

**BIOLOGY OF *Cryptolaemus montrouzieri* Mulsant AND
MANAGEMENT OF GRAPEVINE MEALYBUG,
Maconellicoccus hirsutus (Green)**

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INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the most important commercial fruit crops of sub-tropical, tropical and temperate regions of the world. The prevailing sub-tropical and tropical climatic condition of India, is well suited for higher sucrose level and berry yield. It is widely grown in China, Italy, United States, Africa, Australia, Algeria and India, where India stands in ninth position by sharing 3.31 per cent of world's production (Anon., 2010). Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Punjab, Madhya Pradesh and Haryana are the major grape growing states in India. Grape is being grown as economically important and job providing commodity in the states of Maharashtra, Andhra Pradesh and Karnataka.

The area under grape is constantly increasing year after year in India due to its prolific yield, export potential and good returns, which aroused considerable interest among the cultivators for its cultivation in large area. At present, in India grapes are cultivated in an area of 1,11,400 ha with a production of 12.35 lakh tones annually (Anon., 2011). Maharashtra state stands first with 86,000 hectares followed by Karnataka having 18,100 ha with an annual production of 7.74 and 3.30 lakh tonnes, respectively. Bengaluru, Bagalkot, Bijapur, Belgaum, Kolar and Gulbarga districts are the major grape growing areas in Karnataka (Anon., 2006a).

The fresh and dried fruits are having importance in Ayurvedic and Unani medicine because of its laxative, stomachic, diuretic and cooling characters. Apart from these, fresh fruits contain good amount of sugars, carbohydrates, vitamins, proteins and minerals. Fruits are being used for the purpose of raw consumption, preparation of wine, juice, raisins and canning. The juice of unripe berries is used as an astringent for treating throat infections.

Grape is an important crop fetching valuable foreign currency for the country and it can be reached only by maintaining the international qualitative and quantitative standards. The major constraints to achieve these international standards are pests and pesticide residues.

The importance of this fruit crop created interest in the cultivators to go for extensive and intensive cultivation of grapes, which tend to attract various kinds of insect pests to the vineyards (Alexandri, 1973). As many as 132 insect pests are recorded on grapevine in the world as documented by Bournier (1977), whereas Wadhi and Batra (1964) listed 60 species of insects and few mites damaging grapevines and over 85 species of insect pests are known to occur on grapes in India as per the reports of Butani (1979). Balikai and Kotikal (2003) recorded 26 pests infesting grapevines in northern Karnataka. Out of these, two insects viz., flea beetle, *Sceledonta strigicollis* Mots. and mealybug, *Maconellicoccus hirsutus* (Green) were recorded as major pests on this crop.

A total of 20 species of mealybugs have been reported on grapevine in the world, but only six species have been reported from different states in India (Babu and Azam, 1987a). Among them the most devastating species in India is unquestionably the grape mealybug, *M. hirsutus*. Its first occurrence on grapevine was reported by Fletcher (1919). Severe outbreak of mealybugs was reported during 1974 in Andhra Pradesh by Tejkumar *et al.* (1977) and subsequently in several other places. Babu and Azam (1989) reported grapevine mealybug, *M. hirsutus* as a serious vineyard pest in India. Occasionally, it causes havoc in citrus, custard apple, guava, mango, mulberry gardens and ornamentals like *Hibiscus*. The infestation is becoming more severe year after year. In case of severe mealybug infestation in the nursery, young vines are often killed. In case of severe attack in main field, up to 90 per cent clusters are damaged. When vines are pruned, the mealybug attacks tender developing sprouts causing stunted growth. Malformation of growing shoots and leaves occurs due to its feeding and sticky honeydew excreted by mealybug predisposes mould growth (*Capnodium* sp.). Heavily infested clusters shrivel and drop or become sticky and unfit for consumption and raisin making. The quality of wine is also affected when prepared from mealybug infested bunches. Azam (1983) reported that the losses are more conspicuous subsequent to winter pruning (78%) than after summer pruning (58%).

Lower (1968) described the mealybug as "hard to kill pest of fruit trees". Perhaps the most important factor is the habitat of the mealybug. Mealybugs live in protected areas such as cracks and crevices of bark, at the base of leaf petioles, on the under side of the leaves and also inside the grape bunches. Eggs of the mealybugs which are protected by waxy filaments, are almost impossible to be penetrated with insecticidal sprays. Late instar nymphs and adult female mealybugs are not affected by foliar application of insecticides since they are also covered with waxy coating (McKenzie, 1967).

Mani *et al.* (1987) reported six parasitoids and seven predators of the mealybugs. In fact, insecticidal sprays have direct adverse effect on the natural enemy population of the pest resulting in resurgence of the pest. The recommended chemical pesticides alone, are not only unable to check the infestation satisfactorily, but also create the problem of hazardous levels of residues and thereby hamper export potential of the grape fruits.

Various pesticides have been tried either singly or in combinations for the control of this pest (Anon., 1995). Few of them are only temporarily effective. They kill only those mealybugs that are exposed, those sheltering in the crevices of the bark and inside bunches escape and quickly rebuild their population and cause serious damage (Manjunath, 1985). Even when effective chemicals are available, the extensive host range of the pest afford them facilities for taking shelter on wild hosts while such measures are instituted and reinfesting the field later. The grape mealybug has also become serious on account of indiscriminate use of pesticides. The natural enemies are usually present in crop ecosystem, but their effectiveness is impaired by excessive use of pesticides. But the crawler stage is the most fragile and easily controllable stage. Recently some organophosphates, insect growth regulators (IGRs) and bio-pesticides have been recommended for the management of mealybug (Suresh *et al.*, 2010).

The Australian ladybird beetle, *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) is a general predator of wide range of mealybugs at all the stage of development. It is commonly referred as mealybug destroyer. It has been employed as the possible solution for combating the menace of the pest around the world. It is native of Australia and was introduced into India during 1898 in an attempt to control coffee green scale by H.O. Newport (Mayne, 1953). Though the predator did not establish on green scale, it was responsible to check mealybug in coffee growing zones (Chacko *et al.*, 1978). The biological suppression of mealybugs through this potent predator in India has been well documented (Rao *et al.*, 1971; Babu and Azam, 1989; Mani *et al.*, 1995; Srinivasan and Sundara Babu, 1989; Mani and Krishnamoorthy, 1990). In California, *C. montrouzieri* has been proved effective as evidenced from the study of Smith and Armitage (1920) who succeeded in keeping under check the destructive mealybugs by large scale multiplication. The mass multiplication and periodic release of this predator against various mealybug pests of citrus has been in vogue for the last century.

Therefore, it is necessary to understand the status of grape mealybug with respect to its seasonal fluctuation along with its natural enemies. The studies on life history and feeding potential of predator, *C. montrouzieri* on different stages of mealybugs are also essential. Evaluation of new and safer molecules, conventional pesticides and biopesticides along with various adjuvants against mealybug is necessary to coin eco-friendly management tactics. Keeping the above points in view, the detailed investigations on mealybug were undertaken with the following objectives:

1. Biology and predatory potential of coccinellid, *C. montrouzieri* on grapevine mealybug, *M. hirsutus*
2. Seasonal incidence of grapevine mealybug, *M. hirsutus* and its natural enemies and correlation with weather parameters for the development of prediction models.
3. Evaluation of biorationals and newer insecticides along with different adjuvants against grapevine mealybug under laboratory condition.
4. Evaluation of promising treatments (from laboratory studies) for the management of grapevine mealybug under field condition.

REVIEW OF LITERATURE

Grape mealybug, *Maconellicoccus hirsutus* (Green) has recently become most serious pest of vineyards in India. Since 1989 the pest has assumed serious form on grapevine in Bijapur district of Karnataka (Hiremath *et al.*, 1990). In the context of earlier studies and the published literature pertaining to the bionomics of mealybugs, economic status, seasonal incidence, biology and management with respect to mealybug is reviewed and presented below indicating the important research findings about the pest.

2.1 Biology and predatory potential of *Cryptolaemus montrouzieri* on grape vine mealybug

Biology and habits of the coccinellid predator has been studied by several workers (Van der Goot, 1920; Hall, 1926; Bishop, 1931; Rao and David, 1958; Fisher, 1963; Liotta and Mineo, 1965; Mineo, 1967 and Bhat *et al.*, 1981).

2.1.1 Pre-mating period

Rao and David (1958) reported that pre-mating period ranged between 8 to 11 days. Liotta and Mineo (1965) noticed the pre-mating period of 1 to 2 days. While, it was observed as 3 to 4 days at temperature of 25 °C (Mineo, 1967). Bhat *et al.* (1981) recorded pre-mating period of 6.2 days while, Mani (1986) studied biology of *C. montrouzieri* and recorded pre-mating period between 5 to 17 days and 3 to 10 days was observed by Shekhar (2001). Gosalwad *et al.* (2009) found that the incubation period of *C. montrouzieri* was 4.78 and 4.88 on *M. hirsutus* and *P. solenopsis*, respectively. Solangi *et al.* (2012) reported that, in laboratory condition, the pre-mating, pre-oviposition and oviposition period of *C. montrouzieri* was 5.6±0.08, 9.9±0.19 and 76.4±1.30 days, respectively.

2.1.2 Pre-oviposition period

According to Rao and David (1958) the pre-oviposition period ranged between 9 to 13 days. Bhat *et al.* (1981) observed it as 14 to 15 days.

Gokuldas Kumar and Vijayalaxmi (1986) recorded pre-oviposition period as 6.0 to 7.8 days while, Babu and Azam (1987b) found it to be 9.6 days at a temperature of 20°C, whereas Shekhar (2001) recorded the same as 4 to 10 days. About five days are required at the beginning for egg laying after the emergence of adults (Anon., 2006b). Gosalwad *et al.* (2009) reported that the pre-oviposition period of *C. montrouzieri* was 7.90 and 9.00 on *M. hirsutus* and *P. solenopsis*, respectively.

2.1.3 Oviposition period

Oviposition of *C. montrouzieri* was reported to extend up to 93 days in one case with an average of 75 days (Rao and David, 1958). However, the oviposition period reported by Bhat *et al.* (1981) and Mani (1986) was 47.91 and 42.50 days, respectively. Merlin *et al.* (1996) studied the ovipositional behaviour of *C. montrouzieri* under laboratory conditions. The results showed that the females delayed oviposition and withheld mature eggs in their lateral oviducts in absence of wax filament produced by the prey. Shekhar (2001) reported the ovipositional period of 52 to 84 days with an average of 69.4 days. While, Anil and Jeevan (2008) reported ovipositional period of 54 to 83 days in the adults feeding on mealybug, *M. hirsutus*. Gosalwad *et al.* (2009) reported that the oviposition period of *C. montrouzieri* was 67.10 and 68.00 on *M. hirsutus* and *P. solenopsis*, respectively.

2.1.4 Incubation period and hatching percentage

Hall (1927) reported the incubation period of 3 to 4 days while, Bishop (1931) reported it to last for 8 to 10 days. Rao and David (1958) observed incubation period in the range of 2-4 days. While studying the biology of *C. montrouzieri*, Mani (1986) reported it for 4 to 5 days. The eggs laid among the cottony egg masses of mealybug required 5-6 days for hatching at 27°C (Anon., 2006b). Similarly, Solangi *et al.* (2012) reported the incubation period of 5.3±0.07 days.

According to Babu and Azam (1987b) higher temperature shortened the incubation period and it was 52 per cent longer at 20°C (6.2 days) than at 30°C (3.0 days). The egg viability in *C. montrouzieri* as reported by Mineo (1967) was 97 per cent while, Bhat *et al.* (1981) found it to be 100 per cent. Anil and Jeevan (2008) studied on the life history of *C. montrouzieri* on grapevine mealybug, *M. hirsutus*, having incubation period of 3 to 7 days.

Gosalwad *et al.* (2009) reported that the incubation period of *C. montrouzieri* on two species of mealybugs (*M. hirsutus* and *P. solenopsis*) was 4.78 and 4.88 days, respectively.

2.1.5 Grub development

Van der Goot (1920) studied the biology of *C. montrouzieri* in Jawa and documented that the grub period ranged from 13 to 23 days with an average of 20 days. According to Bishop (1931) the grub development was completed within 8 to 10 days. Rao and David (1958) suggested that the temperature range of 24 to 29°C was favourable for rearing *C. montrouzieri* and they noted the developmental period of 14 to 16 days for grubs. The studies made by Liotta and Mineo (1965) and Bhat *et al.* (1981) on biology of *C. montrouzieri* when reared on *M. hirsutus*, revealed that the grub completed its developmental period within 14 to 17 and 18 to 21 days, respectively.

The grub of the predator had four instars in their life and the duration of first, second, third and fourth instars were 3 to 4, 4, 4 to 5 and 7 to 8 days, respectively as reported by Bhat *et al.* (1981). Mani (1986) noted that the total grub development was 13 to 16 days.

Babu and Azam (1987b) studied the effect of temperature on the development of grubs of *C. montrouzieri* and reported that the duration of 1st, 2nd, 3rd and 4th instars occupied 2.7, 3.5, 4.1 and 5.5 days at temperature of 30°C and 6.2, 7.0, 13.5 and 17.7 days at temperature of 20°C, respectively. Whereas, the duration of each instar was reported as 8.90, 4.05, 5.25 and 9.45 days, respectively and grub completed its development in 27.20 days when fed on eggs of mango mealybug, *Rastrococcus iceryoides* (Green) (Anon., 1994).

According to Shekhar (2001) the duration of each instar was 5.8, 3.5, 5.4 and 6.8 days, respectively and average grub development duration was 21.5 days. The *C. montrouzieri* required 31 and 45 days to complete their life cycle at 27 and 21°C, respectively (Anon., 2006b). Having larval period of 12-27 days it consumed around 250 mealybugs. Anil and Jeevan (2008) reported that the duration of the first, second, third and fourth instar grubs were 4 to 7, 3 to 5, 5 to 10 and 7 to 11 days, respectively.

Gosalwad *et al.* (2009) conducted study on biology of *C. montrouzieri* on two species of mealybug indicated that the duration of I, II, III and IV instar was 5.14, 3.88, 6.84, 8.04 and 5.52, 4.58, 7.42, 8.20 days on *M. hirsutus* and *P. solenopsis*, respectively.

Solangi *et al.* (2012) reported that, the mean developmental period for the 1st, 2nd, 3rd and 4th instars of *C. montrouzieri* were 5.9±0.15, 5.0±0.16, 7.0±0.18 and 8.3±0.13 days, respectively, with total larval development of 26.2±0.61 days.

2.1.6 Pre-pupal period

The results of the biology studies conducted by Bhat *et al.* (1981), Murthy and Narayana (1986a) and Anil and Jeevan (2008) revealed the pre-pupal period of 3 to 4, 1 to 2 and 2 to 3 days, respectively.

2.1.7 Pupal period

The studies were made on biology of *C. montrouzieri* by Van der Goot (1920), Hall (1926), Bishop (1931), Rao and David (1958), Liotta and Mineo (1965), Bhat *et al.* (1981), Mani (1986), Shekhar (2001), Anon. (2006a) and Anil and Jeevan (2008) and reported that the pupal period of *C. montrouzieri* ranged from 6 to 9, 6 to 9, 14 to 20, 7 to 8, 6 to 13, 7 to 8, 7 to 9, 7 to 11, 7 to 10 and 6 to 10 days, respectively. Babu and Azam (1987b) reported it to be 6.2 and 14.3 days at constant temperatures of 30 and 20°C, respectively.

Gosalwad *et al.* (2009) reported that the pre-pupal and pupal duration of 2.80 and 2.96 and 8.08 and 8.28 days were recorded by *C. montrouzieri* on *M. hirsutus* and *P. solenopsis*, respectively. Solangi *et al.* (2012) reported that, the mean pre-pupal and pupal periods were 2.9±0.07 and 8.5±0.2 days, respectively. Total development period from egg to adult was 42.9±0.95 days.

2.1.8 Total developmental period

According to Van der Goot (1920), Hall (1926), Bishop (1931), Rao and David (1958), the development of *C. montrouzieri* from egg to adult emergence was completed in 22 to 35, 21 to 35, 32 to 36 and 24 to 28 days, respectively.

Fisher (1963) attempted mass multiplication of *C. montrouzieri* and found that the development from egg to adult was completed in 43 to 47 days at 21 °C and 28 to 29 days at 26.7 °C

with 60 per cent relative humidity. Liotta and Mineo (1965) and Bhat *et al.* (1981) reported that, the total developmental period occupied 22 to 27 and 33 to 39 days, respectively.

Babu and Azam (1987a) observed that, when the predator was subjected to controlled conditions of temperature, there was extension in life cycle (65.1 days) at lower temperature of 20°C than higher temperature of 30°C (25.2 days). Srinivasan (1994) attempted the mass multiplication of *C. montrouzieri* and found that the development from egg to adult was 30 days.

2.1.9 Fecundity

Studies conducted by Van der Goot (1920), Rao and David (1958), Fisher (1963), Liotta and Mineo (1965), Mineo (1967) and Satyanarayanamurthy (1982) indicated that, the fecundity was 64 to 176, 207, 194 to 729, 90 to 100, 60 to 120 and 89.93 eggs, respectively.

Bhat *et al.* (1981) noted fecundity in the range of 85 to 336 eggs with an average of 164.1 eggs, when reared on mealybugs plus honey sugar. While 66 to 367 eggs with an average of 229.2 eggs when reared on mealybug alone.

Gokuldas Kumar and Vijayalaxmi (1986) observed that the mean total fecundity of the beetle was significantly high when *P. citri* was the prey and ranged from 864 to 1235 eggs with an average of 1062.6 eggs.

Shirke and Salunkhe (1996) reported that the fecundity of *C. montrouzieri* was greater when fed on *M. hirsutus* alone than when honey sugar added to it. It was reported that each female laid 5-10 eggs per day, a total of 400-500 eggs in their 50 days life time (Anon., 2006b).

Gosalwad *et al.* (2009) reported that the fecundity of *C. montrouzieri* on two species of mealybug was 478.20 and 460.42 on *M. hirsutus* and *P. solenopsis*, respectively. Solangi *et al.* (2012) reported that, the fecundity of 486.9 ± 1.417 per female.

2.1.10 Adult longevity

Rao and David (1958) indicated that males survived for 52.5 days and reached maximum of 65 days while female survived for 80.2 days with a maximum of 105 days. Whereas, Liotta and Mineo (1965) reported the adult longevity of 60 days for both male and females.

According to Bhat *et al.* (1981) males lived for 61 to 97 days with an average of 75.3 days and female lived for 61 to 92 days with an average of 67.9 days, when reared on grape vine mealybugs only.

Babu and Azam (1987b) studied the effect of temperature on *C. montrouzieri* and concluded that the adult longevity of the predator was maximum when maintained at 20°C. The longevity drastically reduced at both the extreme temperatures of 10 and 40°C. However, the higher temperature proved to be more detrimental. Further, it was concluded that the longevity of female appeared to be slightly more than that of male irrespective of the temperature. Shirke and Salunkhe (1996) reported that the longevity of *C. montrouzieri* was greater when reared on *M. hirsutus* alone than on honey sugar. Anil and Jeevan (2008) reported that, the males and females lived for 69.7 and 74.7 days, respectively, when reared on *M. hirsutus*.

Gosalwad *et al.* (2009) conducted study on biology of *C. montrouzieri* on two species of mealybug and indicated that the adult longevity of female and male was 77.44 and 72.38 days on *M. hirsutus* and 80.49 and 78.44 days on *P. solenopsis*. Solangi *et al.* (2012) reported that, the mean longevities for male and female adults were 80.9 ± 0.89 and 84.4 ± 0.9 days, respectively.

2.1.11 Feeding potential of *Cryptolaemus montrouzieri*

Whitecomb (1940) studied on biological control of mealybugs with *C. montrouzieri* in green house and reported that on an average one grub fed about 1325 eggs of *P. citri* equivalent of three to four egg masses during its life cycle. Mineo (1967) reported that each grub consumed 1450 eggs and 650 first instar nymphs, whereas each adult consumed 220 eggs.

According to Oncuer and Baylan (1982) an individual fourth instar grub consumed on an average of 3330.6 eggs of *P. citri* in Turki. Satyanarayanamurthy (1982) reported that a single fourth instar grub consumed 188.2 eggs of *M. hirsutus* or 157.0 eggs of *P. citri*.

Murthy and Narayana (1986a) studied the feeding behaviour of *C. montrouzieri* and stated that both grubs and adults fed extensively on all stages of mealybugs and also on the eggs and

crawlers of some scale insects. However, grubs were found more voracious feeders. They further observed that the mean number of eggs consumed by each instar grubs (first to fourth) was progressively high. According to Mani and Thontadarya (1987a) a single grub consumed on an average 881.30 eggs or 239 nymphs or 27.5 adult females of *M. hirsutus*.

The results of the studies made on feeding potential of *C. montrouzieri* revealed that a grub of predatory beetle consumed 100.5 nymphs of *F. virgata* in 17.3 days while the grub consumed 3766 eggs of *Chloropulvinaria psidii* (Maskell) during its developmental period of 17.60 days (Anon., 1988).

Babu and Azam (1988) studied predatory potential of *C. montrouzieri* and found that the first, second, third and fourth instar grubs of *C. montrouzieri* consumed daily 18.6, 49.5, 1420 and 1886 eggs or 6.9, 42.1, 140.1 and 354.7 nymphs of *M. hirsutus* at 25 °C, respectively. The female adult consumed more eggs (305.1) and crawlers (181.7) of *M. hirsutus*, than that of the male (258.3 eggs and 165.9 crawlers).

The predatory potential of adults of coccinellids, *C. montrouzieri* and *S. coccivora* on eggs, nymphs and adults of pseudococcids, *P. citri* and *M. hirsutus* was assessed in the laboratory at 27.7-30.5°C and 57-93 per cent relative humidity. The feedings rate of *C. montrouzieri* was higher than that of *S. coccivora* for all prey stages. Females of *C. montrouzieri* consumed more of all stages of the prey during their life span than males and the predation rate of both sexes was higher compared to *S. coccivora* (Jayaraman *et al.*, 1988).

Srinivasan and Sundara Babu (1989) evaluated the activity of the coccinellid predator, *C. montrouzieri* against grape mealybug. The maximum effect of the predator was observed at six weeks after the initial release with 64.3 per cent control of the pseudococcid population when predators were released @ 10 grubs per vine.

The number of mealybug eggs consumed by the first, second, third and fourth instar grubs of *C. montrouzieri* averaged 7.14, 80, 138.45 and 190.10, respectively. Further, single predatory grub consumed 497.75 mealybug nymphs of 10 to 15 days old during the development. The fourth instar grub was more voracious feeder than the earlier instar grubs. The male predator consumed comparatively less number of mealybug eggs than the female predator (Anon., 1994).

Gosalwad *et al.* (2009) reported that the predatory grub consumed on an average 752.60 eggs with 242.00 nymphs of *M. hirsutus* and 742.80 eggs with 222.80 nymphs of *P. solenopsis*. Adult female consumed 4355.00 eggs along with 241.20 nymphs and 4340.20 eggs along with 235.20 nymphs of the above two mealybug species, respectively. While male beetle devoured 3586.00 eggs along with 149.60 nymphs and 3519.20 eggs along with 148.00 nymphs of *M. hirsutus* and *P. solenopsis*, respectively.

Kour and Virk (2011) reported that fourth instar grub and adults of *C. montrouzieri* were the most voracious feeders on different instars of mealybug. The number of 1st, 2nd and 3rd instar nymphs of mealybug, *P. solenopsis* that were consumed by of 1st, 2nd, 3rd and 4th instar grubs and adult beetles of *C. montrouzieri* were 15.56, 11.15 and 1.80; 41.01, 26.35 and 6.36; 125.38, 73.66 and 13.32; 162.69, 76.04 and 21.16 and 1613.81, 787.95 and 114.66, respectively.

Mishra *et al.* (2012) reported that, the first, second, third and fourth instar grubs of *C. montrouzieri* consumed 18.2, 51.3, 140 and 190.7 eggs and 6.4, 45.2, 139.3 and 352.6 crawlers per day.

Khan *et al.* (2012a) carried out studies on predatory potential of *C. carnea* and *C. montrouzieri* in no choice (only first, second or third instar mealybug, *P. solenopsis* were offered at a time) and choice (first, second and third instar were offered simultaneously) feeding tests. They recorded highest feeding potential of *C. montrouzieri* on all the stages of mealybugs supplied as compared to *C. carnea*. The consumption rate of first, second and third instar mealybug by *C. montrouzieri* larvae was highest in no choice-feeding test. However, the first instar mealybugs are more preferred for feeding than older instars by *C. montrouzieri* but the larval duration extended when predator fed on older instar mealybugs.

2.2 Seasonal incidence of grapevine mealybug and its natural enemies and development of prediction models

2.2.1 Record and distribution of the pest

Maconellicoccus hirsutus was first recorded by Green (1908) from an undisturbed shrub. It is distributed in Oriental and Australian (Green, 1908), Palearctic (Hall, 1921) and Ethiopian (Bedford, 1935) zoogeographical realms. The destructive nature of the pest from West Bengal was first revealed by Misra (1919) who established it as the causal organism of 'tukra' disease of mulberry plants. Hall (1921a) reported its outbreak on a large number of species in Egypt. The first record of the pest on grapevine in India was made by Manjunath (1985). Ranga Reddy and Lakshminarayana (1987) reported *M. hirsutus* as a new pest of grape in Hyderabad provinces.

