IPM module (M_4) may be recommended for the management of fruit borer on pomegranate to harvest higher yield, quality fruits and better economic benefits.

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Appendix I: Weekly Meteorological data recorded during experimental period from September 2016 to March 2017 (Bagalkot)

Month	Week	% fruit damage (Average)	Temperature		Relative humidity		Rain fall	
			Maximum	minimum	morning	evening	mm	days
September	1st	60.10	30.46	19.83	83.71	82.60	0.00	0.00
	2nd	14.22	25.86	19.70	84.00	80.00	24.1	2.00
	3rd	8.51	24.37	19.47	89.50	86.00	32.2	4.00
	4th	17.15	27.26	20.33	86.57	87.33	15.3	1.00
October	1st	9.32	30.49	20.00	86.57	80.00	0.00	0.00
	2nd	8.63	32.37	19.64	85.60	65.00	0.00	0.00
	3rd	8.00	32.23	16.89	84.20	73.29	0.00	0.00
	4th	8.00	31.89	17.03	87.60	71.00	0.00	0.00
November	1st	6.72	30.86	15.97	73.57	83.29	0.00	0.00
	2nd	5.96	30.71	12.23	64.14	80.50	0.00	0.00
	3rd	6.09	30.94	15.71	65.43	66.29	0.00	0.00
	4th	6.37	30.07	12.84	62.14	58.43	0.00	0.00
December	1st	6.47	30.91	15.97	75.86	81.00	0.00	0.00
	2nd	6.01	30.89	12.23	60.71	57.83	0.00	0.00
	3rd	5.99	29.94	15.71	63.71	78.57	0.00	0.00
	4th	5.37	31.26	12.84	57.57	76.57	0.00	0.00
January	1st	13.2	31.00	11.60	66.40	57.83	0.00	0.00
	2nd	10.04	30.89	12.00	60.71	78.57	0.00	0.00
	3rd	13.73	29.94	14.60	63.71	76.57	0.00	0.00
	4th	12.33	31.64	19.40	63.04	48.29	0.00	0.00
February	1st	15.33	33.54	18.16	55.06	83.29	0.00	0.00
	2nd	7.33	34.14	21.11	53.44	80.50	0.00	0.00
	3rd	7.07	34.27	23.34	41.49	66.29	0.00	0.00
	4th	9.91	36.36	25.10	29.30	68.43	0.00	0.00
March	1st	8.67	36.61	23.66	23.66	39.99	0.00	0.00
	2nd	12.00	35.71	22.79	22.79	44.46	33.29	2.00
	3rd	10.43	36.16	25.67	25.55	50.27	0.00	0.00
	4th	3.37	38.77	28.14	28.14	51.23	0.00	0.00

Appendix II: List of chemicals used in the experiment during *Hasta bahar*, 2016-17

Sl. No.	Chemical name	Formulation	Dosage (g or ml/l)	Trade name	Quantity of insecticides	Price (Rs.)
1	Cyazypyr	10.26 % OD	1.50 ml	Benevia 10.26% OD	240 ml	2400
2	Rynaxypyr	18.50% SC	0.30 ml	Coragen 18.5% SC	10 ml	193
3	Spinosad	45 SC	0.25 ml	Tracer 45 SC	75 ml	1260
4	Lambda cyhalotrin	4.90% CS	0.50 ml	Matador 4.90% CS	250 ml	1725
5	Emamectin benzoate	5% SG	0.25 g	Proclaim 50 SG	250 g	1725
6	Azadirachtin	10,000 ppm	1.00 ml	Neemgold 10000 ppm	1000 ml	1075
7	Quinalphos	25% EC	2.00 ml	Ekalux 25% EC	250 ml	160
8	*Bacilous thurengenicis*		1.00 g	Lipel $_{sp}$	250 g	375
9	Malathion	50% EC	2.00 ml	Malik 50% EC	1000 ml	405
10	Deltamethrin	25% EC	1.00 ml	Auzar 25% EC	500 ml	295
11	Azadirachtin	1500 ppm	5.00 ml	Neemraj 1500 ppm	1000 ml	210
12	*Trichogramma chilonis*					250/card

Appendix III: Abbreviations

@	: at the rate
DAS	: day after spray
DBS	: day before spray
EC	: emulsifiable concentrate
g	: gram
g/l	: gram per litre
l	: liter
ml	: milli litre
ml/l	: milli liter per litre
OD	: oil dispersion
ppm	: parts per million
S.D	: standard deviation
SC	: suspension concentrate
SL	: soluble concentrate
SP	: soluble powder
UTC	: untreated control
WDG	: water dispersible granule
WG	: water dispersible granule

STUDIES ON SEASONAL INCIDENCE AND MANAGEMENT OF POMEGRANATE FRUIT BORER, *Deudorix* (= *Virachola) isocrates* (Fab.) DURING *Hasta Bahar*

VANITHA K. **2017** **Dr. VENKATESHALU**
Major Advisor

ABSTRACT

The investigation on seasonal incidence and management of pomegranate fruit borer was conducted at the Department of Entomology, College of Horticulture, Bagalkot, Karnataka during the year 2016-17. Studies on incidence of fruit borer on pomegranate revealed two peaks with major peak during first week of September followed by first week of February.