2.2.2 Mealybug species on grapevine and their status

A total of 20 species of mealybugs have been reported to occur on grapevine in the world, but only six species have been reported from different states in India (Table 1).

2.2.3 Seasonal incidence of mealybugs

Maconellicoccus (= *Phenacoccus*) *hirsutus* (Green) was first reported on grapevine by Fletcher (1919). Fletcher (1919) reported that *M. hirsutus* had ten generations per year in India. In the Mediterranean climate of Egypt, it hibernated in the egg stage (Hall 1921a). The incidence of *Ferrisia virgata* (Ckll.) has been reported to be more severe during dry season or prolonged period of drought (Ramchandra Rao, 1926). Tejkumar *et al.* (1977) observed severe incidence of grape mealybug, *Pseudococcus* sp. for the first time in the vine yards around Hyderabad. The mealybug causing severe damage to grapevine in Andhra Pradesh was later identified as *M. hirsutus* (Anon., 1982). According to Azam (1983), the incidence of *M. hirsutus* resulted in yield losses of 50 to 100 per cent. Serious outbreaks of *M. hirsutus* in some parts of Karnataka and Andhra Pradesh have also been reported by Manjunath (1985).

Das *et al.* (1948) observed high build-up of *F. virgata* during July- August on jute while on garden land in fruit crops during winter and early spring in Dacca. The mealybug was observed to be the most active and numerous during August-November, 1965 and March-April, 1966. Mainly adult females were found during December 1965 as well as January, May and June, 1966 in Madhya Pradesh (Rawat and Modi, 1969). In India, Singh and Ghosh (1970) studied the seasonal activity of *M. hirsutus* on mesta. Under outdoor conditions, the mealybug over-wintered in overlapping stages in the capsules of mesta beneath the persistent calyx and epicalyx of the old and dried plants and also in the soil during December and January, when food plants were not available. But the breeding of the pest was

uninterrupted even in the cooler months provided young mesta plants were available. Under natural conditions, however, the activity of the mealybug was observed from the month of March. The peak infestation was usually noted from the first week of September to the last week of October. Ghose (1972) was of the opinion that *M. hirsutus* was active during winter also, without hibernation but was most active during March-October on roselle around West Bengal.

Azam (1983) found that the active period of *M. hirsutus* was during June-August and October-March on grapes around Hyderabad. Manjunath (1985) reported serious outbreak of mealybug on grapevine in parts of Bangalore, Tumkur and Bangarpet in Karnataka. The pest was present throughout the year, there being peak period of infestation during February-March and to a lesser extent during October-November. Different grape varieties were attacked including Thompson Seedless, Anab-e-Shahi and Bangalore Blue.

Babu and Azam (1987b) surveyed the population density of grape mealybug, *M. hirsutus* around Hyderabad during 1984-85. The pest was found infesting the vegetative parts of the crop from early June (1.7 female adults/twig) to the end of December (5.1 female adults/twig). During first fortnight of September to second fortnight of October the female adult population decreased largely due to pruning operation. The mealybug again became active during January (22.5 female adults / bunch) and increased as the grape cluster developed and was abundant by March (32.5 female adults /bunch) when the fruits were ripening.

Table 1. Mealybug species on grapevine in India

Sl. No.	Mealybug species	State	Status	Reference
1.	<i>Maconellicoccus hirsutus</i> (Green) = <i>Phenacoccus hirsutus</i> (Green) = <i>Pseudococcus</i> sp.	Karnataka Karnataka Maharashtra Tamil Nadu Andhra Pradesh New Delhi Andhra Pradesh	Major Major Major Major Major Major Major	Manjunath (1985), Mani and Thontadarya (1987a) Hiremath <i>et al.</i> (1990); Balikai and Bagali (2000) Balikai and Kotikal (2003) Mani (1989) Mani (1989) Murthy and Babu (1996) Fletcher (1923) Tejkumar <i>et al.</i> (1977)
2.	<i>Dysmicoccus brevipes</i> (Ckll.)	Karnataka	Major	Mani and Thontadarya (1987a)
3.	<i>Nipaecoccus viridis</i> (Newstead) = <i>Pseudococcus filamentosus</i> (Ckll.) = <i>Nipaecoccus vastator</i> (Maskell)	Punjab New Delhi	Minor Minor	Anon. (1946) Subba Rao <i>et al.</i> (1965)
4.	<i>Ferrisia virgata</i> (Ckll.)	Tamil Nadu	Major	Raman (1958)
5.	<i>Planococcus</i> sp. nr. <i>robustus</i>	Karnataka	Minor	Puttarudraiah and Murthy (1976)
6.	<i>Planococcus citri</i> (Risso)	Karnataka	Major	Mani and Thontadarya (1987a)

Mani and Thontadarya (1987b) reported that, the population of the mealybug, *M. hirsutus* was found to be heavy from January to May and low from June to December in vineyards of south India. Maximum temperature showed positive and significant correlation with the mealybug population, while the relative humidity showed negative correlation.

Shreedharan *et al.* (1989) reported that the mealybug, *P. citri* was severe in summer season (March-July) and no incidence in winter season (October - November) in Mandarin orange (*Citrus reticulata* Blaw). They also studied the association with weather factors and found that the population of mealybug was positively correlated with the temperature, negatively with relative humidity, while it had no clear correlation with total rainfall.

During the survey of the pests of grapevine gardens at Arvi-Pimpalgaon of Pune district (Maharashtra) in 1991-92, it was observed that, the mealybug population was maximum from middle of February to May and middle of September to middle of November. The pest was found to be inactive from middle of November to middle of February (Anon., 1992).

The population growth pattern of the Pseudococcid, *Phenacoccus manihoti* Mat.-Ferr. was studied over two population cycles in cassava fields during 1985-87 in Freetown, Sierra Leone. The number and rate of dispersal of the insects were higher and the damage was more severe in dry season than in rainy season. During the rainy season, the pest population consisted of mainly adults. Although rain was an important known abiotic natural control factor for the pest, the decline in the insect number started before the rainy season (James and Fofanah, 1992).

Field studies were carried out during 1995-96 in Andhra Pradesh, India to investigate fluctuation in *M. hirsutus* populations in grapes and *Annona reticulata* (L.). The greatest populations were found in grapes during the first half of July (vegetative phase) and during the second half of March (reproductive phase) and in *A. reticulata* during June (Murthy and Babu, 1996). Studies were carried out to determine the seasonal dynamics and damage potential of subterranean mealybug, *Rhizoecus kondonis* (Kuwana) to lucerne. It completed three generations per year with peak abundance during July-August, December-January and March-April months (Godfrey and Pickel, 1998).

Seasonal incidence of *M. hirsutus* on Thompson Seedless grape was studied in farmers field at Tikota village, near Bijapur (Karnataka) during 1990-92. Mealybug was recorded throughout the year. Following pruning in October, the mealybug population started to increase from January and peaked during February-March before harvesting. After harvesting, the mealybug population remained low from May to December (Balikai, 1999a).

Balikai and Bagali (2000) carried out studies in Bijapur, Karnataka, India during 1998 to assess the population density of *M. hirsutus* on ber and economic losses sustained. On an average there were 80.6 colonies per plant, each colony having 17.8 individuals. Similarly, 15.4 egg masses covered with white waxy mealy matter were observed per plant, each egg mass containing 90.7 orange coloured oval shaped eggs.

The seasonal abundance and distribution of mealybugs, *Pseudococcus maritimus* (Ehrhorn.) were studied in six commercial grapevines in California, USA, during 1998-99. Mealybugs were found on sampled vines during warmer days near bud break, when first instar crawlers were seen in mass on pruned scars from late June to early July, when first generation mealybugs matured and retread beneath the bark of the cordon to spin egg sacs and at the harvest in late August and September when second generation mealybugs matured in bunches (Geiger *et al.*, 2001).

Koli (2003) was of the opinion that, grape mealybug was active during September to March in Rahuri (Maharashtra). The number of egg sacs, nymphs and adults per bud varied from 0.8 to 1.83, 8.3 to 61.58 and 2.16 to 17.08, respectively from September to March. The egg sacs, nymphs and adults of mealybugs on grapes showed highly significant positive correlation with maximum and minimum temperature and highly significant negative correlation with morning and evening relative humidity and non-significant negative correlation with rainfall.

Katke *et al.* (2009) reported that the mealybugs were noticed throughout the year. The peak population of 14.5 and 32.4 colonies per vine were observed during 36th meteorological standard week (MSW) in the vegetative and 10th MSW in the fruiting season, respectively. The initial population of mealybugs (25.0 colonies/vine) was observed during 14th MSW (April). Due to pruning during April (7.4 colonies/vine during 22nd MSW) and September (5.0 colonies/vine during 44th MSW) the population of mealybug drastically declined. But, the population of mealybug recovered and increased

slowly after every pruning and activity of the mealybug population was present on the crop throughout the year. Mealybug incidence correlated significantly and negatively with minimum temperature, bright sunshine hours and rainfall during real time and at three lead (previous) weeks, but positively with morning and afternoon relative humidities at two and three lead weeks, respectively during pre-monsoon season. During the monsoon season, the mealybug incidence correlated negatively and significantly with maximum and minimum temperatures at four and two lead weeks, respectively. During post-monsoon season, the incidence of mealybug correlated negatively and significantly with maximum temperature during real time. During winter season, which coincided with fruiting period, the association of mealybug incidence was significant and positive with maximum temperature during the week of observation and at one and two lead weeks and negative with morning and afternoon relative humidity during the week of observation as well as at all individual lead weeks.

Reddy *et al.* (2009) reported that the population of *M. hirsutus* was higher in the first half of 2005 than in second half. The highest mean number of individuals per shoot were found in January, March and May on *Hibiscus* plant. However, the population build up on *Hibiscus* started from October upto May 2005, 2006 and 2007. But population was generally low during 2006 and 2007 as compared to 2005.

Peak activity of mealybug, *M. hirsutus* was observed from March to April (7 to 14 meteorological standard week) in grape garden. Mahima and Prasanna Kumar (2010) reported that, mealybugs were present throughout the year except rainy months followed by winter season on mulberry plants. The population was low during rainy season. The mealybugs preferred tender leaves and twigs. Continuous feeding by mealybugs caused severe tukra symptoms on mulberry (Anon., 2010).

Samuthiravelu *et al.* (2010) reported that the infestation of tukra mealy bug, *M. hirsutus* was observed through out the year and high (8.18%) in July month on mulberry. Rosas Garcia and Parra Bracamonte (2011) reported the incidence of the pink hibiscus mealybug, *M. hirsutus* by monitoring each developmental stage viz., first instar nymphs or crawlers (N1), second instar nymphs (N2), third instar nymphs (N3), females (F), and ovisacs (O) on Tommy Atkins, Haden, Manila, Ataulfo, Keitt, and Kent cultivars of mango. Results indicated that average monthly incidence of N1 and N2 individuals was higher between January and February, May and June, and August and September, while the incidence of N3 individuals was also higher between July and August. All developmental stages showed the highest incidence in cultivar Ataulfo.

2.2.4 Natural enemies of *Maconellicoccus hirsutus*

As *M. hirsutus* is a widely distributed species, several parasitoids and predators on this pest have been reported from different parts of country.

A total of twenty eight parasitoids all belonging to the order Hymenoptera have been recorded on *M. hirsutus* (Table 2). Of these parasitoids, *Anagyrus kamali* Moursi parasitized mealybug, *M. hirsutus* to an extent of 66-100 per cent in Egypt (Moursi, 1948). In India, *Anagyrus* sp. was an important parasitoid causing 19-47 per cent parasitisation in West Bengal. It was observed from April to November and abundant mainly during October-November. The parasitoid, *Allotropa citri* Muesebeck was recorded from the nymphs of *M. hirsutus* during May to November (Ghose, 1971). According to Manjunath (1985), *Anagyrus dactylopii* (How.) was found parasitizing *M. hirsutus* on grapes to an extent of 70 per cent in Bangalore.

Ghose (1971) reported the activity of natural enemies in relation to *M. hirsutus*. *Brumus suturalis* Fab. was found in association with the mealybug on ramie (*Boechmeria nivea* (L.)) in April and on roselle (*Hibiscus sabdariffa* var *altissima* (Wester)) during May, September and October. *Nephus* sp. was found during April on ramie. *Scymnus coccivora* (Ayyar) adults were fairly abundant on mulberry from April to November. Maggots of *Diadiplosis* sp. were found on roselle feeding on all stages of the mealybug from September to January and were predominant during October-November. An unidentified drosophilid predator was found feeding on *M. hirsutus* during December-January.

Mani (1986) recorded six parasitoids, the Encyrtids, *A. dactylopii*, *Gyranusoidea mirazi* (Agarwal) and *Alamella flava* (Agarwal), the Platygasterid, *Allotropa* sp., the Eucoilids, *Leptopilina* sp. and *Chartocerus* sp. and seven predators, the Coccinellids, *Scymnus* sp., *S. coccivora* and *C. montrouzieri* (Mulsant), *Chrysopa* sp., the Lycaenid, *Spalgis epius* (Westwood), the Drosophilid, *Cacoxenus perspicar* (Knab.) and the Cecidomyiid, *Triommata occidivora* (Felt.), Except *A. dactylopii* remaining parasitoids and all predators were new records on *M. hirsutus* in the country.

Forty two species of predators belonging to five insect orders have been reported on *M. hirsutus* (Table 3). Of these predators, *C. montrouzieri* has been introduced and evaluated for the control of *M. hirsutus* in Egypt and India (Hall, 1926; Ranga Reddy and Lakshminarayana, 1986). Several species of *Scymnus* were also recorded as active predators of *M. hirsutus* (Dutt *et al*, 1951; Hall, 1921b, Misra, 1919 and Rao, 1967).

According to Misra (1919), the predatory caterpillar, *S. epius* appeared in late October and cleared all the colonies of *M. hirsutus*. During July-September, the mealybugs were preyed by *Eublemma* sp. Life cycle of *M. hirsutus* was completed in 24-29 days during March-October but prolonged with the advancement of cold. During winter, one of the undetermined chalcid parasitoids of the mealybug was found to hibernate in its pupal stages on the stem or leaves. The predaceous, *Diadiplosis indica* (Felt.) was predominant from August to November and thereafter hibernated in the pupal stage in the colonies of mealybugs on the shoots.

Hymenopteran parasitoid, *Promuscidea unfasciativentris* Girault (Chalcidoidea: Aphelinidae) on mealybug was reported from Andhra Pradesh, Bihar, Delhi, Karnataka and Maharashtra by Sinha *et al.* (1985) and Hayat (1986). Mani (1986) conducted a field experiment to study the population of grape mealybug and its predator, *C. montrouzieri* at Kadur. Initial population of mealybug was 53.40 per ten shoots, after releasing predator at five adults per vine reduced the population to 12.25 per ten shoots within 90 days. According to Mani and Thontadarya (1987c) the activity of the natural enemies coincided with that of the mealybugs. A positive and significant relationship between the dominant parasite, *A. dactylopii* and *M. hirsutus* was observed.

Jayaraman *et al.* (1988) reported that *S. coccivora* and *C. montrouzieri* were potential predators of *M. hirsutus*. The feeding rate of *C. montrouzieri* was higher than that of *S. coccivora*. The green lacewing, *Mallada boninensis* (Okamoto) is a common predator of the pink mealybug, *M. hirsutus* infesting grapevine. Results of the study indicated that the development of *M. boninensis* was completed in 25.80 days on *M. hirsutus*. A single chrysopid larva consumed 237.90 mealybug nymphs in its larval development (Mani and Krishnamoorthy, 1989).

Malleshaiah (1995) reported the consumption of citrus mealybug by different instars of predator, *C. carnea*. Individual grub of predator consumed 3583.75, 728.52 and 96.39 eggs, nymphs and adults of citrus mealybug, respectively.

Gowda *et al.* (1996) reported that, in Karnataka, the larvae of Lycaenid, *S. epius* were found feeding voraciously on all stages of *M. hirsutus*, indicating it as a potential predator in mulberry.

According to Mani and Krishnamoorthy (1997), parasitoids such as *Coccidoxenoides peregrinus* (Timberlake) and *Leptomastix dactylopii* (How.) were potential parasitoids of *P. citri* on sapota. However, they failed to regulate *P. citri* throughout the year and were active only during specified months. Among the predators *S. coccivora*, *C. montrouzieri*, *Chrysopa* sp. and *S. epius* recorded maximum activity and predation. Above mentioned parasitoids and predators were also reported on citrus mealybug by Malleshaiah *et al.* (2000).

Michaud and Evans (2000) reported coccinellid predator species, *Cylonea sanguine limbifer* Casey, *Coelophora inequalis* (F.), *Diomus* sp., *C. montrouzieri*, *Scymnus* sp. and *Zilus eleutherae* Casey preying on pink *Hibiscus* mealybug, *M. hirsutus*. They also recorded one eulophid, *Aprostocetus minutes* Howard, hyperparasitoid of encyrtids and aphelinids and four encyrtid parasitoids, *A. kamali*, *Gyranusoidea indica* Shafee Alam and Agarwal, *Acerophagous nubilipennis* Dozier, *Cheiloneurus inimicus* Compere from Puerto Rico with a range of 4 to 71 per cent parasitization.

Sureshan and Narendran (2005) reported the hymenopteran parasitoid, *P. unfasciativentris* on coccids of *Hibiscus rosasinensis* in Maharashtra. Flores (2005) reported that, parasitoids, *A. kamali* and *G. indica* and a predatory ladybird, *C. montrouzieri* gave over 98 per cent reduction in mealybug population density.

Gautam *et al.* (2007) reported the various predators viz., *Brumoides lineatus* (Weise), *B. suturalis*, *Cheilomenes sexmaculata* (Fab.), *Nephus regularis* (Sicard), *C. montrouzieri*, *C. carnea*, *Mallada astur* (Banks) and *M. boninensis*. They also recorded two unidentified parasitoids, encyrtid and dipteran on mealybug, *P. solani* during surveys from December 2004 to June 2007 in and around Delhi.

Table 2. Hymenopteran parasitoids of *Maconellicoccus hirsutus*

Sl. No.	Species	Family	Country	References
1.	<i>Aphelinus</i> sp.	Aphelinidae	India	Rao (1967)
2.	<i>Erioporus aphelinoides</i> Compere	Aphelinidae	India	Rao (1967)
3.	<i>Phanerotoma dentate</i> Panzer	Braconidae	Egypt	Hall (1921b)
4.	<i>Achrysophagus</i> sp.	Encyrtidae	India	Rao (1967)
5.	<i>Anagyrus</i> sp.	Encyrtidae	India	Ghose (1971)
6.	<i>Anagyrus dactylopii</i> How.	Encyrtidae	India	Manjunath (1985), Nalini and Manickavasagam (2011)
7.	<i>Anagyrus greeni</i> How.	Encyrtidae	India	Rao (1967)
8.	<i>Anagyrus kamali</i> Moursi	Encyrtidae	Egypt, Puerto Rico India	Moursi (1948) Michuad and Evans (2000) Nalini and Manickavasagam (2011)
9.	<i>Cheiloneurus</i> sp.	Encyrtidae	India	Ghose (1971)
10.	<i>Leptomastix phenacocci</i> Compere	Encyrtidae	Egypt	Compere (1938)
11.	<i>Leptomastix dactylopii</i> How.	Encyrtidae	India	Mahima and Prasanna Kumar (2010)
12.	<i>Allotropa citri</i> Muesbeck	Platygasteridae	India	Rao (1967) and Ghose (1971)
13.	<i>Promuscidea unfasciativentris</i> Girault	Aphelinidae	India	Sinha <i>et al.</i> (1985), Hayat (1986) and Sureshan and Narendran (2005)
14.	<i>Alamella flava</i> Agarwal	Encyrtidae	India	Mani (1986), Nalini and Manickavasagam (2011)
15.	<i>Allotropa</i> sp.	Encyrtidae	India	Mani (1986)
16.	<i>Leptopilina</i> sp.	Eucoilidae	India	Mani (1986)
17.	<i>Aprostocetus minutes</i> Howard	Eucoilidae	Puerto Rico	Michuad and Evans (2000)
18.	<i>Gyranusoidea indica</i> Shafee, Alam and Agarwal	Encyrtidae	Puerto Rico India	Michuad and Evans (2000) Nalini and Manickavasagam (2011)

Contd...

Table 2. Hymenopteran parasitoids of *Maconellicoccus hirsutus* (Contd...)

Sl. No.	Species	Family	Country	References
19	<i>Acerophagous nubilipennis</i> Dozier	Encyrtidae	Puerto Rico	Michuad and Evans (2000)
20	<i>Cheiloneurus inimicus</i> Compere	Encyrtidae	Puerto Rico	Michuad and Evans (2000)
21	<i>Adelencyrtus coxalis</i> Hayat, Alam and Agarwal	Encyrtidae	India	Nalini and Manickavasagam (2011)
22	<i>Aenasius advena</i> Compere	Encyrtidae	India	Nalini and Manickavasagam (2011)
23	<i>Anagyrus chrysos</i> Noyes and Hayat	Encyrtidae	India	Nalini and Manickavasagam (2011)
24	<i>Anagyrus mirzai</i> Agarwal and Alam	Encyrtidae	India	Nalini and Manickavasagam (2011)
25	<i>Aenasius indicus</i> (Narayanan and Subba Rao)	Encyrtidae	India	Nalini and Manickavasagam (2011)
26	<i>Homalotylus turkmenicus</i> Myartseva	Encyrtidae	India	Nalini and Manickavasagam (2011)
27	<i>Homalotylus eytelweinii</i> (Ratzeburg)	Encyrtidae	India	Nalini and Manickavasagam (2011)
28	<i>Aenasius bambawalei</i> Hayat	Encyrtidae	India	Nalini and Manickavasagam (2011)

Table 3: Predators of *Maconellicoccus hirsutus*

Sl. No.	Species	Family	Order	Country	Reference
1	<i>Geocoris tricolor</i> (Fab.)	Coreidae	Hemiptera	India	Rao (1967)
2	<i>Chrysopa</i> sp.	Chrysopidae	Neuroptera	India	Manjunath (1985), Mani (1986)
3	<i>Chrysopa scelestes</i> Bank	Chrysopidae	Neuroptera	India	Rao <i>et al.</i> (1984)
4	<i>Chrysoperla</i> (= <i>Chrysopa</i>) <i>carnea</i> Stephens	Chrysopidae	Neuroptera	Egypt	Hall (1921b), Malleshaiah (1995), Alizadeh <i>et al.</i> (2013)
5	<i>Mallada boninensis</i> Okamoto	Chrysopidae	Neuroptera	India	Jayaraman <i>et al.</i> (1988) and Mani and Krishnamoorthy (1989)
6	<i>Conwentzia psociformis</i> (Curtis)	Coniopterygidae	Neuroptera	Egypt	Hall (1921b)
7	<i>Sympherobius pyomeaus</i> (Curtis)	Sympherobidae	Neuroptera	Egypt	Hall (1921b)
8	<i>Spalgis epius</i> Westwood	Lycaenidae	Lepidoptera	India	Misra (1919), Pushpaveni <i>et al.</i> (1973), Rao <i>et al.</i> (1984) Mani (1986), Gowda <i>et al.</i> (1996)
9	<i>Eublemma</i> sp.	Noctuidae	Lepidoptera	India	Misra (1919), Ghose (1971)
10	<i>Eublemma oeyri</i> Rothchild	Noctuidae	Lepidoptera	Egypt	Hall (1921b), Wiltshire (1948)
11	<i>Eublemma silicua</i> Sic.	Noctuidae	Lepidoptera	India	Rao <i>et al.</i> (1984)
12	<i>Eublemma</i> sp. nr. <i>trifaciata</i> Moore	Noctuidae	Lepidoptera	India	Misra (1919)
13	<i>Diadiplosis</i> sp.	Cecidomyiidae	Diptera	Egypt	Hall (1921b)
14	<i>Diadiplosis indica</i> Felt	Cecidomyiidae	Diptera	India	Misra (1919) and Felt (1920)
15	<i>Cacoxenus</i> (= <i>Gitonides</i>) <i>persipicax</i> Knab	Drosophilidae	Diptera	India	Fletcher (1920), Rao (1967), Manjunath (1985)
16	<i>Triommata occidivora</i> Felt	Cecidomyiidae	Diptera	India	Mani (1986)

Contd...

Table 3: Predators of *Maconellicoccus hirsutus* (Contd...)

Sl. No.	Species	Family	Order	Country	Reference
17	<i>Brumoides suturalis</i> Fab.	Coccinellidae	Coleoptera	India	Ghose (1971)
18	<i>Hyperaspis maindronii</i> Sic.	Coccinellidae	Coleoptera	India	Rao (1967)
19	<i>Cheilomenes sexmaculata</i> (Fab.)	Coccinellidae	Coleoptera	India	Rao (1967)
20	<i>Cryptolaemus montrouzieri</i> Muls.	Coccinellidae	Coleoptera	Egypt	Hall (1926 and 1927)
				India	Satyanarayanamurthy (1982) and Ranga Reddy and Lakshminarayana (1986)
				Puerto Rico	Michaud and Evans (2000)
21	<i>Oxynychus erythrocephalus</i> Fab.	Coccinellidae	Coleoptera	Egypt	Hall (1921b)
22	<i>Rodolia cardinalis</i> (Muls.)	Coccinellidae	Coleoptera	Egypt	Hall (1921b)
23	<i>Scymnus biverrucata</i> Panzer	Coccinellidae	Coleoptera	Egypt	Hall (1921b)
24	<i>Scymnus</i> sp. nr. <i>nubilus</i> Muls.	Coccinellidae	Coleoptera	India	Ghose (1971)
25	<i>Scymnus</i> (= <i>Pullus</i>) <i>pallidicollis</i> Muls.	Coccinellidae	Coleoptera	India	Dutt <i>et al.</i> (1951), Rao (1967) and Misra (1919)
26	<i>Scymnus pyrocheilus</i> (Muls.)	Coccinellidae	Coleoptera	India	Rao (1967) and Ghose (1971)
27	<i>Scymnus seriacus</i> Marshall	Coccinellidae	Coleoptera	Egypt	Hall (1921b) and Tawfik <i>et al.</i> (1962)
28	<i>Scymnus</i> sp.	Coccinellidae	Coleoptera	India Puerto Rico	Mani (1986) Michaud and Evans (2000)
29	<i>Scymnus coccivora</i> Ayyar	Coccinellidae	Coleoptera	India	Mani (1986), Jayaraman <i>et al.</i> (1988)
30	<i>Nephus</i> sp.	Coccinellidae	Coleoptera	India	Ghose (1971)

Contd...

Table 3: Predators of *Maconellicoccus hirsutus* (Contd...)

Sl. No.	Species	Family	Order	Country	Reference
31	<i>Sericoderus percikanus</i> Reitter	Corylophidae	Coleoptera	Egypt	Hall (1921b)
32	<i>Melanophthalma carinulata</i> Motschulsky	Lathrididae	Coleoptera	Egypt	Hall (1921b)
33	<i>Cylonedra sanguine limbifer</i> Casey	Coccinellidae	Coleoptera	Puerto Rico	Michaud and Evans (2000)
34	<i>Coelophora inequalis</i> F.	Coccinellidae	Coleoptera	Puerto Rico	Michaud and Evans (2000)
35	<i>Zilus eleutherae</i> Casey	Coccinellidae	Coleoptera	Puerto Rico	Michaud and Evans (2000)
36	<i>Diomus</i> sp.	Coccinellidae	Coleoptera	Puerto Rico	Michaud and Evans (2000)
37	<i>Illeis cincta</i> (Fab.)	Coccinellidae	Coleoptera	India	Mahima and Prasanna Kumar (2010)
38	<i>Nephus arcuatus</i> Kapur	Coccinellidae	Coleoptera	Iran	Alizadeh <i>et al.</i> (2013)
39	<i>Hyperaspis polita</i> Weise,	Coccinellidae	Coleoptera	Iran	Alizadeh <i>et al.</i> (2013)
40	<i>Hyperaspis vinciguerrae</i> Capra	Coccinellidae	Coleoptera	Iran	Alizadeh <i>et al.</i> (2013)
41	<i>Exochomus nigripennis</i> Erichson,	Coccinellidae	Coleoptera	Iran	Alizadeh <i>et al.</i> (2013)
42	<i>Scymnus</i> (=Pullus) <i>syriacus</i> Marseu	Coccinellidae	Coleoptera	Iran	Alizadeh <i>et al.</i> (2013)

Tanwar *et al.* (2008) conducted survey in five Tehsils of Parbhani district (Maharashtra) indicating the presence of cocoons of parasitoid, *P. unfasciiventris* parasitizing *P. solenopsis* on cotton and *P. hystrophorus* in four out of the five Tehsils. This parasitoid is a solitary endoparasitoid causing mealybugs to swell and change their colour to light brown. The developing larva at the later stage turned the mealybug into a legless, brown, barrel-shaped mummy with dark brown in colour.

Saini *et al.* (2009) observed a nymphal parasitoid, *Aenasius* sp. during sampling and rearing of mealybug on cotton and the same has been named as *Aenasius bambawalei* Hayat (Encyrtidae: Hymenoptera), which caused 5-90 per cent parasitization of this pest in different areas. It also parasitized mealybugs present on other host plants, indicating its great potential for exploitation in biological control.

The percentage of parasitization was significantly highest with the peak parasitization rate of 60 per cent which occurred in October 2005. Highest percentage of parasitization in 2006 (56%) was recorded during August with the exception of January and April, when parasitization was 6 and 44 per cent, respectively. Almost no parasitization was observed in the first half of 2007. However, during the second half of the year, with exception to November, parasitization was observed monthly with a range of 17-37 per cent in Guam. The predator *C. montrouzieri* was slightly higher from January through June and then decreased for the rest of the year. In 2006, number of predators ranged from zero to three per sample, whereas in 2007, the species was virtually absent throughout the year (Reddy *et al.*, 2009).

A survey conducted on the occurrence of natural enemies of mealybugs during 2007 and 2008 seasons on cotton led to records of higher diversity and abundance of hymenopteran parasitoids on *M. hirsutus* than *P. solenopsis*. A total of three and nine parasitoids were documented on *P. solenopsis* and *M. hirsutus*, respectively. While, *A. bambawalei* (Encyrtidae) was recorded only on *P. solenopsis*, two species viz., *P. unfasciiventris* and *Aprostocetus bangaloricus* Narendran (Eulophidae) were recorded on both *P. solenopsis* and *M. hirsutus* (Pinjarkar *et al.*, 2009).

The aepfly, *S. epius* occurred in India, Burma and Sri Lanka (Bingham, 1907), Philippines and Java (Le Pelley, 1943), Bangladesh (Ali, 1978) and Thailand (Lohman and Samarita, 2009). The aepfly, *S. epius* been recorded as a predator of various species of mealybugs, viz., *Dactylopius* sp., *Planococcus virgatus* (Ckll), *P. lilacinus*, *P. citri*, *F. virgata*, *Paracoccus marginatus* Williams and Granara de Willink and *M. hirsutus* (Dinesh and Venkatesha, 2011; Dinesh *et al.* 2010; Thangamalar *et al.*, 2010). Of the several insect predators of mealybugs in India, the larva of *S. epius* has been reported as a potential predator of *P. citri* and *P. lilacinus* in coffee plantations (Chacko *et al.*, 1977; Rahiman and Vijayalakshmi, 1998), *M. hirsutus* in mulberry gardens (Pushpaveni *et al.*, 1973; Gowda *et al.*, 1996) and *P. lilacinus* in ber crop, *Zizyphus mauritiana* L. (Mani and Krishnamoorthy, 1996) in India.

Mahima and Prasanna Kumar (2010) observed two predatory beetles, *N. regularis* and *Illeis cincta* (Fab.) on mealybug, *M. hirsutus*. Their occurrence was higher during winter months. They also noticed the small parasitoid, *L. dactylopii* which was rarely seen in the garden. However, the parasitized mummies of mealybug were seen during non-rainy months.

Nalini and Manickavasagam (2011), recorded twenty nine parasitoids occurring on *M. hirsutus* in Tamil Nadu during 2008-2010. Among them, *Adelencyrtus coxalis* Hayat, Alam and Agarwal, *Aenasius advena* Compere, *A. bambawalei*, *Alamella flava* Agarwal, *Anagyrus chrysos* Noyes and Hayat, *A. dactylopii*, *Aenasius indicus* (Narayanan and Subba Rao), *A. kamali*, *Anagyrus mirzai* Agarwal and Alam, *G. indica*, *Homalotylus turkmenicus* Myartseva and *Homalotylus eytelweinii* (Ratzeburg) occur on *M. hirsutus*.

Arve *et al.* (2011) reported that the nymph and adult female of mealybugs were found to be preyed by two predators viz., *S. epius* and *S. coccivora* on *Hibiscus* plant. The populations of both predators related directly to the population of host, *P. solenopsis* and showed significant positive relationship with mealybug population.

Alizadeh *et al.* (2013) carried out studies to identify the natural enemies associated with pink hibiscus mealybug, *M. hirsutus* on Chinese hibiscus shrubs, *Hibiscus rosa-sinensis* L. in the areas of Ahvaz, located at southwest Iran during 2011-12. The identified natural enemies included: *Nephus arcuatus* Kapur, *Hyperaspis polita* Weise, *Hyperaspis vinciguerrae* Capra, *Exochomus nigripennis* Erichson, *Scymnus* (=Pullus) *syriacus* Marseul (Coleoptera; Coccinellidae), *C. carnea* (Neuroptera: Chrysopidae) and *Anagyrus* sp. (Hymenoptera; Encyrtidae). Also one parasitoid of coccinellid larvae and three species of hyperparasitoids were identified as follows: *Homalotylus quaylei* Timberlake

(parasitoid of coccinellid larvae), *Prochiloneurus aegyptiacus* (Mercet), *Prochiloneurus bolivari* Mercet (Hymenoptera; Encyrtidae) and *Chartocerus kurdjumovi* (Nikol'skaya) (Hymenoptera; Signiphoridae). The coccinellid *H. vinciguerrae* was new to the fauna of Iran. The natural enemies, i.e., *N. arcuatus* and *Anagyrus* sp. had the highest populations on the host plants throughout the year.

2.3 Management of mealybug by biorationals and entomopathogens

2.3.1 Management of mealybug by Biorationals

The soaking of potato tubers in fish oil rosin soap (0.03%) for one hour at 21°C temperature killed about 80 per cent mealybug population (Ogilvie, 1926). Verghese and Tandon (1987) recorded that *Pongamia* oil (2%) was very effective in killing crawlers of *M. hirsutus*. Kumar *et al.* (1989) showed that both 1 and 4 per cent neem kerosene emulsions were effective against *Coccus viridis* (Green) causing 80 to 90 per cent mortality in 13-19 days. Manjunath *et al.* (1992) also reported that neem oil was found to be effective with maximum mortality of mealybug (48.2%) followed by neem seed kernel extract (45.0%) and *Pongamia* oil (39.8%).

Raman Suresh Babu *et al.* (1994) revealed the use of aqueous plant extracts on *M. hirsutus* prepared from *A. indica*, *Rhizophora apiculata* Blume, *Adathoda vasica* Nees, *Parthenium hysterophorus* (Santa Maria Feverfew), *Lantana camera* L. and *Prosopis juliflora* (Sw.) DC. when directly used as a foliar spray on six mulberry varieties viz., M₅, S₁₃, MR₂, Kosen, BC2-59 and Tr₄ prevented the spread of *M. hirsutus*. Whereas, all the botanicals tested were found better in preventing the spread of the mealybug on mulberry varieties. On the basis of a field trial in Karnataka, neem (*Azadirachta indica* (A. Juss.)) and karanj oil (*Pongamia pinnata* (L.)) both at 4 per cent were recommended for the control of *P. citri* on guava. They caused 93.2 and 89.39 per cent mortality of the insect, respectively at 10 days after second spray (Hussain *et al.*, 1996).

Verghese (1997) studied the effects of 5 and 2.5 per cent neem seed kernel extracts (NSKE) and Azadirachtin (Econeem) 9 ppm on newly hatched and late first instar (4 days old) nymphs of *M. hirsutus* under laboratory. After 24 and 48 hours, mortality of early first instar nymphs was greatest with 5 per cent NSKE. The mortality of late first instar nymphs after 24 and 48 hours was greatest with 9 ppm Azadirachtin.

The effect of neem kernel water extract (NKWE) in different concentrations on *P. manihoti* was investigated in the laboratory at 23°C and in greenhouse on cassava. A choice test showed that, neem treated cassava leaves were less attractive to first instar nymphs than untreated leaves. Pseudococcids that started feeding on treated leaves died in the second instar. A greenhouse experiment showed that three applications of NKWE at weekly intervals protected cassava against established early instar nymphs (Mourier, 1997).

Shekhar and Satya Prasad (1998) reported that, the neem seed kernel extract and neem based products viz., Rakshak and Amurthaguard (0.5%) showed lesser ovicidal action (11.42 to 16.8 %) and appreciable nymphal and adult mortality (95 to 98 % and 51.75 % respectively) of *M. hirsutus* under laboratory condition. Field spraying of these products reduced the mealybug population to less than five bugs per plant from 25 mealybugs per plant on fifth day.

Balikai (1999b) noted that mealybug population was lowest (2.78/vine at 30 days after treatment) on grapes when sprayed with NSKE @ 5%.

Veeranna *et al.* (2000) reported that the aqueous neem kernel extract (NSKE @ 4%) was tested on different stages of mealybug raised on sweet pumpkin. It was found that NSKE 4% was effective in killing different stages of mealybug.

Laboratory studies carried out by Handique and Baruah (2000) showed that, biomix-1 at 1 per cent concentration [based on plant extracts of unstated composition] was as effective against *M. hirsutus* as equaling to dimethoate (0.1%). Koli (2003) reported that, NSKE (4%) and nimbecidine (0.5%) were comparatively less effective as compared to conventional and bioinsecticides.

Satyanarayana *et al.* (2003) reported the graded impact of botanicals on *M. hirsutus*. After treatment imposition, the growth and development of *M. hirsutus* was affected very much and caused 68.50, 50.40 and 46.50 per cent mortality when *A. indica*, *Ocimum canum* L. and *Clerodendron inerme* L., respectively were sprayed.

Venugopal *et al.* (2004) reported that spraying of neem seed kernel extract, *Pongamia* seed kernel extract, neem and *Pongamia* oil suppressed the tukra incidence to 3.85, 5.35, 9.57 and 11.64 per cent, respectively from 30.92 per cent in the control.

Satya Prasad and Dandin (2005) reported that the application of *Annona squamosa* L. extract resulted in the mortality of nymphal, adult and egg stages of pink mealybug by 96, 100 and 70 per cent after 48 hours of spray followed by 73, 66 and 40 per cent due to *Adhatoda vasica* L. and 53, 60 and 40 per cent due to *Eucalyptus globules*, respectively.

Govindaiah *et al.* (2006) reported that the efficacy of aqueous leaf extracts of medicinal plants viz., *E. globulus*, *Ocimum sanctum* and *Piper betle* were evaluated against the hatching of eggs, mortality of nymphs and mortality and fecundity of adult mealybugs (*M. hirsutus*) under *in vitro* conditions. Totally seven concentrations viz., 1, 5, 10, 20, 50, 70 and 100 per cent were tested against mealybugs. The results revealed that with the increase in the concentration of extracts, there was a corresponding decrease in hatching, nymphal and adult mortality and fecundity in all the extracts tested. The hatching of eggs was minimum (20.00%) at 100 per cent concentration in *E. globules* followed by *O. sanctum* (30.42%) and *P. betle* (36.06%) over control (96.73%).

Neem kernel extract and a commercially produced neem extract based product (Rakshak) induced mild ovicidal action and appreciable nymphal and adult mortality of *M. hirsutus*, comparable to the effect of dichlorvos (Srinivas *et al.*, 2007).

Katke (2008) reported that, more than 30 per cent decrease in mealybug population was observed when sprayed with NSKE 5 per cent + Soap powder at 1 per cent and Neem oil at 2 per cent + Soap powder at 1 per cent. The least percentage was observed in *Lantana camera* at 5 per cent (9.8%) followed by Neem Cake Extract at 5 per cent (11.7%) and *Clerodendron inerme* at 5 per cent (17.4%).

Sunitha *et al.* (2009) found that azadirachtin @ 0.03% was most effective against mealybug, *M. hirsutus* with reduction of 43.86, 86.18 and 86.72 per cent after 10 days of 2nd, 3rd and 4th spray, respectively. On bunches azadirachtin @ 0.03% recorded reduction of 51.01 per cent with fruit yield of 100.73 q/ha.

Satyaseelan and Bhaskaran (2010) reported that, botanical extract of *Nelavembu* (48.5%) showed higher repellency of mealybug followed by *Leucas* leaf extract (45.1%) and NSKE (43.2%). *Vitex* leaf extract and Fish oil rosin soap showed on par repellency against mealybugs. *Ocimum* stands the next in position (22.4%). The least repellency was recorded from *Lawsonia* leaf extract (18.3%) against mealybugs during 24 hours of release.

Muhammad Mamoon-Ur-Rashid *et al.* (2011) evaluated the efficacy of Commando (97% DF), Confidor (20% SL), Lannate (40% SP), Actara (25% WG) at field recommended doses and neem oil at 1.5 and 2.0% concentrations against cotton mealybug, *P. solenopsis*. Under laboratory and field environment, Commando at recommended dose resulted 95.20 per cent 2nd instar nymphal mortality and 80.60 per cent mealybug mortality after 72 hours exposure period, respectively. However, under field conditions, neem oil recorded 43.48 and 52.97 per cent mealybug mortality at 1.5 and 2 per cent concentration than Confidor (73.29%), Lannate (70.93%) and Actara (74.36%) but the neem oil at both concentrations was found less toxic than the rest of the synthetic insecticides experimented.

Mukhopadhyay *et al.* (2011) reported that application of 1.5 per cent *Pongamia* oil, 2 per cent Neem oil and 1 per cent Neem oil + *Pongamia* oil (1:1) at 14 days after spray revealed consistent reduction in pink mealybug population and proved effective in management of this pest.

Khan *et al.* (2012b) reported that the natural product tobacco extract comprising nicotine as active ingredient was found to be the best in causing mortality (98.60%) of the mealybug at 24 hours after treatment, followed by neem oil comprising azadirachtin as active ingredient (89.32%), neem seed extract (80.37%) and garlic extract (75.82%), respectively. Similar trend of mortality was observed even after 48 and 72 hours of treatments on *M. hirsutus* under field condition.

Maduri (2012) reported that, seed kernel extracts were superior in inducing nymphal mortality of pink mealybug over leaf extracts. Among the seed kernel extract, neem (78.67%) was most effective followed by *Pongamia* (56.00%) and Mahua (46.67%). Whereas, leaf extracts of *Pongamia* (41.33%) was most effective botanical followed by *Adathoda* (40.00%), neem (38.67%), Mahua (22.67%) and *Lantana* (20.00%).

2.3.2 Management of mealybug by Entomopathogens

Games *et al.* (1973) reported that *Verticillium lecanii* (Zimm.) Viegas is one of the common entomopathogenic fungus on coccids and some other sucking pests. White halo fungus, *V. lecanii* (Moliniales; Moniliaceae) is a possible microbial agent for the control of aphids, mealybugs, red spider mites and spiraling whitefly (Humber and Soper, 1981).

Eswaramoorthy and Jayaraj (1987) reported that the *V. lecanii* was highly effective for the control of *C. viridis* under field condition in Tamil Nadu, India with fortnightly application of 1.6×10^6 spores / ml. The maximum mortality (73.1%) of the bug occurred two weeks after second application. The mortality increased (92.6%) when 0.05% tween-20 was added to the spore suspension.

Shelke (2001) observed that, Fish oil rosin soap (0.5%) with *V. lecanii* (0.4%) or *C. montrouzieri* was the safest and most suitable treatment against grapevine mealybug, *M. hirsutus*. The fungus, *V. lecanii* (2×10^5 cfu/ml) caused 80.20 per cent mortality of sucking pest, *M. hirsutus* in Maharashtra, India within two weeks of spray (Jayachakravarthy, 2002). According to Koli (2003) *V. lecanii* WP @ 0.3% was found to be the best against nymphs and adults of grape mealybug in Maharashtra.

A study by Ujjan and Shahzad (2007) showed that three different strains of the pathogenic fungus, *Metarhizium anisopliae* var. *acridum* (Metsch.) infected adults of *M. hirsutus* within two days with 90 per cent adult mortality achieved within eight days and 100 per cent of 2nd instar mortality achieved by the fourth day. Glare and Milner, (1991) opined that the use of *M. anisopliae* may show promise in laboratory studies, more studies are needed regarding its biology and application especially in the field, as different levels of humidity and temperature are known to limit fungal development on insects. The neem oil @ 0.03 EC (77.13%) and herbal product (72.00%) comparatively performed well, whereas *V. lecanii* (61.20%) and *Beauveria bassiana* (Balsamo-Crivelli) (55.02%) caused moderate mortality (Anon., 2009).

Gulsar Banu *et al.* (2009) made survey in order to get information on the role of naturally occurring pathogens in the regulation of mealybug population. Survey revealed the recovery and isolation of the following fungi from mealybug, *Aspergillus clavatus* (Demazieres), *A. oryzae*, *A. terreus* (Thom.), *Verticillium* sp. and *Lecanicillium lecanii* (Zimm.) Zare & Gams. Among them *L. lecanii* was found to be highly pathogenic to *P. solenopsis* under laboratory condition. At an initial inoculum of 1×10^4 conidia ml/l, lethal time (LT₅₀) was 3.77 and 2.51 days for nymphs and adults, respectively and this was the first report on the natural occurrence of entomopathogenic fungi from mealybug.

Makadia *et al.* (2009) conducted study to evaluate the efficacy of *V. lecanii* at 2.0 g/l water combined with spreaders/stickers: Ranipal at 1 ml/l water and Teepol at 1 ml/l water, sprayed on custard apple (*A. reticulata*) against the mealybug *M. hirsutus*. All the treatments were non-significant one day after treatment, although the highest (3.1%) crawlers' mortality of the mealybug was obtained with *V. lecanii* combined with Ranipal. The mortality increased at 3 days after treatment but all the treatments were found superior over the control. The highest percentage mortality of 18.9% was found with *V. lecanii* combined with Ranipal, which was on par with *V. lecanii* alone and *V. lecanii* combined with Teepol (18.3 and 17.8% mortality, respectively) and remained significantly different from the control. A similar trend also observed at 5, 7 and 10 days after treatments.

Kharbade *et al.* (2009) reported that, *M. anisopliae* @ 2000 g/ha was most effective by recording minimum of 87.46 mealybugs/ 5 cm shoot tip length/plant resulting in reduction of mealybugs over untreated control. This treatment was statistically on par with neem oil @ 2000 ml/ha and Dashparni @ 10% in which average of 108.73 and 110.33 mealybugs/ 5 cm shoot tip length/plant were recorded, respectively. The higher seed cotton yield of 1521 kg/ha was obtained from the treatment with *M. anisopliae* @ 2000 g/ha. The untreated control recorded maximum of 322.06 mealybugs/ 5 cm shoot tip length/plant with lower seed cotton yield of 913 kg/ha.

According to Gulsar Banu *et al.* (2010) the botanical NSKE @ 5% resulted 42.22 and 55.56 per cent mortality in nymphs and adults of mealybug, *P. solenopsis*, respectively and similarly, neem oil+ Nirma powder caused 46.67 and 57.78 per cent mortality of nymphs and adults after 48 hours of treatment, respectively. Whereas the entomopathogens, *V. lecanii* @ 5 g/l (2×10^8 cfu/g) and *M. anisopliae* @ 5g/l (2×10^8 cfu/g) showed 37.78, 55.56 and 31.11, 48.86 per cent mortality of nymphs and adults of mealybug, respectively under laboratory condition.

Aida *et al.* (2010) recorded the reduction of mean population of the pink hibiscus mealybug, *M. hirsutus* by 65.45, 66.55, 65, 67.6, 82.53 and 77.35 per cent with spray of Biofly (*B. bassiana*) @ 1.5 ml/l, Biovar (*B. bassiana*) @ 2 g/l, Bioranza (*M. anisopliae*) @ 2 g/l, Admiral @ 0.75 ml/l, Cidal @ 1.5 ml/l and orange oil @ 8 ml/l, respectively after four weeks of spray.

Ibarra-Cortes (2012) observed that, mortality of third instar mealybug was greatest when inoculated with *M. anisopliae* isolates Ma65 and Ma129. The isolate Ma65 showed the best potential for developing as a microbial control agent for *M. hirsutus*.

2.4 Management of mealybugs using insecticides

Avidow *et al.* (1960) tested organo-phosphorus insecticides for the control of *P. citri* on grapes. Parathion alone or with malathion gave instant kill. Dorge and Murthy (1974) reported that in a field test on effectiveness of various insecticides against *F. virgata* on custard apple, 0.1% malathion applied at 6.5 litres per tree caused the greatest reduction in pest population. The pest can be checked by spraying the trees with diazinon or phosphamidon (0.03% each) emulsion or malathion or diamethoate (0.05 % each) insecticides (Atwal, 1976).

Narsimha Rao *et al.* (1977) inferred that dichlorvos @ 0.15% in combination with fish oil rosin soap @ 2.5% gave 80 per cent mortality of mealybugs while dichlorvos @ 0.15% alone gave 67 per cent mortality. Butani (1978) recommended spraying with malathion @ 0.04% or phosphamidon @ 0.03% against young nymphs and with diazinon @ 0.1% or monocrotophos @ 0.1% against older nymphs and adults of mealybug.