Among the different new insecticides evaluated against fruit borer on pomegranate, cyazypyr 10.26% OD @ 1.50 ml per l recorded significantly highest fruit yield (12.16 t/ha) and lowest fruit borer damage of 2.51 per cent followed by rynaxypyr 18.5% SC @ 0.30 ml (10.76 t/ha and 2.07%, respectively). The next best treatments were emamectin benzoate 5% SG @ 0.25 g and spinosad 45 SC @ 0.25 ml. Spraying of cyazypyr 10.26% OD @ 1.50 ml recorded highest net returns of Rs. 7,41,100 per ha followed by rynaxypyr 18.5% SC @ 0.30 ml (Rs. 6,38,865/ha) and emamectin benzoate 5% SG @ 0.25 g (Rs. 5,62,563/ha). In terms of benefit cost ratio, cyazypyr 10.26% OD @ 1.50 ml proved best (4.20) followed by rynaxypyr 18.5% SC @ 0.30 ml (3.88).

Among the five IPM modules formulated and evaluated against fruit borer on pomegranate, M_4 - (Emamectin benzoate 5% SG @ 0.25 g/l – cyazypyr 10.26% OD @ 1.5 ml/l – spinosad 45 SC @ 0.25 ml/l - collection and destruction of affected fruits) recorded significantly highest fruit yield (15.50 t/ha) and lowest fruit borer damage (1.07 %) followed by M_3 - (Release of *Trichogramma chilonis* @ 2.5 lakh/ha – cyazypyr 10.26% OD @ 1.50 ml/l – spinosad 45 SC @ 0.25 ml/l – collection and destruction of affected fruits) (14.05 t/ha and 1.00 %, respectively). IPM module M_3 recorded highest net returns of Rs. 10,85,491 per ha followed by M_4 (Rs. 10,16,268/ha). So, adoptable IPM module, M_3 has proved effective and can be recommended for pomegranate to reduce fruit borer damage and safer to natural enemies and for higher net profit during *Hasta bahar.*

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¸ªÄUæ QÃl ¤ªðºu ªiÁzjU¼° JA-4 (JªÄªÄQ£ï ¨AeÆAiÄÃmï 5% (0.25 UÁæ/°Ã) - ¸ghÆ¦gï 10.26% Nr (1.50 «Ä. °Ã. /°Ã - ¸ö£Æ¸qï 45 J¸ï. ¹. (0.25 «Ä. °Ã. /°Ã) - ¨Á¢v ºtÄU¼£Äß ¸AUæ¹ £Á±ªiÁqÄªÁzÄ) UªÄ£ÁºðªÁV Cv¢P ºt£ E¼Äªj (15.50 l£ï/º) ªÄvÄ PrªÄ ºt£ PÆgAiÄÄ«P (1.07%) ºÆA¢zÄ JA. 3 (mæÄPÆUÁæÄ a¯Æ¤¸ï ©qÄUq (2.5 ®P/º) - ¸ghÆ¦gï 10.26% Nr (1.5 «Ä. °Ã. /°Ã - ¸ö£Æ¸qï 45 J¸ï. ¹. (0.25 «Ä. °Ã. /°Ã) - ¦Ãrv ºtÄU¼ ¸AUæ ªÄvÄ £Á±) PæÄªÁV ºPÃjU 14.05 l£ï E¼Äªj ªÄvÄ ±Ã.1.00 QÃl¨Áz ºÆA¢zÄ £Avg ¸Á£z°z. DzjAz C¼ªr¸§ºÄzÁz ¸ªÄUæl ¤ªðºu ªiÁzj (JA3) AiÄ° ºtÄ PÆgAiÄÄª ºÁ¤ PrªÄEzÄ ªÄvÄ £¸VðP ±vÄæ½U ¸ÄgQvªÁVqÄªÁz£Äß vÆÃj¹z ªÄvÄ ºa£ ¤ª¼ ¯Á¨ª£Äß º¸ ¨Áºgï£ CrAiÄ° ¨¼z zÁ½A¨AiÄ° ¥qAiÄ§ºÄzÁVzÄ Ez£Äß ²¥Ág¸Ä ªiÁq§ºÄzÄ.