The effectiveness of sprays of ten insecticides for the control of *Planococcoccus pacificus* (Cox.) on custard apple was determined in laboratory and in fields in Karnataka. The results showed that dimethoate, phosphamidon, dichlorvos and monocrotophos all at 0.05% gave the best control (Shukla and Tandon, 1984).

Shreedhar Rao *et al.* (1988) observed that the knock down in colonies of *M. hirsutus* at 10 days after spraying in Anabe-Shahi was 51 and 52 per cent by dichlorvos and dimethoate, respectively. In Thomson seedless also the results were more or less similar.

Su and Wang (1988) reported that the pseudococcid, *P. citri* infesting grapevine in Taiwan was effectively controlled by the application of methidathion 40 EC and dimethoate 44 EC causing 93-100 per cent mortality of the pest. Debarking of infested vines followed by sprays of dichlorvos @ 0.02% in combination with fish oil rosin soap @ 2.5% helped to control *M. hirsutus* on grapevine (Mani, 1990).

Beevi *et al.* (1992) tested ten insecticides as sprays in laboratory against eggs of mealybug, *M. hirsutus*. Hatching was least in eggs treated with neem oil followed by monocrotophos, methyl demeton and fish oil rosin soap + dichlorvos @ 0.2%.

Bedford *et al.* (1996) evaluated the buprofezin against mealybug (*P. citri*) on celery plants. Destructive analysis of all plants revealed that infestation was significantly reduced and the effects on mealybugs were greater with higher rate of buprofezin.

Balikai (1999b) noted that mealybug population was lowest (1.17 and 5.9/vine at 30 and 60 days after treatment, respectively) on grapes where the pest colonies were disturbed with tooth brush and then vines were sprayed with dichlorvos @ 2 ml/l followed by lannate 24 L @ 2 ml + Teepol @ 0.5 ml/l and dichlorvos 76 EC @ 2 ml/l + Neemark @ 5 ml + Teepol @ 0.5 ml/l.

Baskaran *et al.* (1999) reported that, *F. virgata* was the dominant coccid species, infesting 98 per cent of guava trees followed by *M. hirsutus*. Monocrotophos (0.072%), malathion (0.25%), dimethoate (0.06%) and phosalone (0.175%) were evaluated for *F. virgata* control. Dimethoate and malathion were most effective in controlling *F. virgata*. Guava leaf disks were offered to *F. virgata* after treating with phosalone (0.175%), phosphamidon (0.086%), monocrotophos (0.072%), dichlorvos (0.1%), malathion (0.25%) and dimethoate (0.06%) by leaf dipping and leaf spraying methods. The leaf dip assay was most effective recording cent per cent mortality at 24 h after treatment.

Irulandi *et al.* (2001) reported that spraying of neem formulations alone @ 15 or 25 ml/l resulted in significant reduction of 86.56 to 88.33 per cent of coffee mealybug (*P. citri*) population as against 83.55 per cent at recommended dose of quinalphos 25 EC @ 2 ml/l. Combination spray of azadirachtin @ 10 ml/l + quinalphos 25 EC @ 0.75 ml/l recorded maximum control of 86.82 per cent.

Balikai (2002) reported that buprofezin 25 SC @ 1000 ml/ha recorded maximum protection of 80.4 per cent of mealybug, *M. hirsutus* on grape when sprayed along with fish oil rosin soap (Meenark) @ 3125 g/ha.

Results of field trial conducted to evaluate the efficacy of buprofezin 25 SC (Applaud 25 SC) during *rabi* 2000-01 revealed that on 10th day after first, second and third spray, buprofezin 25 SC @ 2250 ml/ha recorded least number of mealybug colonies per vine (27.7, 19.3 and 8.2, respectively) and was at par with buprofezin 25 SC @ 1500 ml/ha which in turn was at par with buprofezin 25 SC @ 1125 ml/ha. Similarly, on 10th day after first, second and third spray, buprofezin 25 SC @ 2250 ml/ha recorded least number of mealybug colonies per bunch (6.8, 2.9 and 2.0, respectively) followed by its lower dosages *i.e.*, buprofezin 25 SC @ 1500 and 1125 ml/ha which were at par with each other. Thus, looking to the efficacy of insecticides both on vine and bunches, the lower dosage of buprofezin 25 SC @ 1125 ml/ha along with fish oil rosin soap (Meenark) @ 3125 g/ha could be recommended for the management of mealybugs on grape (Balikai, 2005).

According to Muthukrishnan *et al.* (2005) foliar spray of buprofezin @ 1125 and 1500 ml/ha reduced the nymphal and adult population of *M. hirsutus* on vines and bunches and increased the fruit yield as compared to untreated check. As the efficacy of both the dosages was statistically on par with each other, the lower dose of 1125 ml/ha was recommended as it was sufficient to effectively suppress the mealybug colonies.

Biradar *et al.* (2006) reported that, diafenthiuron 50 SC @ 800 and 1600 g a.i./ha gave better control of mealybugs on grapes and recorded higher fruit yield of 24.7 and 25.0 t/vine with higher C:B ratio of 11.1 and 11.4, respectively.

Vaughn *et al.*, (2006) reported that mating disruption was the most effective when the mealybug density was low, suggesting that for best results a combination of buprofezin application and mating disruption may be necessary, at least initially. Pre-bloom applications of buprofezin produced the longest sustainable mortality rates of mealybugs, *Pseudococcus* spp. in pomegranate fruits, table and wine grapes (Gonzales and Volosky, 2006).

Dhawan (2007) gave brief note on the management of mealybug which involved several aspects *viz.*, taking care of ants that are important for the dispersal of mealybugs. Uprooting and destroying of the alternate host plants of mealybug that are growing on field bunds, water channels and wastelands during off-season of cotton. Not allowing for throwing the uprooted infested plants in cotton fields/water channels to check further spread of mealybugs and following cultural operations at monthly interval up to the end of May. The recommended insecticides included carbamates like carbaryl 50 WP and thiodicarb 75WP and organophosphates like profenophos 50 EC, quinalphos 25 EC, acephate 75 SP and chlorpyrifos 20 EC for better management of mealybugs.

According to Dhawan *et al.* (2008), the order of toxicity of insecticides was same for both one day old nymphs/crawlers and adult females. The order of toxicity was spirotetramat > clothianidin > profenophos > thiodicarb > quinalphos > buprofezin > acephate with their relative toxicity values being 5.05, 2.93, 1.00, 0.84, 0.82, 0.29, 0.25 $\mu\text{g ml}^{-1}$ for one day old nymphs/crawlers and 5.29, 2.41, 1.00, 0.96, 0.73, 0.35, 0.19 $\mu\text{g ml}^{-1}$ for the adult female, respectively. Profenophos and thiodicarb proved to be the best insecticides for mealybug control and acephate was least toxic against both nymph and adult mealybugs.

Dhawan *et al.* (2009) made studies on persistence and residual toxicity of profenophos, thiodicarb, buprofezin, quinalphos, chlorantraniliprole, spirotetramat, acephate, carbaryl and chlorpyrifos at recommended concentrations in field on cotton against first instar and adult female of mealybug, *P. solenopsis*. Based on the index of persistence toxicity, the order of effectiveness for the crawlers was profenophos (637.1) > thiodicarb (587.9) > buprofezin (492.3) > quinalphos (407.9) > chlorantraniliprole (380.0) > spirotetramat (371.6) > acephate (345.7) > carbaryl (314.6) > chlorpyrifos (273.4). Similarly, for the adult female the order of effectiveness was profenophos (572.9) > buprofezin (483.1) > thiodicarb (430.0) > quinalphos (379.9) > chlorantraniliprole (371.6) > spirotetramat (361.3) > acephate (296.7) > carbaryl (260.0) > chlorpyrifos (252.3).

Agarwal *et al.* (2009) evaluated nine treatments of spirotetramat and imidacloprid in mixtures and alone at different dosages including two checks, thiodicarb (Larvin 75 WP) and profenophos (Curacron 50 EC) and compared to test their effectiveness against mealybug on cotton. Three days after second spray, profenophos 50 EC recorded 93.73 per cent mortality over control and was at par with spirotetramat 12% + imidacloprid 36% 480 SC (36+108 g a.i./ha) (85.09% mortality) and thiodicarb 75 WP @ 750 g a.i./ha (84.48% mortality).

The mortality of mealybug due to single molecule at different dosages ranged between 53.04 and 62.39 per cent while the checks showed the promising results as compared to other treatments after first spray. Out of 12 insecticides tried as curative spray at 2, 7 and 14 days, acephate 70 SP followed by profenophos 50 EC and dichlorvos 76 EC was effective in the management of mealybug. The yield of seed cotton was significantly highest in acephate 70 SP (22.2 q/ha) and profenophos 50 EC (22.2 q/ha) which were at par with each other (Bhosle *et al.*, 2009).

Profenophos 50 EC @ 1250 ml/ha and monocrotophos 36 SL @ 1250 ml/ha were the most effective insecticides against *P. solenopsis*. However, among the various insecticides, chlorpyrifos 20 EC @ 5000 ml/ha, carbaryl 50 WP @ 2500 g/ha, thiodicarb 75 WP @ 625 g/ha and acephate 75 SP @ 2000 g/ha were effective in reducing mealybug population (Anon., 2009).

Eight days after treatment on sprouted potato the insecticides viz., chlorpyrifos 20 EC and profenophos 50 EC resulted cent per cent mortality of cotton mealybug, *P. solenopsis* population followed by triazophos 40 EC (98.99%), dimethoate 30 EC (97.43%), methyl parathion 50 EC (97.09%), quinalphos 25 EC (96.26%) and acephate 75 SP (96.26%). Nitrosoguanidines like thiodicarb 75 WP (95.05%), acetamiprid 20 SP (86.06%), thiamethoxam 25 WG (78.21%) and imidacloprid 17.80 SL (74.00%) showed better results. IGR buprofezin 25 SC (64.32%) and synthetic pyrethroids viz., cypermethrin 10 EC (60.00%) led to moderate mortality whereas fenvalerate 20 EC (35.00%) and deltamethrin 2.8 EC (29.82%) were least effective (Anon., 2009).

Sunitha *et al.* (2009) reported that the treatments of acetamiprid 20 SP @ 0.30 g/l, imidacloprid 17.8 SL @ 0.30 g/l and thiamethoxam 25 WG @ 0.30 g/l recorded 88.08, 87.88 and 84.87 per cent reduction after second spray; 93.72, 95.52 and 90.30 per cent reduction after third spray and 97.37, 96.57 and 93.53 per cent reduction in mealybug population after fourth spray after 10 days of spraying, respectively. Whereas acetamiprid 20 SP was significantly superior by recording least bunch infestation of 11.4 per cent and highest yield of 266.80 q/ha which was on par with imidacloprid 17.8 SL (15.79% bunch infestation, 248.55 q/ha fruit yield), thiamethoxam 25 WG (12.50% bunch infestation, 242.30 q/ha fruit yield) and acephate 75 SP @ 1.00 g/l (15.12% bunch infestation, 215.08 q/ha fruit yield).

Suresh *et al.* (2010) evaluated the effectiveness of different insecticides on *P. solenopsis* by leaf dip method at both 24 and 48 hours after treatment under laboratory condition. Chlorpyrifos recorded 100 per cent mortality followed by dichlorvos (90%), imidacloprid (86.66 %), thiamethoxam (80 %) and profenophos (70 %) while neem oil recorded the least mortality of 53.33 per cent after 24 hours of treatment.

Suresh *et al.* (2010) evaluated efficacy of different insecticides/ entomopathogens against *P. solenopsis* on cotton under field condition. The insecticides, profenophos 50 EC and methyl parathion 50 EC were quite effective and caused cent per cent mortality at one day after treatment while imidacloprid, fish oil rosin soap, dimethoate 30 EC, thiamethoxam 25 WG and acephate 75 SP caused cent per cent mortality within two to three days of the treatment imposition. All the tested insecticides quite effective upto 10 days of application. *Beauveria* sp. was moderately effective and caused 77 per cent mortality after 10 days of treatment. Suresh *et al.* (2010) evaluated efficacy of insecticides (profenophos 50 EC, dichlorvos 76 WC and acephate 75 SP) alone and in combination with fish oil rosin soap under field condition. The insecticides used in combination with fish oil rosin soap were significantly effective in reducing papaya mealybug, *Paracoccus marginatus* Williams and Granara De Willink at one day after treatment imposition than insecticides used alone. However, insecticides alone were effective after three days of treatment imposition.

According to Patel *et al.* (2010) more than 95 per cent reduction in mealybug population over control was observed at three days after spraying with buprofezin 25 SC in all the three dosages (250, 312.5 and 625 g a.i./ha). The efficacy of buprofezin against early and later instar nymphs of *P. solenopsis* under laboratory condition was also dose dependent and it was more toxic to early instars than later instar nymphs. It was most effective against early as well as later instars nymphs at highest dose (625 g a.i./ha). At two lower dosages (250 and 312.5 g a.i./ha), its effectiveness was comparable to chlorpyrifos 20 EC @ 400 g a.i./ha and carbaryl 50 WP @ 1000 g a.i./ha. Kulkarni *et al.* (2012) reported that, the methomyl 40 SP @ 300 g a.i./ha and dichlorvos 75 WSC @ 2 ml/l were most effective and recorded lowest number of mealybugs (3.12 and 3.62 colonies/vine) at ten days after third spray.

MATERIAL AND METHODS

Present investigations on biology of *Cryptolaemus montrouzieri* and management of grapevine mealybug, *Maconellicoccus hirsutus* were carried out during the year 2009-10 and 2010-11. The laboratory studies were carried out at the Department of Agricultural Entomology, College of Agriculture, Dharwad and field studies were carried out at the Horticultural Research Station, Tidagundi (Bijapur) and on farmer's field at Bagalkot and Athani. Materials used and methods employed for these studies are presented in this chapter.

3.1 Biology and predatory potential of *Cryptolaemus montrouzieri* on grape vine mealybug

3.1.1 Laboratory multiplication of mealybug, *Maconellicoccus hirsutus*

The grapevine mealybug, *M. hirsutus* was used as prey throughout the study period. The mass production of mealybugs was done on medium sized ripened red pumpkin (*Cucurbita maxima* Duch.) under laboratory conditions at $25\pm 5^{\circ}\text{C}$ temperature and 75 ± 5 per cent relative humidity as suggested by Chacko *et al.* (1978) and Singh (1978).

3.1.1.1 Rearing of mealy bugs on red pumpkin

Just ripened red pumpkins with ridges and grooves and bearing a small stalk were selected for easy handling. They were washed with water to remove dust on them. In order to prevent rotting, the pumpkins were treated with 0.1 per cent carbendazim 50 WP (1 g/l) (Babu and David, 1999). Wounds on the pumpkins were plugged with paraffin wax. The egg sacs of mealybugs from which the eggs have just started hatching were placed on pumpkins. The inoculation was done at regular intervals to ensure regular supply of all the stages of mealybugs throughout the study period. The inoculated pumpkins were kept in wooden cages (30 x 30 x 33 cm) with sliding glass in the front and cloth on either sides as suggested by Padmaja *et al.* (1995) and Katke and Balikai (2008). Care was taken to close all cracks and crevices with wax to prevent the escape of early instars. Fully matured mealybugs developed within 30 to 40 days.

3.1.2 Mass rearing and biology of the predator, *Cryptolaemus montrouzieri*

The method adopted by Chacko *et al.* (1978) and Singh (1978) was followed for rearing the predator after sufficient development of mealybugs on pumpkins. About 8-10 pairs of predators were released into the cage. The beetles besides feeding on the mealybugs, laid their eggs singly or in groups inside the egg sacs of mealybugs. Full grown grubs pupated on pumpkins or corner of the breeding cage. The first beetle emerged within 30 days from the date of exposure of mealybugs to the beetle, the emerging adults were used for further studies. The beetles were provided with enough number of preys during the study period (Plate 1a and 1b).

3.1.2.1 Pre-mating period

It is the period between emergence of adults and first mate of female with male. The period during which female get mated with male was recorded for the ten pairs and the average was worked out.

3.1.2.2 Pre-oviposition period

It is the period between first mating to laying of first egg by female. The period between female get mated with male and first egg laying was recorded for the ten pairs and the average was worked out.

3.1.2.3 Oviposition period

The period between first egg laying upto the last egg laying *i.e.* period during which female laid eggs was recorded for the ten females and the average was worked out.

3.1.2.4 Incubation period and hatching percentage

Ten eggs laid by each of the ten females were transferred to ten petriplates (10 x 2 cm) separately, using moist camel hair brush. Grub emergence was recorded from those ten petriplates. The average incubation period and hatching percentage were worked out.



Fig 1 a : Rearing of *Cryptolaemus montrouzieri* on mealy bug under laboratory condition

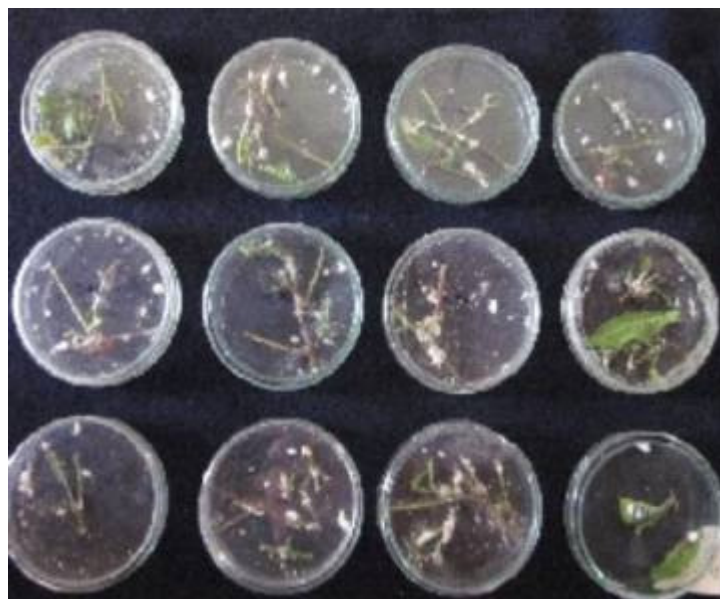


Fig 1b : *Cryptolaemus montrouzieri* feeding potential study under laboratory condition

3.1.2.5 Grub development

The grubs hatched from each of the petriplate containing ten eggs kept for earlier observations were transferred separately to ten such petriplates with a moist camel hair brush. The grubs were provided daily with fresh mealybugs. These grubs were observed daily for exuviae of the grubs, from this duration of larval instar was noted in days. Four such instars were noted and duration of each instar was recorded. Average duration of each instar and total larval period was worked out.

3.1.2.6 Pre- pupal period

The period from grub which ceases feeding till it gets fixed was considered as pre-pupal period. In this way ten grubs were observed for the pre-pupal period, which were observed for pupal development. The data thus obtained were averaged.

3.1.2.7 Pupal period

The same ten grubs which were about to pupate were kept under observations for calculating duration of pupal period. Each pupa was observed till adult emergence and then average was worked out.

3.1.2.8 Total developmental period

Total developmental period from egg laying till adult emergence was computed by combining the data obtained from the observations of incubation period upto the pupal period.

3.1.2.9 Fecundity

To study the fecundity, ten pairs of the beetles which were previously used for the study *i.e.* pre-mating, mating, pre-oviposition and oviposition period were observed and number of eggs laid were recorded daily. The total number of eggs laid by each female in its life time were recorded. During this period, the pairs were supplied with sufficient number of mealybugs. From the data obtained average fecundity was calculated.

3.1.2.10 Adult longevity

Ten pairs of newly emerged adults were used for the study. The longevity of male and female adults in each pair was recorded and average of such ten individuals was worked out.

3.1.3 Studies on feeding potential of *Cryptolaemus montrouzieri* on various bio-stages of mealybugs

In order to determine the feeding potential of both the stages (grub and adult) of the predator, known number of nymphs (2nd instar) and adults of mealybugs were supplied separately. For the test, newly hatched 1st, 2nd, 3rd and 4th instar grubs and emerged adults of *C. montrouzieri* were taken at the rate of ten numbers per replication with following treatment details.

Experimental details

Stage of predator	Stage of prey
1 st Instar <i>C. montrouzieri</i>	2 nd Instar <i>M. hirsutus</i>
1 st Instar <i>C. montrouzieri</i>	3 rd Instar <i>M. hirsutus</i>
2 nd Instar <i>C. montrouzieri</i>	2 nd Instar <i>M. hirsutus</i>
2 nd Instar <i>C. montrouzieri</i>	3 rd Instar <i>M. hirsutus</i>
3 rd Instar <i>C. montrouzieri</i>	2 nd Instar <i>M. hirsutus</i>
3 rd Instar <i>C. montrouzieri</i>	3 rd Instar <i>M. hirsutus</i>
4 th Instar <i>C. montrouzieri</i>	2 nd Instar <i>M. hirsutus</i>
4 th Instar <i>C. montrouzieri</i>	3 rd Instar <i>M. hirsutus</i>
Adult male <i>C. montrouzieri</i>	2 nd Instar <i>M. hirsutus</i>
Adult male <i>C. montrouzieri</i>	3 rd Instar <i>M. hirsutus</i>
Adult female <i>C. montrouzieri</i>	2 nd Instar <i>M. hirsutus</i>
Adult female <i>C. montrouzieri</i>	3 rd Instar <i>M. hirsutus</i>

Petriplates (10 x 2 cm) were used for grubs while the adults were confined to transparent glass container (vials) with muslin cloth. Feeding potential of male and females were studied separately (Plate 2).

Observations were recorded at an interval of 24 hours on number of preys consumed by the grubs and adults. It was computed by subtracting the number of mealybugs left out from total number of insects provided. Fresh preys were supplied daily to the grubs and adults until the grubs pupated and the adults died.

The total number of bio-stages consumed by different larval instars as well as by male and female and also the total development period of grub and longevity of adults were recorded. The data were subjected to statistical analysis.



1st Instar grub of *C. Montrouzier*



2nd Instar grub of *C. Montrouzier*



3rd Instar grub of *C. Montrouzier*



4th Instar grub of *C. Montrouzier*



Pupal of Stage of *C. Montrouzier*



Adult Stage of *C Montrouzier*



Plate 3a : Mealy bug, *Maconellicoccus hirsutus* colonies on grape shoot



Plate 3b : Mealy bug, *Maconellicoccus hirsutus* colonies on grape fruit bunch



Plate 3c : Mealy bug, *Maconellicoccus hirsutus* colonies on grape main stem

3.2 Seasonal incidence of grapevine mealybug and its natural enemies and development of prediction models

3.2.1 Seasonal incidence of *Maconellicoccus hirsutus* and its natural enemies

The population dynamics of *M. hirsutus* and its natural enemies was studied on Thompson seedless variety. The crop was pruned during September and April, and all other recommended cultural practices were followed. Observations were made at 15 days interval for a period of two years i.e., from July 2009 to June 2011. Ten plants were selected at random in each vineyard and observations were made on 10 randomly selected shoots during the vegetative phase or 10 randomly selected bunches during the fruiting phase in each plant (Plate 3a-3c). From each bunch, one secondary rachis with berries was sampled from the middle of the grape bunch. At each observation, the infested shoots/berries from each sampled vine were collected and brought to the laboratory for counting the mealybugs. After counting, the infested shoots/berries were placed over the pumpkin in wooden cages for the emergence of parasitoids and predators. Parasitoids and predators which emerged in the cage were collected and preserved in alcohol or pinned for identification.

Identification of the mealybug natural enemies particularly parasitoids was done by Prof. T.C. Narendran Trust for Animal Taxonomy, Calicut, Kerala. Similarly, identification of the mealybug natural enemies particularly predators was done by Dr. David Jacob, National Bureau of Agriculturally Important Insects, Bengaluru.

3.2.2 Collection of Meteorological data

In order to study the influence of abiotic factors (meteorological parameters) on seasonal incidence, the meteorological data on maximum and minimum temperature, relative humidity (morning and evening), sunshine hours and rainfall were collected from the nearest AICRP on Agrometeorology situated at the Regional Agricultural Research Station, Bijapur.

3.2.3 Development of prediction models and its validation

The correlations were worked out between mealybug population and weather parameters that existed during the week of observations and one, two, three and four weeks lead time considering two seasons (38th to 12th MSW; N= 14 observations) data in order to develop valid prediction models. For better validation of the prediction model, the post-monsoon and winter season covering 38 to 50 and 50 to 12 standard week mealybug population and weather parameters were used. To validate the prediction model, previous two year data on mealybug population and weather parameters were considered from the findings of Katke (2008).

3.3 Evaluation of biorationals and newer insecticides along with different adjuvants against grapevine mealybug under laboratory condition

Seven adjuvants (viz., Fish oil rosin soap (FORS) @ 5 g/l, Triton-20 @1 ml/l, APSA-80 @1 ml/l, Active-80 @ 0.5 ml/l, Envoy @1 ml/l, Dhanuvit @ 1 ml/l and Kutir @1 ml/l) were tested for mealy matter clearing over test insect and observed for six hours at hourly intervals. Out of these, the best performing three adjuvants (viz., APSA-80, Dhanuvit and FORS) were selected and included for testing along with botanicals and chemical insecticides for further studies.

3.3.1 Evaluation of botanicals along with different adjuvants against grapevine mealybug, *Maconellicoccus hirsutus*

The details of treatments of botanicals along with different adjuvants are given below:

Treatment combination: 18 (6 x 3)

Design : 2 Factor CRD

Replications : 3

Factors : 2

Factor-1: Botanicals (6)

1. *Pongamia* oil @ 2%
2. Neem oil @ 2%

3. Custard apple seed kernel extract (CASKE) @ 5%
4. *Pongamia* seed kernel extract (PSKE) @ 5%
5. Neem seed kernel extract (NSKE) @ 5%
6. Adjuvants

Factor-2: Adjuvant (3)

1. APSA-80 @ 1 ml/l
2. Dhanuvit @ 1 ml/l
3. Fish Oil Rosin Soap (FORS) @ 5 ml/l

The known number of different stages (1st, 2nd and 3rd instars) of test insect, *M. hirsutus* were released on potato sprouts kept in 500 ml capacity plastic bowl one day before imposition of treatment. It is done to avoid death of test insect by mechanical injury while transferring on sprouts and only thirty insects were maintained per replication at time of imposing treatment.

The botanicals along with different adjuvants of respective treatments were mixed thoroughly and sprayed on potato sprouts having test insect, with help of hand atomizer. After ten minutes of air drying bowls were covered with muslin cloth and tightened with rubber band (Plate 4a - 4d).

Observations were recorded at 12 h, 1, 2, 3 and 5 days after spraying on mortality of different stages of grapevine mealybug, *M. hirsutus*. The per cent mortality was worked out by using Abbott's formula (Finney, 1971) for each treatment in all replications. Before transformation of data for analysis of variance, all the zero and 100 values of per cent mortality were replaced by using formula "1/4n" and "100-1/4n", respectively (Gomez and Gomez, 1984). The corrected per cent mortality was subjected to the analysis of variance by adopting "Fishers Analysis of Variance Technique" as outlined by Gomez and Gomez (1984).

3.3.2 Evaluation of botanicals in combination with entomopathogenic fungi against *Macronellicoccus hirsutus*

The treatment details of botanicals in combination with entomopathogenic fungi (*Lecanicillium lecanii* (Zimmerman) and *Metarhizium anisopliae* (Metsch.) with or without adjuvant (Fish oil rosin soap (FORS)) are as follows.

Treatment combination: 20 (5 x 2 x 2)

Design : 3 Factor CRD

Replications : 3

Factors : 3

Factor-1: Botanicals (5)

1. *Pongamia* oil @ 2%
2. Neem oil @ 2%
3. Custard apple seed kernel extract (CASKE) @ 5%
4. *Pongamia* seed kernel extract (PSKE) @ 5%
5. Neem seed kernel extract (NSKE) @ 5%

Factor-2: Entomopathogens (2)

1. *Lecanicillium lecanii* @ 2 g/l (2×10^8 cfu/ml)
2. *Metarhizium anisopliae* @ 2 g/l (2×10^8 cfu/ml)

Factor-3: Fish Oil Rosin Soap (2)

1. With FORS @ 5 ml/l
2. Without FORS

The methods followed for recording of observation in this experiment are similar as mentioned in 3.3.1.



Plate 4a : Rearing mealy bugs on pumpkin under laboratory condition



Plate 4b : Mealy bugs on potato sprouts under laboratory condition



Plate 4c : Experimental set up under laboratory condition



Plate 4d : Preparation of treatments dilutions with soaps under laboratory condition

3.3.3 Evaluation of newer insecticides against grapevine mealybug, *Maconellicoccus hirsutus* along with different adjuvants

The experiment details of respective treatment of new insecticides in combination with different adjuvants are given below:

Treatment combination: 42 (14 x 3)

Design : 2 Factor CRD

Replications : 3

Factors : 2

Factor-1: Chemicals (14)

1. Thiacloprid 240 SC @ 0.2 ml/l
2. Thiamethoxam 25 WG @ 0.3 g/l
3. Acetamiprid 20 SP @ 0.3 g/l
4. Imidacloprid 70 WG @ 0.3 g/l
5. Imidacloprid 17.8 SL @ 0.3 ml/l
6. Chlorfenapyr 10 SC @ 1 ml/l
7. Enamectin benzoate 5 SG @ 0.3 g/l
8. Buprofezin 25 SC @ 2.0 ml/l
9. Bifenthrin 10 EC @ 1 ml/l
10. Profenophos 50 EC @ 2 ml/l
11. Diafenthiuron 50 WP @ 1.2 g/l
12. Dimethoate 30 EC @ 1.7 ml/l
13. Dichlorvos 76 EC @ 0.5 ml/l
14. Adjuvants

Factor-2: Adjuvant (3)

1. APSA-80 @ 1 ml/l
2. Dhanuvit @ 1 ml/l
3. FORS @ 5 ml/l

The methods followed for recording the observations in this experiment are similar as mentioned under section 3.3.1.

3.4 Evaluation of promising treatments for the management of grapevine mealybug under field condition

This experiment was laid out during post rainy season of 2010-11 in Randomized Block Design with three replications. Well established seven years old grape vineyard located at Athani was selected for the study. The study was conducted on Thompson seedless variety planted at a spacing of 3 x 1 m. The crop was pruned in October and April every year and all the agronomic practices were followed as per the package of practices for higher yields of horticultural crops except plant protection measures for pest management (Anon., 2002).

The best performing treatments from the above three experiments were selected for further studies at field level are given below:

a) Insecticides:

Treatments	Details
T ₁	Thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @1 ml/l
T ₂	Thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @1 ml/l
T ₃	Imidacloprid 70 WG @ 0.3 ml/l + Dhanuvit @1 ml/l
T ₄	Imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @1 ml/l
T ₅	Buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @1 ml/l
T ₆	Bifenthrin 10 EC @ 2 ml/l + Dhanuvit @1 ml/l
T ₇	Profenophos 50 EC @ 2 ml/l + Dhanuvit @1 ml/l
T ₈	Dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @1 ml/l
T ₉	Dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @1 ml/l
T ₁₀	Water spray

b) Biorationals:

Treatments	Details
T ₁	Neem oil @ 2% + Dhanuvit @1 ml/l
T ₂	Neem seed kernel extract @ 5% + Dhanuvit @1 ml/l
T ₃	Neem oil @ 2% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/l
T ₄	Neem oil @ 2% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/l
T ₅	Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/l
T ₆	Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/l
T ₇	Water spray

3.4.1 Preparation of spray

a) Insecticides

The volume of spray solution required was calculated at each time by spraying water on control treatments. The quantity of insecticide required for preparing spray solution was calculated by using the formula $Q \times A.I = C \times V$.

Where Q= Quantity of insecticide required

A.I= Active ingredient in product

C= Required concentration

V = Volume of spray solution required

The known quantity of insecticide was mixed with little quantity of water and then the solution was poured in the bucket containing the desired volume of water. It was thoroughly stirred with the help of wooden stick.

b) Plant products

Neem seed kernel extract @ 5% was prepared by soaking fifty grams of neem seed kernel powder in 500 ml of water, filtered through muslin cloth and volume of extract was adjusted to one litre by adding clean water. The procedure of extraction through muslin cloth as suggested by Pradhan *et al.* (1962) was followed.

3.4.2 Method of spraying

The chemical spray was applied with the help of Knapsack sprayer. All the vines were treated at a time, avoiding the drifts of spray chemical on neighbouring plots. Care was taken to wash the spray pump with water thoroughly well before using other chemicals. Two applications were given at

ten days interval with the help of knapsack sprayer using spray volume of 1000 litres per hectare. First spray was given when incidence of mealybug was high enough during first fortnight of January 2011 and subsequent sprays were applied at 10 days later.

3.4.3 Method of recording observations

Five vines were selected from each treatment and marked with paraffin coated paper tag. The observations were recorded from main stem and side branches of the grapevine marked with paraffin coated labels.

The efficacy of various treatments was assessed by recording the number of mealybug colonies per plant from five vines in each treatment. Pre treatment count as number of mealybug colonies per vine was recorded at one day before treatment. Subsequent observations on post treatment counts were recorded at two, five and ten days after each spraying. Similar observations were made on bunches also. The observations recorded on tenth day after first spray served as pre-treatment count for second spray.

3.4.4 Assessment of effectiveness of insecticides

From the pre and post treatment counts, the per cent protection over untreated check and per cent reduction in the population over pre-count were worked out after the second spray using the following formulae.

$$\begin{aligned} \text{Population in the UTC} &= \text{Population in treatment} \\ \text{\% Protection} &= \frac{\text{Population in the UTC} - \text{Population in treatment}}{\text{Population in the UTC}} \times 100 \\ \text{Popln. at Pre-count} &= \text{Popln. after last spray} \\ \text{\% Decrease over Pre-count} &= \frac{\text{Popln. at Pre-count} - \text{Popln. after last spray}}{\text{Population at Pre-count}} \times 100 \\ \text{Popln. after last spray} &= \text{Popln. at Pre-count} \\ \text{\% Increase over Pre-count} &= \frac{\text{Popln. after last spray} - \text{Popln. at Pre-count}}{\text{Population at Pre-count}} \times 100 \end{aligned}$$

3.4.5 Fruit Yield

Fruits after maturity were harvested separately from net plot consisting of five plants in each treatment and weighed. The fruit yield was expressed in terms of tonnes per hectare.

3.4.6 Analysis of experimental data

The mean data on bio-efficacy and fruit yield were statistically analyzed and subjected to the analysis of variance by adopting the appropriate methods as outlined by Panse and Sukhatme (1978) and Gomez and Gomez (1984) by adopting "Fishers Analysis of Variance Technique".

EXPERIMENTAL RESULTS

The results of the studies carried out on the seasonal incidence, feeding potential of *Cryptolaemus montrouzieri* and management of grapevine mealybug, *Maconellicoccus hirsutus* are presented in this chapter.

4.1 Biology and predatory potential of *Cryptolaemus montrouzieri* on grape vine mealybug, *Maconellicoccus hirsutus*

4.1.1 Pre-mating period, Pre-oviposition, Oviposition, Adult longevity, Incubation period and egg hatching percentage of *Cryptolaemus montrouzieri*

The freshly laid eggs were pale yellowish white, smooth and cylindrical in shape. At the time of hatching the shining of egg disappeared and a longitudinal depression was seen on the eggs. The grubs emerged out through eggs by breaking at the weak point of this longitudinal depression.

Ten eggs of ten sets were observed for eleven days from a day after laying for incubation period. The incubation period ranged between 3.6 to 7.9 days with an average of 5.75 days (Table 4). The average egg hatching percentage was 95 with a range of 80 to 100 per cent.

The data presented in Table 4 reveals that the pre-mating period of *C. montrouzieri* lasted for an average of 6 days with range of 4-9 days. Pre-oviposition period lasted for 8.7 days with a range of 6 to 11 days.

The oviposition period lasted for 73.80 days (58 to 89 days). Whereas average adult longevity was 78.00 and 88.50 days with a range of 61 to 91 and 72 to 109 days in male and female beetles, respectively. Number of eggs laid per female beetle varied from 472 to 652 with a mean of 550.30.

4.1.2 Developmental period of *Cryptolaemus montrouzieri*

The developmental period of *C. montrouzieri* was studied by providing second and third instar nymphs of *M. hirsutus* under laboratory condition. The newly hatched grubs were smooth and pale grayish in colour. They were devoid of wax strands at the time of hatching but developed within 2-3 hours of hatching. The length of these wax strands were found increasing with each instars. The grubs moulted three times during their post embryonic development before undergoing pupation, exhibiting four instars.

The duration of the first instar was 3.83 ± 0.53 and 3.53 ± 0.51 days with an average of 3.68 ± 0.36 days, when fed on second and third instar mealybugs, respectively. Whereas, the second instar grub took 4.83 ± 0.65 and 4.53 ± 0.51 days with an average of 4.68 ± 0.33 days when reared on second and third instar mealybugs, respectively. The third instar grub lasted for 6.03 ± 0.85 and 5.57 ± 0.50 days with an average of 5.80 ± 0.57 days when reared on second and third instar mealybugs, respectively. While, the duration of fourth instar grub fed with second and third instar mealybugs was 5.67 ± 0.66 and 5.50 ± 0.51 days, respectively with an average of 5.58 ± 0.46 days (Table 5).

The total developmental period of grub varied when reared on different stages of mealybugs. The days taken by grub were 20.37 ± 1.29 and 19.13 ± 0.86 days with a mean of 19.75 ± 0.77 days when fed on second and third instar mealybugs, respectively (Table 5).

The period of 1.73 ± 0.52 and 1.67 ± 0.55 ; 8.70 ± 0.88 and 8.53 ± 1.22 days with an average of 1.70 ± 0.39 and 8.62 ± 0.82 days to complete pre pupal and pupal period by grubs, when fed on second and third instar mealybugs, respectively. Longevity of male was found as 55.80 ± 3.19 and 60.59 ± 3.73 days with a mean of 58.18 ± 2.13 days when reared on second and third instar mealybugs, respectively. While, female lived for 63.83 ± 1.91 and 61.28 ± 2.21 days with an average of 62.48 ± 1.422 days when fed on second and third instar mealybugs, respectively.

The male could be distinguished from female by colouration of first pair of legs, having brown and black colour in male and female beetle, respectively. The middle and hind pair of legs were black in both the sexes.

4.1.3 Feeding potential of *Cryptolaemus montrouzieri*

The data on feeding potential of different larval instars as well as adult male and female beetles of *C. montrouzieri* on second and third instar mealybugs during their developmental period are presented in Table 6.

Table 4. Mating period, oviposition period, adult longevity, fecundity, incubation period and hatching percentage of *Cryptolaemus montrouzieri*

Particulars	Pre-mating period (Days)	Pre-oviposition period (Days)	Oviposition period (Days)	Adult longevity (Days)		Total number of eggs laid	Incubation period (Days)	Hatching (%)
				Male	Female			
Range	4-9	6-11	58-89	61-91	72-109	472-652	3.6-7.9	80-100
Average	6.00 ± 2.06	8.70 ± 1.64	73.80 ± 13.02	78.00 ± 10.83	88.50 ± 14.86	550.30 ± 62.68	5.75 ± 0.72	95

Number of pairs used (n) = 10 pairs

Table 5. Developmental period of *Cryptolaemus montrouzieri* fed on second and third instar mealybug, *Maconellicoccus hirsutus*

Particulars		Duration (Days) (Mean $\pm$ S.D)		
Egg Period		5.75 $\pm$ 0.68		
Grub Period		Feeding on 2 nd Instar Mealybug	Feeding on 3 rd Instar Mealybug	Mean
I Instar		3.83 $\pm$ 0.53	3.53 $\pm$ 0.51	3.68 $\pm$ 0.36
II Instar		4.83 $\pm$ 0.65	4.53 $\pm$ 0.51	4.68 $\pm$ 0.33
III Instar		6.03 $\pm$ 0.85	5.57 $\pm$ 0.50	5.80 $\pm$ 0.57
IV Instar		5.67 $\pm$ 0.66	5.50 $\pm$ 0.51	5.58 $\pm$ 0.46
Total		20.37 $\pm$ 1.29	19.13 $\pm$ 0.86	19.75 $\pm$ 0.77
Pupa	Pre pupa	1.73 $\pm$ 0.52	1.67 $\pm$ 0.55	1.70 $\pm$ 0.39
	Pupa	8.70 $\pm$ 0.88	8.53 $\pm$ 1.22	8.62 $\pm$ 0.82
Adults	Male	55.80 $\pm$ 3.19	60.59 $\pm$ 3.73	58.18 $\pm$ 2.13
	Female	63.83 $\pm$ 1.91	61.28 $\pm$ 2.21	62.48 $\pm$ 1.42

Predatory grubs N= 30 numbers

Table 6. Feeding potential of *Cryptolaemus montrouzieri* on second and third instar mealybug, *Maconellicoccus hirsutus*

Average number of mealybugs of different instars consumed (Mean $\pm$ S.D)				
Particulars		2 nd Instar Mealybugs	3 rd Instar Mealybugs	Mean
Grub				
I Instar		4.20 $\pm$ 2.33	1.83 $\pm$ 0.91	3.02 $\pm$ 1.33
II Instar		10.83 $\pm$ 2.23	4.20 $\pm$ 0.81	7.52 $\pm$ 1.28
III Instar		83.50 $\pm$ 6.56	10.57 $\pm$ 1.85	47.03 $\pm$ 3.61
IV Instar		152.30 $\pm$ 6.22	15.20 $\pm$ 1.42	83.75 $\pm$ 3.44
Total		250.00 $\pm$ 10.43	31.80 $\pm$ 2.77	141.32 $\pm$ 5.85
Adults	Male	301.33 $\pm$ 24.10	38.00 $\pm$ 7.32	169.67 $\pm$ 13.20
	Female	379.07 $\pm$ 25.52	42.97 $\pm$ 5.51	211.02 $\pm$ 13.72

Predatory grubs N= 30 numbers

The number of second and third instar mealybugs consumed by the first, second, third and fourth instar grubs were 4.20 ± 2.33 and $1.83 \pm .91$; 10.83 ± 2.23 and 4.20 ± 0.81 ; 83.50 ± 6.56 and 10.57 ± 1.85 and 152.30 ± 6.22 and 15.20 ± 1.42 with an average of 3.02 ± 1.33 , 7.52 ± 1.28 , 47.3 ± 3.61 and 83.75 ± 3.44 , respectively. The total number of second and third instar mealybugs consumed by grubs during their developmental period were 250.00 ± 10.43 and 31.80 ± 2.77 , respectively with a mean of 141.32 ± 5.85 . The adult male and female beetles of *C. montrouzieri* consumed 301.33 ± 24.10 and 38.00 ± 7.32 and 379.07 ± 25.52 and 42.97 ± 5.51 with an average of 169.67 ± 13.20 and 211.02 ± 13.72 second and third instar mealybugs, respectively.

4.2 Seasonal incidence of grapevine mealybug and its natural enemies and development of prediction model

4.2.1 Bijapur area

4.2.1.1 Seasonal incidence of grapevine mealybug in Bijapur area

In the first season, the mealybug population ranged from 3.2 to 24.8 egg masses and 6.3 to 38.3 colonies per vine. The mealybug population of 7.3 egg masses and 13.3 colonies was observed during 28th meteorological standard week (MSW) and increased to 8.9 egg masses and 23.2 colonies during 36th MSW. Thereafter it declined and reached to a minimum of 8.8 egg masses and 10.3 colonies during 46th MSW due to September pruning and once again increased during fruiting season and reached peak with 23.8 egg masses and 38.3 colonies per vine during 12th MSW (Table 7). Thereafter it declined and reached to a minimum of 5.1 egg masses and 6.3 colonies during 20th MSW due to April pruning. From 22nd MSW again increased and reached peak during 26th MSW (11.8 egg masses and 10.7 colonies/vine).

During the second season, the mealybug population of 13.8 egg masses and 18.5 colonies per vine was observed during 28th MSW and thereafter it reached to a minimum of 3.6 egg masses and 6.3 colonies per vine during 44th MSW due to September pruning. From 46th MSW it again increased and reached the peak with 26.3 egg masses and 38.3 colonies per vine during 12th MSW. Due to April pruning effect the population of mealybug egg masses and colonies declined from 14th to 20th MSW, again from 22nd MSW increased and reached the peak with 17.8 egg masses and 17.2 colonies during 26th MSW (Table 7).

The seasonal incidence of mealybug over two seasons indicated that the mealybug was noticed throughout the year. The mealybug population of 10.6 egg masses and 15.9 colonies per vine was observed during 28th MSW and increased to reach a peak population of 9.4 egg masses and 19.4 colonies per vine during 36th MSW. From 38th MSW onwards it again declined and reached to a minimum of 6.1 egg masses and 8.8 colonies during 44th MSW due to September pruning and once again increased steadily in the fruiting season and reached a peak with 25.1 egg masses and 37.3 colonies per vine during 12th MSW (Table 7). Due to April pruning the population of mealybug reduced to a minimum of 4.4 egg masses and 13.0 colonies during 14th MSW, again increased and reached to a maximum of 14.8 egg masses and 14.0 colonies per vine during 26th MSW (Table 7).

4.2.1.2 Seasonal incidence of natural enemies of grapevine mealybug in Bijapur area

Totally seven predators were recorded (Table 8) on grape vine mealybug, *M. hirsutus* viz., four from coleopteran coccinellids (*Scymnus nubilus* Mulsant, *Nephus regularis* (Sicard), *Scymnus coccivora* Ayyar and *Cryptolaemus montrouzieri* Mulsant), two from dipteran family Chamaemyiidae (*Leucopis* sp.) and Drosophilidae (*Cacoxenus (Gitonides) perspicax* Knab) and one from lepidopteran family Lycaenidae (*Spalgis epieus* Westwood) (Plate 5).

During first season the population of predators viz., coccinellid beetles and lepidopteran predators (Table 8) ranged from 0 to 4.3 number per vine. During 28th to 48th and 16th to 26th MSW population of predators continued predating on mealybugs. Because of regular management treatments during fruiting season from 50th to 14th MSW, the population of predator vanished from the garden. As that of first season, similar and consistent trend was observed in the second season and mean of two years with respect to predator population on grapevine mealybug, *M. hirsutus* (Table 7).

Totally twelve parasitoids were recorded belonging to the order hymenoptera viz., *Coccophages pseudococci* Compere, *Coccophagus* sp. near *sexvittatus* Hayat, *Coccophagus* sp. near *javensis* Girault, *Promuscidea unfasciativentris* Girault and *Euryischomyia* sp. from family Aphelinidae, *Aenasius bambawalei* Hayat, *Leptomastix dactylopii* Howard, *Leptomastix lyciae* Howard and *Homalotylus eytelweinii* Ratzeburg belonging to family Encyrtidae and *Oomyzus* sp.,

Table 7. Seasonal incidence of grapevine mealybug and its natural enemies in Bijapur area during 2009-10 and 2010-11

Meteorological Standard week (MSW)	Month and Date	No. of egg masses/vine			No. of mealybug colonies/ vine			Number of natural enemies/ vine					
		2009-10	2010-11	Mean	2009-10	2010-11	Mean	Predators			Parasitoids		
								2009-10	2010-11	Mean	2009-10	2010-11	Mean
28	Jul 09-15	7.3	13.8	10.6	13.3	18.5	15.9	3.4	3.1	3.3	8.3	3.4	5.9
30	Jul 23-29	6.8	9.3	8.1	13.8	17.8	15.8	2.3	2.4	2.4	10.3	1.8	6.1
32	Aug 06-12	7.8	8.3	8.1	16.3	12.6	14.5	4.3	2.8	3.6	6.8	5.6	6.2
34	Aug 20-26	8.2	9.2	8.7	18.4	14.3	16.4	2.8	3.4	3.1	9.3	3.2	6.3
36	Sep 03-09	8.9	9.8	9.4	23.2	15.6	19.4	3.4	2.1	2.8	5.4	3.3	4.4
38	Sep 17-23	4.8	4.8	4.8	10.3	14.8	12.6	2.4	1.3	1.9	2.7	2.1	2.4
40	Oct 01-07	3.8	3.6	3.7	8.8	9.8	9.3	2.6	0.3	1.5	3.3	1.3	2.3
42	Oct 15-21	5.2	4.3	4.8	9.3	7.8	8.6	1.8	0.4	1.1	4.8	0	2.4
44	Oct 29 – 04	6.8	5.3	6.1	11.2	6.3	8.8	0.6	0.6	0.6	2.5	0.2	1.4
46	Nov 12-18	8.8	5.8	7.3	10.3	10.5	10.4	0.8	0.2	0.5	2.2	0	1.1
48	Nov 26-02	19.8	8.3	14.1	13.8	13.6	13.7	1.2	0	0.6	3.8	0.8	2.3
50	Dec 10-16	12.5	9.4	11.0	21.3	14.3	17.8	0	0	0.0	1.2	1.8	1.5
52	Dec 24-31	13.8	12.3	13.1	18.5	18.4	18.5	0	0	0.0	2.3	0.8	1.6
2	Jan 08-14	19	18.6	18.8	24.3	21	22.7	0	0	0.0	1.3	1.3	1.3
4	Jan 22-28	23.6	23.3	23.5	28.2	28.4	28.3	0	0	0.0	0.2	0.2	0.2
6	Feb 05-11	24.8	28.2	26.5	27.4	33.5	30.5	0	0	0.0	0.8	0.9	0.9
8	Feb 19-25	23.8	23.2	23.5	34.6	34.6	34.6	0	0	0.0	1.8	0.8	1.3
10	Mar 05-11	21.2	17.8	19.5	32.3	34.4	33.4	0	0	0.0	0.3	0	0.2
12	Mar 19-25	23.8	26.3	25.1	38.3	36.3	37.3	0	0	0.0	0	0	0.0
14	Apr 02-08	3.6	5.2	4.4	11.2	14.8	13.0	0	0.7	0.4	0	0	0.0
16	Apr 16-22	4.2	7.7	6.0	11.3	10.7	11.0	1.3	1.1	1.2	0	0	0.0
18	Apr 30-06	3.2	8.9	6.1	8.3	11.9	10.1	0.8	0	0.4	1.8	4.3	3.1
20	May 14-20	5.1	13.2	9.2	6.3	10.8	8.6	3.2	2.1	2.7	4.2	5.6	4.9
22	May 28-03	10.7	12.8	6.8	7.4	14.7	11.1	2.6	1.8	2.2	6.8	3.7	5.3
24	Jun 11-17	10.5	15.8	13.2	8.3	16.6	12.5	4.3	3.2	3.8	5.2	6.8	6.0
26	Jun 25-01	11.8	17.8	14.8	10.7	17.2	14.0	3.5	2.9	3.2	4.1	5.8	5.0

Table 8. Parasitoids and predators of mealybug, *Maconellicoccus hirsutus* recorded during 2009-11

Sl. No.	Species	Family	Order
Parasitoids			
1.	<i>Coccophagus pseudococci</i> Compere	Aphelinidae	Hymenoptera
2.	<i>Coccophagus</i> sp. near <i>sexvittatus</i> Hayat	Aphelinidae	Hymenoptera
3.	<i>Promuscidea unfasciativentris</i> Girault	Aphelinidae	Hymenoptera
4.	<i>Coccophagus</i> sp. near <i>javensis</i> Girault	Aphelinidae	Hymenoptera
5.	<i>Euryischomyia</i> sp.	Aphelinidae	Hymenoptera
6.	<i>Aenasius bambawalei</i> Hayat	Encyrtidae	Hymenoptera
7.	<i>Leptomastix dactylopii</i> Howard	Encyrtidae	Hymenoptera
8.	<i>Leptomastix lyciae</i> Howard	Encyrtidae	Hymenoptera
9.	<i>Homalotylus eytelweinii</i> Ratzeburg	Encyrtidae	Hymenoptera
10.	<i>Oomyzus</i> sp.	Eulophidae	Hymenoptera
11.	<i>Centiste</i> sp.	Braconidae	Hymenoptera
12.	<i>Metastenus concinnus</i> Walker	Pteromalidae	Hymenoptera
Predators			
13	<i>Scymnus nubilus</i> Mulsant	Coccinellidae	Coleoptera
14	<i>Nephus regularis</i> (Sicard)	Coccinellidae	Coleoptera
15	<i>Scymnus coccivora</i> Ayyar	Coccinellidae	Coleoptera
16	<i>Cryptolaemus montrouzieri</i> Mulsant	Coccinellidae	Coleoptera
17	<i>Leucopis</i> sp.	Chamaemyiidae	Diptera
18	<i>Cacoxenus (Gitonides) perspicax</i> Knab	Drosophilidae	Diptera
19	<i>Spalgis epieus</i> Westwood	Lycaenidae	Lepidoptera



Cacozenus (Gitonides) prespicax Knab



Leucopis sp.



Ape fly, Spalgis epius Westwood adult



Ape fly larva, Spalgis epius westwood



Cyptolaemus montrouzieri (Muls.)



Nephus sp.

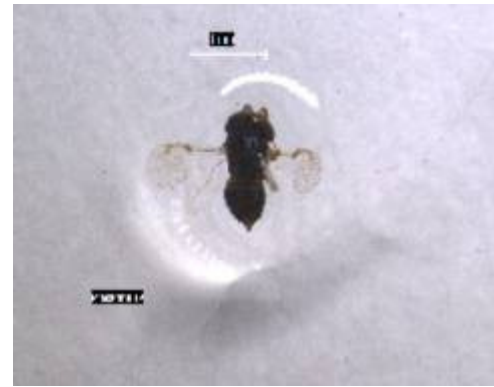


Scymnus Coccivora Ayyar

Plate 5. Parasitoids of mealy bug *Maconellicoccus hirsutus*



***Coccophagus pseudococci* Compere**



***Promuscidea unfasciatiiventris* Girault**



***Promuscidea unfasciatiiventris* Girault**



***Metastenus concinnus* Walker**



***Aenasius bambawalei* Hayat**



***Oomyzus* sp.**



***Leptomastix lyciae* Howard**



***Leptomastix dactylopii* Howard**

Centiste sp. and *Metastenus concinnus* Walker belonging to family Eulophidae, Braconidae and Pteromalidae, respectively (Plate 6).

The parasitoids (Table 8) on the mealybugs were observed throughout the study period which ranged from 0 to 10.3 parasitoids per vine. The peak population of parasitoids was observed during 30th MSW (10.3 parasitoids/vine). The population of parasitoids was affected and reduced to a minimum number after September and April pruning *i.e.* during 36th and 12th MSW. The population of the parasitoids on grapevine mealybug, *M. hirsutus* during second season and mean of two years followed similar trend as that of first year (Table 7).

4.2.2 Bagalakot area

4.2.2.1 Seasonal incidence of grapevine mealybug in Bagalakot area

In the first season, the mealybug population ranged from 3.8 to 31.3 egg masses and 5.7 to 38.3 colonies per vine. At 28th MSW the population was 8.3 egg masses and 12.8 colonies per vine and increased to 13.2 egg masses and 18.8 colonies during 36th MSW. From 38th MSW the egg masses (3.8/vine) and mealybug colonies (8.3/vine), again declined and reached to a minimum of 4.6 egg masses and 6.3 colonies during 44th MSW due to September pruning and once again increased in the fruiting season and reached to a peak with 36.1 egg masses and 37.6 colonies per vine during 12th MSW (Table. 9). Due to April pruning, the population of mealybug declined to 5.2 egg masses and 8.3 colonies per vine during 14th MSW. From 16th MSW again it increased and reached to a peak during 26th MSW (18.2 egg masses and 18.7 colonies/vine).

During the second season, the mealybug population of 19.2 egg masses and 16.7 colonies per vine was observed during 28th MSW and thereafter increased and reached to a maximum of 20.4 colonies during 36th MSW. From 38th MSW it again declined and reached to a minimum of 5.6 egg masses and 9.3 colonies per vine during 44th MSW due to September pruning. The population of mealybug again increased from 46th MSW onwards (8.8 egg masses and 10.2 colonies) in the fruiting season and reached to a peak of 27.9 egg masses and 32.2 colonies during 12th MSW (Table 9). During 14th MSW it declined to 4.1 egg masses and 8.7 colonies per vine due to April pruning. Thereafter, it increased and reached to a maximum of 18.5 egg masses and 14.6 colonies during 26th MSW.

The seasonal incidence of mealybug over two seasons indicated that, the mealybugs were noticed throughout the year. The population of mealybugs observed was 13.6 egg masses and 18.3 colonies per vine during 28th MSW and increased to reach 13.7 egg masses and 19.6 colonies per vine during 36th MSW. From 38th MSW onwards it again declined and reached to a minimum of 7.6 egg masses and 7.8 colonies during 44th MSW due to September pruning and once again increased steadily in the fruiting season and reached to a peak of 32.0 egg masses and 34.9 colonies per vine during 12th MSW (Table 9). The April pruning affected the population of grapevine mealybugs reducing to the minimum of 4.7 egg masses and 8.5 colonies during 14th MSW and again it increased and reached maximum of 18.4 egg masses and 16.7 colonies per vine during 26th MSW (Table 9).

4.2.2.2 Seasonal incidence of natural enemies of grapevine mealybugs in the Bagalakot area

During first season the population of predators *viz.*, coccinellid beetles and lepidopteran predators (Table 8) ranged from 0 to 3.4 per vine. Higher population of predators was observed from 28th to 46th and 10th to 26th MSW. The maximum numbers of predators (3.4/ vine) were observed during 36th MSW. From 48th MSW onwards upto 8th MSW the population of predators vanished from the garden. Similar consistent trend was observed during second season and mean of two years with respect to predator population on a grapevine mealybug, *M. hirsutus*.

The population of parasitoid (Table 8) was observed on the mealybugs throughout the year during first season ranging from 0 to 7.8/vine. The parasitoid population was peak during 36th MSW (7.8/vine). Minimum numbers of parasitoids were observed on mealybug from 40th MSW (during September pruning) and 12th MSW (after April pruning). The population of the parasitoid on grapevine mealybug, *M. hirsutus* in the second season and mean of two seasons followed almost similar trend as that of first season.

4.2.3 Correlation of mealybug population with weather parameters and prediction model for Bijapur area

The mealybug population exerted positive and significant correlation with maximum temperature and bright sun shine hours during the week of observation, one, two and three weeks

Table 9. Seasonal incidence of grape mealybug and its natural enemies in Bagalkot area during 2009-10 and 2010-11

Meteorological Standard week (MSW)	Month and Date	No. of Egg masses/vine			No. of mealybug colonies / vine			Number of natural enemies/ vine					
		2009-10	2010-11	Mean	2009-10	2010-11	Mean	Predators			Parasitoids		
								2009-10	2010-11	Mean	2009-10	2010-11	Mean
28	Jul 09 - 15	8.3	19.2	13.8	19.8	16.7	18.3	1.2	2.1	1.7	3.2	4.2	3.7
30	Jul 23 - 29	8.8	23.1	16.0	17.8	17.2	17.5	0	3.1	1.6	5.2	3.1	4.2
32	Aug 06 - 12	9.8	19.6	14.7	14.3	18.6	16.5	3.2	2.8	3.0	3.4	2.8	3.1
34	Aug 20 - 26	13.8	15.8	14.8	16.8	19.3	18.1	2.8	3.4	3.1	5.8	6.2	6.0
36	Sep 03 - 09	13.2	14.2	13.7	18.8	20.4	19.6	3.4	1.3	2.4	7.8	4.8	6.3
38	Sep 17 - 23	3.8	4.7	4.3	8.3	8.3	8.3	1	1.8	1.4	4.8	5.4	5.1
40	Oct 01 - 07	4.3	5.3	4.8	6.8	7.6	7.2	1.8	0.8	1.3	2.3	2.3	2.3
42	Oct 15 - 21	5.4	4.2	4.8	5.7	6.8	6.3	0.8	0.2	0.5	1.3	1.9	1.6
44	Oct 29 - 04	4.6	5.6	5.1	6.3	9.3	7.8	1.1	0.4	0.8	2.1	2.4	2.3
46	Nov 12 - 18	6.4	8.8	7.6	8.8	10.2	9.5	0.8	0.2	0.5	0.8	0.8	0.8
48	Nov 26 - 02	9.4	11.2	10.3	10.6	12.4	11.5	0	0	0.0	1.1	0.2	0.7
50	Dec 10 - 16	12.1	14.3	13.2	12.6	16.6	14.6	0.2	0	0.1	0.3	0	0.2
52	Dec 24 - 31	16.7	18.2	17.5	15.7	18.7	17.2	0	0	0.0	0.4	0.1	0.3
2	Jan 08 - 14	17.8	17.5	17.7	21.3	22.5	21.9	0	0	0.0	1	0	0.5
4	Jan 22 - 28	19.7	20.3	20.0	25.4	26.7	26.1	0	0.1	0.1	0.8	0.8	0.8
6	Feb 05 -11	22.4	23.8	23.1	28.8	28.6	28.7	0	0	0.0	0.1	0.1	0.1
8	Feb 19 - 25	28	28.7	28.4	31.3	31.6	31.5	0	0	0.0	0.2	0.3	0.3
10	Mar 05 - 11	31.2	28.8	30.0	35.4	36.7	36.1	0.2	0	0.1	0.4	0.2	0.3
12	Mar 19 - 25	36.1	27.9	32.0	37.6	32.2	34.9	0.1	0	0.1	0	0	0.0
14	Apr 02 - 08	5.2	4.1	4.7	8.3	8.7	8.5	0	0.8	0.4	0.1	0	0.1
16	Apr 16 - 22	8.3	6.7	7.5	11.4	6.4	8.9	0.8	1	0.9	0	0	0.0
18	Apr 30 - 06	7.8	7.4	7.6	9.8	6	7.9	0.6	0.6	0.6	0	0.8	0.4
20	May 14 - 20	14.3	9.6	12.0	8.9	9.2	9.1	1.2	2.4	1.8	0.8	1.3	1.1
22	May 28 - 03	18.7	14.2	16.5	10.3	8.8	9.6	2.3	1.8	2.1	1.8	2.8	2.3
24	Jun 11 -17	16.8	17.6	17.2	14.3	11.7	13.0	1.8	2.8	2.3	0.9	3.4	2.2
26	Jun 25 - 01	18.2	18.5	18.4	18.7	14.6	16.7	1.6	2.4	2.0	2.1	3.8	3.0

lead time. Whereas, it correlated negatively and significantly with morning and afternoon relative humidities during the week of observation, one, two and three weeks lead time (Table 10). Rainfall correlated negatively during all the lead time but significant during two and three weeks lead time. However, no correlation existed between the incidence of mealybug and minimum temperature during all the lead weeks but negatively and non-significantly correlated at two and three weeks lead time of observation.

The prediction models developed to forecast incidence of mealybug colonies (38 to 12th MSW) with meteorological variables at different lead weeks at Bijapur are presented in Table 11. It was noticed from the Table 8 that relative humidity was the main controlling variable for mealybug. Even though the R^2 at three weeks lead time was small ($R^2=27$), afternoon relative humidity was the only variable that could be considered to estimate mealybug incidence three weeks later. At two ($R^2=64$) and one ($R^2=60$) week lead time morning relative humidity was important to predict mealybug incidence. The reliability of estimation of mealybug incidence in the current week increased by fifteen per cent compared to the lead periods of two and one week.

The forecasting model developed ($68.03 - 0.6X_{33}$) with higher R^2 (60) in the current study has been validated by substituting the mealybug population and weather parameters of 2005-06 and 2006-07 data into the developed model. The observed population of mealybug was lower than estimated at 38th MSW, but later on the the observed population slowly increased, with that the error in the model decreased (at the time of fruit developing/maturing *i.e.*, 52nd to 12th MSW) during both the years of observation (2005-06 and 2006-07). During the peak infestation of the mealybug, it was observed that the difference between the observed and estimated population was almost equal or lowering and thus reduced the error in the model (Table 12). Using the same model the lead time one and two the mealybug population was predicted. It was found that the same trend in the population of mealybug was observed as it was in the current week (Table 12).

From Table 13 and 14 it is evident that the forecast models of lead weeks performed better in 2006 than in 2005. In both the years as well as pooled, it was noticed that the error with model at lead week one (LW1) gave best results. From error analysis using different methods on pooled data also, it was noticed that the LW1 model gave minimum error. Hence, it could be inferred that the forecast of incidence of mealybug can be made best using the forecast model of LW1, as indicated by the validation of the models for independent data sets of 2005 and 2006.

From Fig. 1, it is very clear that the forecasts using the model LW1 gave best results. Except in the month of November (MSW 46 and 48 which recorded error of 12.23 and 13.63, respectively), in all the other periods the error was less than 10. Lowest errors of less than 5 were noticed in January and February (MSW 2 to 8).

4.2.2.3 Correlation between mealybug population and weather parameters in Bagalkot area

Mealybug egg masses and colonies correlated positively with maximum temperature. Whereas, egg masses and colonies correlated negatively and significantly with minimum temperature. They also correlated negatively and significantly with morning relative humidity and negative non-significant correlation was found with afternoon relative humidity during week of observation. Mealybug egg masses and colonies positively correlated with bright sunshine hours during the week of observation. The egg masses and colonies correlated negatively with the rainfall received during week of observation (Table 15). The influence of all the weather parameters on the egg masses and colonies of mealybugs was to the extent of 39 and 44 per cent, respectively (Table 16).

4.3 Evaluation of biorationals and newer insecticides along with different adjuvants against grapevine mealybug under laboratory condition

4.3.1 Evaluation of different botanicals along with different adjuvants against grapevine mealybugs, *Maconellicoccus hirsutus*

4.3.1.1 Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at twelve hour after treatment (12 HAT)

Table 10. Correlation between weather parameters with mealybug colonies (38th to 12th standard week) at Bijapur (during 2009- 2011)

Parameter	(X ₁)	(X ₂)	(X ₃)	(X ₄)	(X ₅)	(X ₆)
LT3	0.432*	-0.303	-0.549**	-0.683**	0.629**	-0.401*
LT2	0.726**	-0.151	-0.811**	-0.680**	0.573**	-0.412*
LT1	0.661**	0.019	-0.654**	-0.746**	0.644**	-0.327
LT0	0.802**	0.224	-0.830**	-0.607**	0.449*	-0.313

** . Significant at the 0.01 level

* . Significant at the 0.05 level

Table 11. Regression models developed to forecast incidence of mealybug colonies (38 to 12th MSW) with meteorological variables at different lead weeks at Bijapur

Lead time	Regression equation	R ² (%)
LT3	$36.34 - 0.35X_4$	27
LT2	$42.71 - 0.49X_4$	60
	$76.53 - 1.15X_2 - 0.46X_3$	64
	$-13.09 + 1.15X_1 - 0.09X_6$	30
LT1	$68.03 - 0.6X_3$	60
	$40.7 - 0.47X_4$	51
LT0	$43.69 - 0.53X_4$	75
	$65.32 - 0.57X_3$	66
	$-38.52 + 1.91X_1 - 0.06X_6$	52

Note:- LT0- Current week lead time; LT1- Lead time one week; LT2- Lead time two weeks; LT3- Lead time three weeks;

X₁- Max T , X₂- Min T, X₃- RH1, X₄- RH2, X₅- BSS, X₆- RF
n = 14 observations

Table 12. The forecasting of grapevine mealybug infestation on grapes at different lead weeks

Meteorological Standard week (MSW)	Population of mealybugs (2005-06)				Population of mealybugs (2006-07)			
	Observed (LT0)	Estimated			Observed (LT0)	Estimated		
		(Colonies/vine)				(Colonies/vine)		
		LT0	LT1	LT2		LT0	LT1	LT2
38	7.3	11.36	14.03	10.98	15.1	7.12	11.03	10.98
40	6.4	17.72	14.63	11.44	8.3	5.00	11.03	11.44
42	6.0	10.83	12.83	11.21	5.4	22.49	18.83	12.36
44	5.7	21.43	23.63	21.79	4.2	12.42	12.23	20.64
46	6.3	30.44	21.83	28.46	4.5	20.37	15.83	21.46
48	8.4	27.79	20.63	25.24	5.0	20.37	22.43	25.24
50	10.2	28.32	25.43	31.22	9.3	21.96	13.43	31.22
52	12.3	27.26	21.83	29.61	10.2	23.02	13.43	28.46
2	18.4	24.08	17.63	21.79	12.5	24.61	13.43	21.79
4	19.5	31.50	31.43	35.82	16.5	25.14	18.83	31.22
6	21.3	33.62	29.63	33.29	19.3	27.79	16.43	29.84
8	25.6	35.74	37.43	34.67	25.7	26.20	20.03	31.22
10	30.5	29.91	32.63	29.84	34.3	28.32	24.23	21.79
12	31.4	32.03	35.63	27.54	31.4	29.38	21.83	22.94

Note:- LT0- Current week lead time; LT1- Lead time one week; LT2- Lead time two weeks

Table 13. Comparison of efficiency of pest forecast models

Population error: for entire season			
Lead time	2005	2006	Mean
LW2	9.5	8.8	9.1
LW1	7.3	1.2	4.3
LW0	11.4	7.8	9.7

Note: LW1 - Lead week one; LW2 - Lead week two; LW0 – Current week

Table 14. Error analysis of forecast models of mealybug

Error analysis			
Lead time	Mean Error	Mean Absolute error	RMSE
LW2	9.1	10.0	9.8
LW1	4.3	7.0	9.7
LW0	9.7	9.7	11.2

Note: LW1 - Lead week one; LW2 - Lead week two; LW0 – Current week
RMSE- Root mean square error

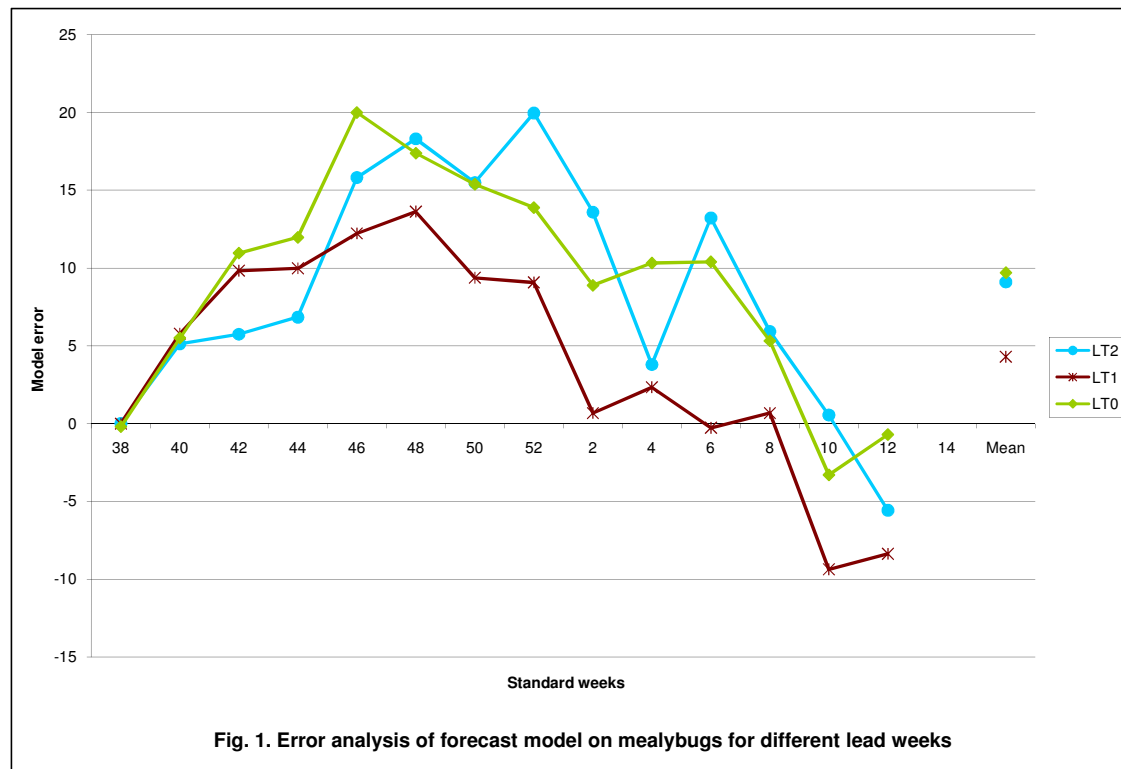


Fig 1. Error analysis of forecast model on mealybugs for different lead weeks

Table 15. Correlation between weather and mealybug colonies and egg masses in Bagalkot

Particulars	Temp. (Max)	Temp. (Min)	RH Morning	RH Evening	Bright sunshine (BSS) (hrs)	Rainfall (RF) (mm)
Mealybug egg masses	0.13	-0.293	-0.479*	-0.327	0.317	-0.335
Mealybug colonies	0.015	-0.410*	-0.509**	-0.383	0.304	-0.31

** . Significant at the 0.01 level n= 26 observations * . Significant at the 0.05 level

Table 16. Regression between weather parameters and mealybug colonies and egg masses in Bagalkot

Particulars	Regression equation	R ²
Mealybug egg masses	$Y = 6.962 + 1.464X_1 - 1.681X_2 - 0.334X_3 + 0.405X_4 - 0.061X_5 - 0.024X_6$	0.39
Mealybug colonies	$Y = 77.317 - 0.733X_1 - 0.477X_2 - 0.406X_3 + 0.071X_4 + 0.121X_5 - 0.015X_6$	0.44

X_1 -Temp. (Max), X_2 - Temp. (Min), X_3 - R_H Morning, X_4 - RH Evening, X_5 – Bright sunshine (hrs), X_6 - Rainfall (mm), n= 26 observations

Table 17. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment during 2009-10

Treatments	Corrected per cent mortality of mealybugs											
Botanicals (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	3.33 (10.52)	3.33 (10.52)	0.00 (0.52)	2.22 (7.01)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Neem oil @ 20 ml/l	4.43 (12.15)	7.80 (16.21)	3.33 (10.52)	5.19 (12.96)	4.43 (12.15)	5.90 (14.05)	5.80 (13.93)	5.38 (13.38)	3.33 (10.52)	8.60 (17.04)	7.87 (16.28)	6.60 (14.61)
CASKE @ 50 ml/l	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	3.32 (10.50)	4.13 (11.72)	4.43 (12.15)	3.96 (11.46)	3.31 (10.48)	4.13 (11.72)	2.97 (9.88)	3.47 (10.69)
PSKE @ 5%	3.33 (10.52)	6.21 (14.41)	0.00 (0.52)	3.18 (8.31)	4.43 (12.15)	5.90 (14.05)	5.59 (13.64)	5.31 (13.28)	2.99 (9.92)	5.59 (13.64)	8.83 (17.26)	5.80 (13.61)
NSKE @ 5%	6.21 (14.41)	9.57 (18.01)	4.73 (12.55)	6.84 (14.99)	3.33 (10.52)	8.03 (16.45)	7.80 (16.21)	6.39 (14.39)	6.21 (14.41)	9.90 (18.33)	7.32 (15.68)	7.81 (16.14)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Mean	2.89 (7.93)	4.49 (9.86)	1.34 (3.84)	2.90 (7.21)	2.59 (7.55)	3.99 (9.38)	3.94 (9.32)	3.51 (8.75)	2.64 (7.55)	4.70 (10.12)	4.50 (9.85)	3.95 (9.18)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.12		0.46		0.13		0.48		0.20		0.78	
B	0.08		0.32		0.09		0.34		0.14		0.55	
A X B	0.21		0.79		0.22		0.84		0.35		1.36	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASKE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

4.3.1.1a 2009-10

First instar mealybugs

The botanical NSKE @ 5% exerted significantly higher mortality of 6.84 per cent followed by neem oil @ 2% with mortality of 5.19 per cent. Among adjuvants, Dhanuvit @ 1 ml/l recorded significantly higher mortality (4.49%). The next better treatment was APSA-80 with an average mortality of 2.89 per cent (Table 17).

Among the interactions, NSKE @ 5% with Dhanuvit @ 1 ml/l resulted significantly higher mortality of 9.57 per cent. The next better treatment was neem oil @ 2% + Dhanuvit @ 1 ml/l (7.80%) compared to other combinations.

Second instar mealybugs

Significantly higher mortality was observed with NSKE @ 5% (6.39%). The next better treatments were neem oil @ 2% and PSKE @ 5% with mortality of 5.38 and 5.31 per cent, respectively compared to other botanicals (Table 17). Dhanuvit @ 1 ml/l and FORS @ 5 ml/l exerted significantly higher mortality of 3.99 and 3.94 per cent, respectively as compared to APSA-80 @ 1 ml/l (2.59%) (Table 17).

The interaction effect of NSKE @ 5% with Dhanuvit @ 1 ml/l resulted significantly higher mortality of 8.03 per cent as compared to rest of the interactions (Table 17).

Third instar mealybugs

Significantly higher mortality was exerted by NSKE @ 5% (7.81%), which was found superior over rest of the treatments. However, the next better treatments included neem oil @ 2% and PSKE @ 5% with a mean mortality of 6.60 per cent (Table 17). Significantly higher per cent mortality was observed in Dhanuvit @ 1 ml/l (4.70%) followed by FORS @ 5 ml/l (4.50%) as compared to APSA-80 (2.64%).

The interaction effect of NSKE @ 5% with Dhanuvit @ 1 ml/l recorded significantly higher mortality of mealybug (9.90%), which was on par with PSKE @ 5% + FORS @ 5 ml/l and neem oil @ 2% + Dhanuvit @ 1 ml/l causing mortality of 8.83 and 8.60 per cent, respectively.

4.3.1.1b During 2010-11

First instar mealybugs

Neem oil @ 2% and NSKE @ 5% registered higher mortality (8.15 % each) of mealybug, *M. hirsutus* (Table 18). However, they were on par with PSKE @ 5% with mortality of 5.93 per cent as compared to rest of the treatments. No significant differences were observed among the adjuvants with respect to mortality of mealybug except APSA-80, which recorded least (3.52 %). However, highest mortality (5.93 %) was observed with Dhanuvit @ 1 ml/l.

The combination of NSKE @ 5% with Dhanuvit @ 1 ml/l exerted significantly higher mortality (12.22 %).

Second instar mealybugs

Significantly superior mortality was exerted by NSKE @ 5% (8.15 %) as compared to other botanicals (Table 18). However, the lowest mortality (2.96 %) was recorded with CAKSE @ 5% among the botanicals tested. Both Dhanuvit @ 1 ml/l and FORS @ 5 ml/l resulted significantly higher mortality (4.81 and 4.44 %, respectively). The lowest mortality of 2.78 per cent was observed in APSA-80.

The combination of NSKE @ 5% with Dhanuvit @ 1 ml/l recorded significantly higher mortality of 10.00 per cent and was on par with combinations, neem oil @ 2% + Dhanuvit @ 1 ml/l and NSKE @ 5% + FORS @ 5 ml/l (7.78 % each) and NSKE @ 5% + APSA-80 @ 1 ml/l (6.67%) (Table 18).

Third instar mealybugs

The botanical NSKE @ 5% was significantly superior in causing mortality (7.78%) of third instar mealybug over rest of the botanicals tested (Table 18). Dhanuvit @ 1 ml/l and FORS @ 5 ml/l caused significantly higher mortality of 4.81 and 4.07 per cent as compared to APSA-80 (2.78%).

Table 18. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment during 2010-11

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	4.44 (12.00)	5.56 (13.48)	5.56 (13.48)	5.19 (12.98)	3.33 (10.52)	4.44 (12.00)	3.33 (10.52)	3.33 (11.01)	3.33 (10.52)	5.56 (13.48)	3.33 (10.52)	4.07 (11.50)
Neem oil @ 2%	7.78 (16.11)	8.89 (17.27)	7.78 (16.11)	8.15 (16.50)	3.33 (10.52)	7.78 (16.11)	4.44 (12.00)	4.81 (12.88)	4.44 (12.00)	5.56 (14.96)	3.33 (10.52)	4.44 (12.49)
CASE @ 5%	0.00 (0.52)	1.11 (3.51)	3.33 (10.52)	1.48 (4.67)	2.22 (7.01)	3.33 (10.52)	3.33 (10.52)	2.96 (9.35)	0.00 (0.52)	3.33 (7.01)	0.00 (0.52)	1.11 (2.34)
PSKE @ 5%	3.33 (10.52)	7.78 (16.11)	6.67 (14.96)	5.93 (13.86)	3.33 (10.52)	4.44 (12.00)	4.44 (12.00)	3.70 (11.50)	3.33 (10.52)	5.56 (13.48)	4.44 (12.00)	4.44 (12.00)
NSKE @ 5%	5.56 (13.48)	12.22 (20.41)	6.67 (14.96)	8.15 (16.28)	6.67 (14.96)	10.00 (18.43)	7.78 (16.11)	8.15 (16.50)	5.56 (13.48)	8.89 (17.27)	8.89 (17.27)	7.78 (16.01)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	3.33 (10.52)	1.11 (3.51)	0.00 (0.52)	0.00 (0.52)	3.33 (10.52)	1.11 (3.51)	0.00 (0.52)	0.00 (0.52)	4.43 (12.00)	1.48 (4.00)
Mean	3.52 (8.68)	5.93 (11.80)	5.56 (13.42)	5.00 (11.30)	2.78 (8.92)	4.81 (11.51)	4.44 (11.94)	4.01 (10.79)	2.78 (7.75)	4.81 (11.03)	4.07 (10.38)	3.89 (9.72)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.71		2.74		0.66		2.55		0.72		2.77	
B	0.50		1.94		0.47		1.80		0.51		1.96	
A X B	1.23		4.74		1.15		4.42		1.25		4.81	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASKE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Table 19. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	3.89 (11.32)	4.44 (12.12)	2.78 (9.48)	3.70 (10.97)	1.67 (7.41)	1.67 (7.41)	1.67 (7.41)	1.67 (7.41)	1.67 (7.41)	2.78 (9.48)	1.67 (7.41)	2.04 (8.10)
Neem oil @ 2%	6.11 (14.28)	8.33 (16.77)	5.56 (13.60)	6.67 (14.88)	3.33 (10.28)	6.67 (14.88)	5.00 (12.80)	5.00 (12.65)	3.89 (11.32)	6.67 (14.88)	5.56 (13.60)	5.37 (13.26)
CASKE @ 5%	0.00 (0.52)	0.56 (2.47)	1.67 (7.41)	0.74 (3.30)	2.22 (7.01)	3.33 (10.52)	3.89 (11.32)	3.15 (9.61)	0.56 (2.47)	2.22 (8.45)	0.00 (0.52)	0.93 (3.64)
PSKE @ 5%	3.33 (10.52)	6.67 (14.88)	3.33 (10.52)	4.44 (11.97)	3.33 (10.52)	5.00 (12.80)	4.44 (12.00)	4.26 (11.77)	2.78 (9.48)	5.00 (12.80)	5.56 (13.40)	4.44 (11.89)
NSKE @ 5%	5.56 (13.60)	10.56 (18.94)	5.00 (12.92)	7.04 (15.15)	5.00 (12.92)	7.78 (16.17)	7.78 (16.17)	6.85 (15.08)	5.56 (13.48)	8.89 (17.32)	7.78 (16.04)	7.41 (15.61)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	1.67 (7.41)	0.56 (2.47)	0.00 (0.52)	0.00 (0.52)	1.67 (7.41)	0.56 (2.47)	0.00 (0.52)	0.00 (0.52)	2.22 (8.44)	0.74 (2.81)
Mean	3.15 (8.28)	5.09 (10.86)	4.33 (10.22)	4.19 (9.79)	2.59 (8.02)	4.07 (10.30)	4.07 (11.18)	3.58 (9.83)	2.41 (7.36)	4.26 (10.49)	3.80 (9.81)	3.49 (9.22)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.46		1.76		0.65		2.51		0.65		2.50	
B	0.32		1.25		0.46		1.77		0.46		1.77	
A X B	0.79		3.05		1.13		4.34		1.13		4.34	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASKE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

The interaction of NSKE @ 5% with Dhanuvit @ 1 ml/l and FORS @ 5 ml/l exerted higher mortality of 8.89 per cent each, as compared to rest of the combinations (Table 18).

4.3.1.1c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The botanical NSKE @ 5% and neem oil @ 2% recorded higher mortality of 7.04 and 6.67 per cent, respectively. No significant differences were observed between Dhanuvit @ 1 ml/l and FORS @ 5 ml/l (5.09 and 3.33%, respectively) as compared to mortality caused by APSA-80 @ 1 ml/l (3.15%) (Table 19).

The combination of NSKE @ 5% and Dhanuvit @ 1 ml/l exerted significantly higher mortality of 10.56 per cent, which was on par with neem oil @ 2% + Dhanuvit @ 1 ml/l (8.33%) as compared to rest of the combinations (Table 19).

Second instar mealybugs

Significantly higher mortality was recorded by NSKE @ 5% (6.85%), which was on par with neem oil @ 2% with a mortality of 5.00 per cent as compared to rest of the botanicals tested (Table 19). The non-significant differences were obtained between Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with mortality of 4.07, per cent each as compared to APSA-80 @ 1 ml/l (2.59%).

The mortality of second instar mealybug was significantly higher in combinations of NSKE @ 5% with Dhanuvit @ 1 ml/l as well as FORS @ 5 ml/l (7.78 %) (Table 25) as compared to other combinations. But, they were on par with neem oil @ 2% with Dhanuvit @ 1 ml/l (6.67%) as well as FORS @ 5 ml/l (5.00%) and PSKE @ 5% with Dhanuvit @ 1 ml/l (5.00%) as well as FORS @ 5 ml/l (4.44%).

Third instar mealybugs

The per cent mortality among the botanical treatments differed significantly. The higher mortality (7.41%) was observed by NSKE @ 5%, which was on par with neem oil @ 2% (5.37%) as compared to rest of the botanicals (Table 19). The mortality did not vary significantly among the adjuvants. However, significantly higher mortality was recorded by Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with 4.26 and 3.80 per cent, respectively (Table 19).

The combination of NSKE @ 5% with Dhanuvit @ 1 ml/l recorded significantly higher mortality of 8.89 per cent. However, rest of the combinations proved to be effective on third instar mealybugs as compared to water spray with adjuvant (Table 19).

4.3.1.2 Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment (1 DAT)

4.3.1.2a 2009-10

First instar mealybugs

Botanical NSKE @ 5% exerted significantly higher mortality of 23.99 per cent, which was superior over rest of the treatments. However, it was followed by neem oil @ 2% with an average mortality of 19.11 per cent as compared to other botanicals (Table 20). FORS @ 5 ml/l was significantly superior among adjuvants causing mortality of 15.60 per cent followed by Dhanuvit @ 1 ml/l (12.64%).

The interaction effect of NSKE @ 5% with Dhanuvit @ 1 ml/l registered significantly higher mortality (27.33%) which was on par with NSKE @ 5% + FORS @ 5 ml/l (23.20%). However, lower mortality (4.44%) was recorded with CAKSE @ 5% + APSA 80 @ 1 ml/l (Table 20).

Second instar mealybugs

Significantly higher mortality was observed in NSKE @ 5% and neem oil @ 2% with a mean of 19.63 and 17.84 per cent, respectively as compared to rest of the botanicals. Among the adjuvants, FORS @ 5 ml/l recorded significantly higher mortality (13.96%). The next better adjuvant was Dhanuvit @ 1 ml/l which caused mortality of 12.71 per cent (Table 20).

The combination of NSKE @ 5% and Dhanuvit @ 1 ml/l resulted significantly higher mortality (21.89 %) and was on par with neem oil @ 2% + Dhanuvit @ 1 ml/l and NSKE @ 5% + FORS @ 5 ml/l with an average of 20.71 and 19.94 per cent mortality, respectively.

Table 20. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2009-10

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Botanicals (A)												
<i>Pongamia</i> oil @ 2%	7.78 (16.11)	7.78 (16.11)	10.00 (18.43)	8.52 (16.88)	7.62 (15.99)	12.00 (20.24)	11.11 (19.42)	10.24 (18.55)	7.78 (16.11)	14.67 (22.49)	9.43 (17.86)	10.63 (18.82)
Neem oil @ 20 ml/l	17.10 (24.41)	20.10 (26.62)	20.13 (26.64)	19.11 (25.89)	16.10 (23.64)	20.71 (27.05)	16.70 (24.11)	17.84 (24.93)	9.55 (17.97)	20.37 (26.81)	17.89 (25.01)	15.94 (23.26)
CASKE @ 50 ml/l	4.44 (12.00)	6.21 (14.41)	9.13 (17.57)	6.60 (14.66)	4.52 (12.08)	7.85 (16.17)	9.45 (17.84)	7.27 (15.36)	4.52 (12.08)	9.13 (17.49)	8.42 (16.80)	7.36 (15.46)
PSKE @ 5%	11.11 (19.42)	14.44 (22.32)	16.66 (24.06)	14.07 (21.93)	8.17 (16.51)	13.83 (21.82)	15.47 (23.15)	12.49 (20.49)	7.93 (16.29)	16.48 (23.94)	15.07 (22.83)	13.16 (21.02)
NSKE @ 5%	21.43 (27.57)	27.33 (31.50)	23.20 (28.78)	23.99 (29.28)	17.07 (24.39)	21.88 (27.87)	19.94 (26.51)	19.63 (26.26)	14.06 (22.01)	18.21 (25.24)	16.73 (24.13)	16.33 (23.80)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	14.46 (22.31)	4.82 (7.44)	0.00 (0.52)	0.00 (0.52)	11.11 (19.42)	3.70 (6.47)	0.00 (0.52)	0.00 (0.52)	7.79 (16.18)	2.60 (5.39)
Mean	10.31 (16.58)	12.64 (18.49)	15.60 (22.97)	12.85 (19.35)	8.91 (15.44)	12.71 (18.86)	13.96 (21.74)	11.86 (18.68)	7.31 (14.08)	13.14 (19.33)	12.56 (20.47)	11.00 (17.96)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.41		1.57		0.46		1.76		0.44		1.69	
B	0.29		1.11		0.32		1.24		0.31		1.19	
A X B	0.71		2.72		0.79		3.04		0.76		2.92	

NSKE- Neem seed kernel extract @ 5%

CASKE- Custard apple kernel seed extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Figures in parentheses are Arcsine transformations

Table 21. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2010-11

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B) Botanicals (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	7.02 (15.01)	10.47 (18.87)	8.21 (16.58)	8.57 (16.82)	4.52 (12.12)	5.71 (13.69)	6.82 (16.22)	5.69 (14.01)	7.93 (16.29)	12.64 (20.78)	15.08 (22.83)	11.88 (19.97)
Neem oil @ 2%	8.18 (16.57)	18.08 (25.15)	13.27 (21.31)	13.18 (21.01)	6.82 (17.49)	11.62 (19.88)	8.13 (17.59)	8.86 (18.32)	15.56 (23.19)	20.00 (26.55)	17.24 (24.33)	17.60 (24.69)
CASE @ 5%	4.44 (12.00)	5.59 (13.54)	6.78 (14.74)	5.61 (13.43)	4.48 (12.06)	7.02 (13.54)	7.04 (13.48)	6.18 (13.02)	7.78 (16.11)	10.23 (18.65)	12.22 (20.41)	10.08 (18.39)
PSKE @ 5%	7.93 (16.29)	9.66 (19.22)	8.33 (16.70)	8.64 (17.40)	4.52 (12.12)	5.71 (16.31)	5.79 (16.22)	5.34 (14.88)	10.00 (18.43)	15.94 (23.49)	14.60 (22.26)	13.51 (21.39)
NSKE @ 5%	14.12 (22.06)	18.54 (25.49)	17.86 (24.99)	16.84 (24.18)	8.05 (16.40)	16.76 (26.17)	9.32 (19.90)	11.38 (20.83)	18.80 (25.67)	26.81 (31.16)	21.96 (27.88)	22.52 (28.24)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	11.49 (19.77)	3.83 (6.59)	0.00 (0.52)	0.00 (0.52)	4.56 (12.14)	1.52 (4.05)	0.00 (0.52)	0.00 (0.52)	5.63 (13.60)	1.88 (4.53)
Mean	6.95 (13.65)	10.39 (17.04)	10.99 (19.01)	9.44 (16.57)	4.73 (11.70)	7.80 (14.93)	6.94 (15.93)	6.49 (14.19)	10.01 (16.62)	14.27 (20.10)	14.46 (21.89)	12.91 (19.54)
Comparing the means of	S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)	
A	0.65		2.50		0.74		2.84		0.66		2.54	
B	0.46		1.77		0.52		2.01		0.47		1.80	
A X B	1.13		4.33		1.28		4.93		1.15		4.41	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Third instar mealybugs

The NSKE @ 5% and neem oil @ 2% showed significantly higher mortality with a mean of 16.33 and 15.94 per cent, respectively followed by PSKE @ 5% (13.16%) (Table 20). Dhanuvit @ 1 ml/l resulted significantly higher mortality (13.14%) followed by FORS @ 5 ml/l with 12.56 per cent mortality.

The interaction of neem oil @ 2% with Dhanuvit @ 1 ml/l caused significantly higher mortality of 20.37 per cent, but it was on par with NSKE @ 5% + Dhanuvit @ 1 ml/l, neem oil @ 2% + FORS @ 5 ml/l, NSKE @ 5% + FORS @ 5 ml/l and PSKE @ 5% + Dhanuvit @ 1 ml/l with mortality of 18.21, 17.89, 16.73 and 16.48 per cent, respectively.

4.3.1.2b During 2010-11

First instar mealybugs

Significantly higher mortality (16.84%) was registered in the botanical NSKE @ 5% on first instar mealybug and proved superior compared to rest of the botanicals (Table 21). The adjuvant, FORS @ 5 ml/l recorded significantly higher mortality of first instar mealybug (10.99%). The next best adjuvant was Dhanuvit @ 1 ml/l with a mean per cent mortality of 10.39 at 1 DAT (Table 21).

The interactions of NSKE @ 5% + Dhanuvit @ 1 ml/l, neem oil @ 2% + Dhanuvit @ 1 ml/l and NSKE @ 5% + FORS @ 5 ml/l recorded significantly higher mortality of 18.54, 18.08 and 17.86 per cent, respectively. However, these were on par with NSKE @ 5% + APSA-80 @ 1 ml/l and neem oil @ 2% + FORS @ 5 ml/l with an average mortality of 14.12 and 13.27 per cent, respectively.

Second instar mealybugs

NSKE@ 5% maintained its superiority in recording significantly higher mortality (11.38%) which was on par with neem oil @ 2% with mortality of 8.86 per cent. All the botanical treatments were effective on the second instar mealybugs except CAKSE @ 5%. Among the adjuvants, FORS @ 5 ml/l was significantly effective in causing mortality of 7.80 per cent, which was on par with Dhanuvit @ 1 ml/l (6.94%).

The combination of NSKE @ 5% + Dhanuvit @ 1 ml/l resulted significantly higher mortality of 16.76 per cent. The next better treatment combinations were neem oil @ 2% with Dhanuvit @ 1 ml/l (11.62%), NSKE @ 5% with FORS @ 5 ml/l (9.32%) and APSA-80 @ 1 ml/l (8.05%), *Pongamia* oil @ 2% with FORS @ 5 ml/l (6.82%) and PSKE @ 5% with FORS @ 5 ml/l (5.79%) and Dhanuvit @ 1 ml/l (5.71%) at 1 DAT (Table 21).

Third instar mealybugs

The botanical NSKE @ 5% showed higher mortality of 22.52 per cent on third instar mealybug. The next best botanical was neem oil @ 2% with a mean per cent mortality of 17.60 as compared to rest of the botanicals (Table 21). Non-significant mortality was observed between adjuvants, FORS @ 5 ml/l and Dhanuvit @ 1 ml/l with an average of 14.46 and 14.27 per cent, respectively as compared to APSA-80 @ 1 ml/l (10.01 %).

The combination of NSKE @ 5% with Dhanuvit @ 1 ml/l was significantly effective to third instar mealybugs causing mortality of 26.81 per cent, which was on par with NSKE @ 5% and FORS @ 5 ml/l with mortality of 21.96 per cent as compared to rest of the combinations (Table 21).

4.3.1.2b Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The botanical NSKE @ 5% recorded significantly higher mortality of mealybugs (18.16%), which was followed by neem oil @ 2% (13.81%) and PSKE @ 5% (11.36%) as compared to rest of the botanicals. The adjuvant, FORS @ 5 ml/l resulted significantly higher mortality (12.07%) followed by Dhanuvit @ 1 ml/l with mortality of 10.98 per cent on first instar mealybugs (Table 22).

The interaction of NSKE @ 5% + Dhanuvit @ 1 ml/l was significantly superior in causing mortality of 20.65 per cent. This was on par with NSKE @ 5% + FORS @ 5 ml/l, neem oil @ 2% + Dhanuvit @ 1 ml/l and NSKE @ 5% + APSA-80 @ 1 ml/l with mortality of 18.37, 17.93 and 15.47 per cent, respectively (Table 22).

Table 22. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments	Corrected per cent mortality of mealybugs											
Botanicals (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	7.40 (15.67)	9.12 (17.56)	9.11 (17.49)	8.54 (16.91)	4.48 (12.17)	6.19 (14.19)	8.97 (17.35)	6.55 (14.57)	7.85 (16.25)	12.99 (21.08)	11.98 (20.22)	10.94 (19.19)
Neem oil @ 2%	9.65 (18.04)	17.93 (25.02)	13.86 (21.76)	13.81 (21.61)	9.08 (17.44)	16.16 (23.68)	11.05 (19.31)	12.10 (20.14)	12.28 (20.49)	20.01 (26.56)	16.41 (23.75)	16.23 (23.60)
CASE @ 5%	4.44 (12.12)	5.57 (13.62)	7.28 (15.49)	5.77 (13.74)	4.50 (12.19)	6.94 (14.73)	7.58 (15.58)	6.34 (14.17)	6.15 (14.24)	9.68 (18.10)	10.00 (18.26)	8.61 (16.87)
PSKE @ 5%	9.52 (17.95)	12.05 (20.18)	12.50 (20.64)	11.36 (19.59)	6.35 (14.47)	7.58 (15.95)	8.72 (17.12)	7.55 (15.85)	8.97 (17.40)	15.54 (23.13)	12.68 (20.66)	12.40 (20.40)
NSKE @ 5%	15.47 (23.14)	20.65 (27.00)	18.37 (25.37)	18.16 (25.17)	9.70 (18.12)	17.80 (24.87)	14.29 (22.17)	13.93 (21.72)	16.44 (23.88)	21.34 (27.50)	18.52 (25.40)	18.77 (25.59)
Adjuvant alone	0.00 (0.52)	0.56 (2.47)	11.30 (19.56)	3.95 (7.34)	0.00 (0.52)	0.00 (0.52)	7.84 (16.17)	2.61 (5.39)	0.00 (0.52)	0.00 (0.52)	6.71 (15.00)	2.24 (5.00)
Mean	7.75 (14.49)	10.98 (17.64)	12.07 (20.05)	10.27 (17.39)	5.69 (12.40)	9.11 (15.57)	9.74 (17.95)	8.18 (15.31)	8.61 (15.38)	13.26 (19.40)	12.72 (20.55)	11.53 (18.44)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.69		2.63		0.80		3.09		0.66		2.55	
B	0.48		1.86		0.57		2.18		0.47		1.80	
A X B	1.19		4.56		1.39		5.35		1.15		4.42	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Table 23. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2009-10

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B) Botanicals (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	18.03 (25.06)	21.74 (27.78)	19.72 (26.33)	19.83 (26.39)	5.83 (13.80)	13.40 (21.45)	14.27 (22.18)	11.17 (19.15)	12.04 (20.25)	20.48 (26.89)	19.52 (26.20)	17.35 (24.45)
Neem oil @ 2%	20.03 (26.58)	32.71 (34.87)	32.33 (34.64)	28.36 (32.03)	7.70 (16.10)	15.13 (22.88)	9.37 (17.81)	10.73 (18.93)	18.44 (25.38)	32.23 (34.56)	25.30 (30.18)	25.32 (30.04)
CASE @ 5%	12.81 (20.65)	14.20 (22.12)	14.43 (22.31)	13.81 (21.69)	4.77 (12.39)	11.05 (19.40)	10.15 (18.44)	8.65 (16.75)	8.30 (16.63)	12.50 (20.68)	14.40 (22.28)	11.73 (19.86)
PSKE @ 5%	19.99 (26.53)	28.68 (32.36)	24.20 (29.44)	24.29 (29.45)	7.28 (15.63)	9.94 (18.33)	13.87 (21.84)	10.36 (18.60)	9.88 (18.24)	15.09 (22.85)	14.77 (22.58)	13.25 (21.22)
NSKE @ 5%	24.40 (29.58)	32.24 (34.58)	27.50 (31.61)	28.05 (31.93)	16.03 (23.59)	30.49 (33.50)	27.07 (31.33)	24.53 (29.48)	24.73 (29.81)	34.96 (36.23)	29.26 (32.73)	29.65 (32.92)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	16.27 (23.75)	5.42 (7.92)	0.00 (0.52)	0.00 (0.52)	5.79 (13.74)	1.93 (4.58)	0.00 (0.52)	0.00 (0.52)	10.80 (19.03)	3.60 (6.34)
Mean	15.88 (21.40)	21.60 (25.29)	22.41 (28.01)	19.96 (24.90)	6.94 (13.59)	13.34 (19.26)	13.42 (20.89)	11.23 (17.91)	12.23 (18.39)	19.21 (23.54)	19.01 (25.50)	16.82 (22.47)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.51		1.97		0.49		1.89		0.50		1.91	
B	0.36		1.39		0.35		1.34		0.35		1.35	
A X B	0.89		3.41		0.85		3.27		0.86		3.30	

NSKE- Neem seed kernel extract @ 5%

CASKE- Custard apple kernel seed extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

FORS- Fish oil rosin soa @ 5ml/l

Figures in parentheses are Arcsine transformations

Second instar mealybugs

The mortality of mealybug was significantly higher in botanical NSKE @ 5% (13.93%) and neem oil @ 2% (12.10%) followed by PSKE @ 5%, *Pongamia* oil @ 2% and CAKSE @ 5% with mortality of 7.55, 6.55 and 6.34 per cent, respectively. The adjuvant, FORS @ 5 ml/l recorded significantly higher per cent mortality (9.74 %) followed by Dhanuvit @ 1 ml/l with mortality of 9.11 per cent, as compared to APSA-80 (5.69%) (Table 22).

The interaction of NSKE @ 5% with Dhanuvit @ 1 ml/l resulted higher mortality of 17.80 per cent on second instar mealybug, which was on par with neem oil @ 2% + Dhanuvit @ 1 ml/l and NSKE @ 5% + FORS @ 5 ml/l with mortality of 16.16 and 14.29 per cent, respectively. However, all the combination of the botanicals with adjuvants were superior over the water spray in combination with different adjuvants (Table 22).

Third instar mealybugs

The botanical NSKE @ 5% and neem oil @ 2% were highly effective against third instar mealybug with mortality of 18.77 and 16.23 per cent, respectively (Table 22). No significant difference was recorded between Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with mortality of 13.26 and 12.72 per cent (Table 22) as compared to APSA-80 @ 1 ml/l (8.61%).

The interaction of NSKE @ 5% and neem oil @ 2% with Dhanuvit @ 1 ml/l registered significantly higher mortality of 21.34 and 20.01 per cent, respectively. These were found on par with NSKE @ 5% + FORS @ 5 ml/l, neem oil @ 2% + FORS 5 ml/l, NSKE @ 5% + APSA-80 @ 1 ml/l and PSKE @ 5% + Dhanuvit @ 1 ml/l with mortality of 18.52, 16.44, 16.41 and 15.54 per cent, respectively. However, rest of the combination of botanicals and adjuvants were effective against mealybug as compared to water spray with adjuvants (Table 22).

4.3.1.3 Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment (2 DAT)

4.3.1.3a. During 2009-10

First instar mealybugs

The botanical neem oil @ 2% registered superiority in causing mortality (28.36%) of first instar mealybug followed by NSKE @ 5% with mortality of 28.05 per cent as compared to other botanicals (Table 23). The adjuvant, FORS @ 5 ml recorded significantly higher mortality of 22.41 per cent. The next better adjuvant was Dhanuvit @ 1 ml/l (21.60%).

The interactions of neem oil @ 2% + Dhanuvit @ 1 ml/l, neem oil @ 2% + FORS @ 5 ml/l and NSKE @ 5% + Dhanuvit @ 1 ml/l recorded significantly superior mortality over other combination of botanicals with adjuvant (32.71, 32.33 and 32.24 per cent, respectively). These were on par with PSKE @ 5% + Dhanuvit @ 1 ml/l and NSKE @ 5% + FORS @ 5 ml/l with a mean mortality of 28.68 and 27.50 per cent (Table 23).

Second instar mealybugs

The botanical NSKE @ 5% was significantly superior in recording highest mortality (24.53%) of second instar mealybug as compared to other botanicals (Table 23). The adjuvants, FORS and Dhanuvit @ 1 ml/l encountered significantly higher mortality (13.42 and 13.34 per cent, respectively) than APSA-80 (6.94%).

The combinations of NSKE @ 5% with Dhanuvit @ 1 ml/l and FORS @ 5 ml/l were found significantly superior over rest of the combinations with mortality of 30.49 and 27.07 per cent, respectively. However, the lower mortality was registered in combination of CAKSE @ 5% and APSA-80 @ 1 ml/l (4.77%).

Third instar mealybugs

Among botanicals, the NSKE @ 5% and neem oil @ 2% resulted significantly superior mortality (29.65 and 25.32 %, respectively) over rest of the botanicals. However, the least mortality was recorded by CAKSE @ 5% (11.73%). The adjuvant, Dhanuvit @ 1 ml/l recorded significantly higher mortality (19.21%) of mealybug followed by FORS @ 5 ml/l (Table 23) with a mean of 19.01 per cent as compared to APSA-80 @ 1 ml/l (12.23%).

Table 24. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2010-11

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Botanicals (A)												
<i>Pongamia</i> oil @ 2%	17.28 (24.53)	23.74 (29.09)	19.43 (25.77)	20.15 (26.46)	10.72 (19.11)	17.06 (24.36)	12.18 (20.38)	13.32 (21.28)	13.84 (21.77)	16.63 (24.04)	11.54 (19.85)	14.01 (21.89)
Neem oil @ 2%	23.31 (28.82)	33.27 (35.21)	31.05 (33.84)	29.21 (32.62)	13.37 (21.42)	21.08 (27.29)	16.41 (23.88)	16.95 (24.20)	17.08 (24.38)	23.52 (28.98)	16.69 (24.10)	19.09 (25.82)
CAKSE @ 5%	12.31 (20.50)	16.02 (23.57)	16.63 (24.04)	14.99 (22.70)	11.74 (20.00)	12.48 (20.42)	13.64 (21.60)	12.62 (20.67)	4.68 (12.33)	7.28 (15.28)	4.86 (12.61)	5.61 (13.41)
PSKE @ 5%	19.75 (26.36)	23.97 (29.26)	21.02 (27.27)	21.58 (27.63)	13.10 (21.17)	19.75 (26.36)	22.20 (28.06)	18.35 (25.19)	16.05 (23.58)	18.63 (25.55)	12.97 (21.06)	15.89 (23.40)
NSKE @ 5%	38.91 (38.58)	46.16 (42.78)	42.12 (40.45)	42.40 (40.60)	32.91 (34.98)	42.12 (40.45)	30.69 (33.62)	35.24 (36.35)	26.00 (30.64)	33.31 (35.23)	23.19 (28.75)	27.50 (31.54)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	19.73 (26.35)	6.58 (8.78)	0.00 (0.52)	0.00 (0.52)	14.25 (22.08)	4.75 (7.36)	0.00 (0.52)	0.00 (0.52)	18.15 (25.19)	6.05 (8.40)
Mean	18.59 (23.13)	23.86 (26.65)	25.00 (29.62)	22.48 (20.74)	13.64 (19.44)	18.75 (24.94)	18.23 (23.15)	16.87 (22.51)	12.94 (18.78)	16.56 (21.51)	14.57 (21.93)	14.69 (26.47)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.73		2.79		0.61		2.35		0.59		2.26	
B	0.51		1.97		0.43		1.66		0.42		1.60	
A X B	1.26		4.84		1.06		4.08		1.02		3.91	

NSKE- Neem seed kernel extract @ 5%

CASKE- Custard apple kernel seed extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Figures in parentheses are Arcsine transformations

The combination of botanical NSKE @ 5% with Dhanuvit @ 1 ml/l registered significantly higher mortality (34.96%), which was on par with neem oil @ 2% + Dhanuvit @ 1 ml/l with 32.23 per cent as compared to rest of the interaction combinations (Table 23). However, the remaining combinations of botanicals with adjuvants were also effective on mealybugs.

4.3.1.3b During 2010-11

First instar mealybugs

The botanical NSKE @ 5% recorded significantly higher mortality (42.40%) of first instar mealybug, among the different botanicals. However, lowest mortality (14.99%) was recorded in CAKSE @ 5% (Table 24). The adjuvant, FORS @ 5 ml/l recorded significantly higher mortality of 25.00 per cent. The next better treatment was Dhanuvit @ 1 ml/l with mortality of 23.86 per cent (Table 24).

Among the combinations of botanicals and adjuvants, the NSKE @ 5% with Dhanuvit @ 1 ml/l and FORS @ 5 ml/l registered significantly higher mortality with 46.16 and 42.2 per cent, respectively, which were on par with NSKE @ 5% with APSA-80 @ 1 ml/l (38.91 %).

Second instar mealybugs

Significantly higher mortality was noted in botanical NSKE @ 5% (35.24%) as compared to rest of the botanicals. The next better botanicals included PSKE @ 5% (18.35%) and neem oil @ 2% (16.95%). Among the adjuvants, Dhanuvit @ 1 ml/l recorded significantly higher mortality on second instar mealybug (18.75 %) (Table 24). The next better adjuvant was FORS @ 5 ml/l (18.23%) followed by APSA-80 @ 1 ml/l (13.64 %).

NSKE @ 5% and Dhanuvit @ 1 ml/l interaction registered significantly higher mortality (42.12 %) as compared to rest of the combinations (Table 24). However, the next better combinations were NSKE @ 5% with APSA-80 @ 1 ml/l (32.91%) and FORS @ 5 ml/l (30.69%).

Third instar mealybugs

The botanical NSKE @ 5% exerted significantly higher mortality of 27.50 per cent on third instar mealybug as compared to rest of the botanicals. However, least mortality was observed in the botanical CAKSE @ 5% (5.61%) (Table 24). No significant differences were observed between the adjuvants Dhanuvit @ 1 ml/l and FORS @ 5 ml/l, which registered a mortality of 16.56 and 14.27 per cent, respectively.

Among the combinations of botanicals with adjuvants, the combination of NSKE @ 5% with Dhanuvit @ 1 ml/l resulted higher mortality (33.31%). The next better combination was NSKE @ 5% with APSA-80 @ 1 ml/l (26.00%).

4.3.1.3c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The botanical NSKE @ 5% recorded significantly higher mortality with a mean of 35.22 per cent (Table 25) followed by neem oil @ 2% (28.78%). However, all the botanicals were found superior over water spray with adjuvants (6.00%). The adjuvant FORS @ 5 ml/l was most effective with a mortality of 23.70 per cent followed by Dhanuvit @ 1 ml/l (22.72%) (Table 25).

Significantly higher mortality was observed in combinations of NSKE @ 5% with Dhanuvit @ 1 ml/l (39.19%) and FORS @ 5 ml/l (34.81%), which were on par with neem oil @ 2% with Dhanuvit @ 1 ml/l (32.98%) and FORS @ 5 ml/l (31.70%) and NSKE @ 5% + APSA-80 @ 1 ml/l (31.65%) (Table 25).

Second instar mealybugs

The botanical NSKE @ 5% exhibited significantly higher mortality (29.94%) of second instar mealybug followed by PSKE @ 5% neem oil @ 2% and *Pongamia* oil @ 2% with a mean mortality of 14.36, 13.84 and 12.02 per cent, respectively. Non-significant differences were observed between adjuvants Dhanuvit @ 1 ml/l (16.01) and FORS @ 5 ml/l (15.77%) as compared to APSA-80 @ 1 ml/l which recorded lowest mortality (10.29%) (Table 25).

Among the interactions, the NSKE @ 5% + Dhanuvit @ 1 ml/l registered significantly higher mortality (36.31%), which was on par with NSKE @ 5% + FORS @ 5 ml/l with a mean mortality of 29.04 per cent as compared to rest of the interactions.

Table 25. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B) Botanicals (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	17.66 (24.80)	22.74 (28.45)	19.58 (26.01)	19.99 (26.42)	8.28 (16.70)	15.07 (22.76)	12.72 (20.62)	12.02 (20.03)	12.94 (21.04)	18.56 (25.50)	15.54 (23.15)	15.68 (23.23)
Neem oil @ 2%	21.67 (27.68)	32.98 (35.00)	31.70 (34.24)	28.78 (32.30)	10.54 (18.91)	18.11 (25.16)	12.89 (20.99)	13.84 (21.69)	17.76 (24.90)	27.87 (31.84)	21.00 (27.26)	22.21 (28.00)
CASKE @ 5%	12.56 (20.71)	15.07 (22.79)	15.53 (23.15)	14.39 (22.22)	8.25 (16.67)	11.76 (19.91)	11.89 (20.08)	10.64 (18.89)	6.49 (14.72)	9.89 (18.22)	9.63 (18.03)	8.67 (16.99)
PSKE @ 5%	19.87 (26.44)	26.33 (30.85)	22.61 (28.35)	22.94 (28.55)	10.19 (18.54)	14.85 (22.64)	18.04 (25.02)	14.36 (22.07)	12.96 (21.09)	16.86 (24.21)	13.87 (21.82)	14.57 (22.37)
NSKE @ 5%	31.65 (34.21)	39.19 (38.74)	34.81 (36.12)	35.22 (36.36)	24.47 (29.59)	36.31 (37.02)	29.04 (32.55)	29.94 (33.06)	25.36 (30.21)	34.13 (35.72)	26.22 (30.73)	28.57 (32.22)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	18.00 (25.09)	6.00 (8.36)	0.00 (0.52)	0.00 (0.52)	10.02 (18.44)	3.34 (6.15)	1.11 (3.51)	0.00 (0.52)	14.48 (22.30)	5.20 (8.60)
Mean	17.24 (22.31)	22.72 (25.97)	23.70 (28.83)	21.22 (25.70)	10.29 (16.73)	16.01 (21.25)	15.77 (22.95)	14.02 (20.31)	12.77 (19.24)	17.89 (22.58)	16.79 (23.88)	15.82 (21.90)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.71		2.72		0.73		2.79		0.74		2.83	
B	0.50		1.92		0.51		1.97		0.52		2.00	
A X B	1.23		4.71		1.26		4.83		1.27		4.90	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASKE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Table 26. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2009-10

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
Botanicals (A)	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	19.13 (25.91)	23.10 (28.71)	26.32 (30.85)	22.85 (28.49)	6.11 (14.28)	10.01 (18.41)	14.18 (22.11)	10.10 (18.27)	17.83 (24.93)	23.21 (28.78)	18.04 (25.06)	19.70 (26.26)
Neem oil @ 2%	32.71 (34.86)	42.20 (40.50)	46.09 (42.74)	40.33 (39.36)	16.73 (24.12)	29.43 (32.84)	17.60 (24.79)	21.26 (27.25)	22.73 (28.39)	32.64 (34.76)	27.12 (31.02)	27.49 (31.39)
CASE @ 5%	19.91 (26.49)	24.80 (29.85)	22.40 (28.23)	22.37 (28.19)	4.23 (11.78)	4.87 (12.67)	14.73 (22.54)	7.94 (15.67)	10.34 (18.65)	12.83 (20.81)	11.59 (19.82)	11.59 (19.76)
PSKE @ 5%	23.54 (29.01)	32.61 (34.80)	35.11 (36.32)	30.42 (33.38)	11.58 (19.86)	8.44 (16.88)	10.03 (18.44)	10.02 (18.39)	19.22 (25.95)	22.53 (28.32)	18.76 (25.56)	20.17 (26.61)
NSKE @ 5%	36.13 (36.92)	45.68 (42.50)	34.60 (36.01)	38.81 (38.48)	25.97 (30.62)	39.80 (39.10)	31.24 (33.93)	32.33 (34.55)	25.54 (30.31)	34.34 (35.68)	28.85 (32.48)	29.58 (32.82)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	19.62 (26.28)	6.54 (8.76)	0.00 (0.52)	0.00 (0.52)	10.18 (18.58)	3.39 (6.19)	0.00 (0.52)	0.00 (0.52)	11.00 (19.27)	3.67 (6.42)
Mean	21.90 (25.53)	28.07 (29.39)	30.69 (33.40)	26.89 (29.44)	10.77 (16.78)	15.43 (19.98)	16.33 (23.40)	14.17 (20.05)	15.94 (21.37)	20.92 (24.72)	19.23 (25.54)	18.70 (23.88)
Comparing the means of	S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)	
A	0.36		1.40		0.40		1.53		0.47		1.81	
B	0.26		0.99		0.28		1.08		0.33		1.28	
A X B	0.63		2.43		0.69		2.65		0.82		3.14	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Third instar mealybugs

Significantly higher mortality was observed in the botanical NSKE @ 5% with a mean of 28.57 per cent (Table 25). The next better botanical was neem oil @ 2% with a mortality of 22.21 per cent as compared to rest of the botanicals. No significant difference was observed between FORS @ 5 ml/l (16.79%) and Dhanuvit @ 1 ml/l (17.89%) on mortality of mealybug as compared to APSA-80 @ 1 ml/l (12.77%) (Table 25).

Significantly higher mortality was recorded in the combination of NSKE @ 5% and Dhanuvit @ 1 ml/l with an average of 34.13 per cent mortality, which was on par with neem oil @ 2% + Dhanuvit @ 1 ml/l (27.87%) (Table 25).

4.3.1.4 Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment (3 DAT)

4.3.1.4a During 2009-10

First instar mealybugs

The botanical neem oil @ 2% proved significantly superior in registering highest mortality (40.33%) followed by NSKE @ 5% with 38.81 per cent mortality. The adjuvant, FORS @ 5% proved significantly superior over other adjuvants with mortality of 30.69 per cent. The next better adjuvant was Dhanuvit @ 1 ml/l (28.07%) on first instar mealybug (Table 26).

Among the combinations, the neem oil @ 2% + FORS @ 5 ml/l, NSKE @ 5% + Dhanuvit @ 1 ml/l and neem oil @ 2% + Dhanuvit @ 1 ml/l registered significantly higher mortality (46.09, 45.68, and 42.20 per cent, respectively) as compared to rest of combinations. The combinations NSKE @ 5% + APSA-80 @ 1 ml/l (36.13%) and NSKE @ 5% + FORS @ 5 ml/l (34.60%) were on par with each other (Table 26). However, lower per cent mortality of mealybug was recorded in combination of *Pongamia* oil @ 2% + APSA-80 @ 1 ml/l (19.13%).

Second instar mealybugs

The botanical NSKE @ 5% exerted significantly higher mortality of second instar mealybug (32.33%), which was superior over other botanicals. The next better botanical was neem oil @ 2% with mortality of 21.26 per cent (Table 26). Significantly, higher mortality was observed in FORS @ 5 ml/l with mortality of 16.33 per cent. The next best adjuvant was Dhanuvit @ 1 ml/l with mean mortality of 15.43 per cent.

The interaction of NSKE @ 5% and Dhanuvit @ 1 ml/l proved to be most effective by causing highest mortality mealybug (39.80%), followed by combination of NSKE @ 5% with adjuvant FORS @ 5 ml/l and neem oil @ 2% + Dhanuvit @ 1 ml/l with mortality of 31.24 and 29.43 per cent, respectively (Table 26).

Third instar mealybugs

Significantly higher mortality of third instar mealybug was recorded in botanical NSKE @ 5% (29.58 %). The next better treatment was neem oil @ 2% (27.49%). However, the lower mortality was observed in the botanical CAKSE @ 5% (11.59%). Among different adjuvants, the Dhanuvit @ 1 ml/l and FORS 5 ml/l exerted significantly higher mortality of mealybugs with a mean of 20.92 and 19.23 per cent, respectively (Table 26).

The combination of NSKE @ 5% and Dhanuvit @ 1 ml/l was found toxic in causing highest mortality (34.34%) of third instar mealybugs, which was on par with neem oil @ 2% + Dhanuvit @ 1 ml/l (32.64 %) as compared to rest of the combinations (Table 26).

4.3.1.4b During 2010-11

First instar mealybugs

The botanical NSKE @ 5% registered significantly higher mortality of 51.28 per cent on first instar mealybug, followed by neem oil @ 2% (40.14%). However, lowest mortality was observed in botanical CAKSE @ 5% (11.88%) (Table 27). The adjuvant FORS @ 5 ml/l registered higher mortality (29.95%) on first instar mealybug. The next better adjuvant was Dhanuvit @ 1 ml/l with mortality of 27.56 per cent as compared APSA-80 @ 1 ml/l (21.58%).

Table 27. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2010-11

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	14.44 (22.31)	18.47 (25.44)	18.84 (25.68)	17.25 (24.48)	18.69 (25.57)	22.07 (28.01)	22.25 (28.11)	21.00 (27.23)	23.91 (29.24)	31.16 (33.91)	31.37 (34.01)	28.82 (32.38)
Neem oil @ 2%	33.82 (35.54)	44.34 (41.72)	42.28 (40.53)	40.14 (39.26)	23.91 (29.25)	33.30 (35.23)	33.45 (35.30)	30.22 (33.26)	35.61 (36.62)	48.05 (43.86)	39.26 (38.78)	40.97 (39.76)
CASE @ 5%	8.47 (16.82)	13.11 (21.13)	14.07 (21.99)	11.88 (19.98)	10.67 (18.98)	12.77 (20.91)	17.19 (24.48)	13.54 (21.46)	12.68 (20.85)	14.69 (22.49)	26.19 (30.74)	17.85 (24.69)
PSKE @ 5%	26.48 (30.96)	32.78 (34.90)	29.84 (33.09)	29.70 (32.98)	17.83 (24.93)	24.60 (29.71)	25.51 (30.28)	22.65 (28.31)	23.09 (28.71)	29.79 (33.06)	26.63 (31.05)	26.50 (30.94)
NSKE @ 5%	46.30 (42.86)	56.67 (48.86)	50.87 (45.48)	51.28 (45.73)	39.65 (39.01)	62.74 (52.37)	46.29 (42.85)	49.56 (44.75)	50.30 (45.15)	64.29 (53.31)	54.06 (47.32)	56.22 (48.59)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	23.81 (29.19)	7.94 (9.73)	0.00 (0.52)	0.00 (0.52)	12.51 (20.71)	4.17 (6.90)	0.00 (0.52)	0.00 (0.52)	19.99 (26.52)	6.67 (8.84)
Mean	21.58 (24.75)	27.56 (28.68)	29.95 (32.66)	26.36 (28.70)	18.46 (22.96)	25.91 (27.70)	26.20 (30.29)	23.52 (26.98)	24.27 (26.76)	31.33 (31.10)	32.92 (34.74)	29.51 (30.87)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.68		2.62		0.50		1.93		0.64		2.45	
B	0.48		1.85		0.36		1.37		0.45		1.73	
A X B	1.18		4.54		0.87		3.35		1.10		4.24	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASKE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Table 28. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
Botanicals (A)	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	16.81 (24.12)	20.78 (27.09)	22.59 (28.33)	20.06 (26.51)	11.79 (20.03)	15.00 (22.76)	18.22 (25.23)	15.00 (22.67)	20.87 (27.14)	27.19 (31.41)	27.71 (29.78)	24.26 (29.44)
Neem oil @ 2%	33.26 (35.21)	43.27 (41.11)	44.18 (41.63)	40.24 (39.32)	20.33 (26.76)	31.39 (34.03)	25.54 (30.28)	25.75 (30.35)	29.17 (32.66)	40.34 (39.39)	33.19 (35.11)	34.23 (35.72)
CASE @ 5%	14.19 (22.08)	18.96 (25.79)	18.23 (25.17)	17.13 (24.35)	8.38 (16.81)	11.18 (19.51)	14.42 (22.16)	11.33 (19.49)	11.51 (19.81)	13.76 (21.68)	18.89 (25.71)	14.72 (22.40)
PSKE @ 5%	25.00 (29.97)	32.69 (34.86)	32.64 (34.81)	30.11 (33.21)	12.77 (20.92)	15.75 (23.37)	17.20 (24.40)	15.24 (22.90)	21.16 (27.36)	26.16 (30.75)	22.69 (28.43)	23.33 (28.84)
NSKE @ 5%	41.21 (39.90)	51.18 (45.67)	40.67 (39.56)	44.35 (41.71)	30.24 (33.30)	51.27 (45.71)	35.52 (36.52)	39.01 (38.51)	37.92 (37.97)	49.31 (44.59)	41.46 (40.06)	42.90 (40.87)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	21.71 (27.71)	7.24 (9.24)	0.00 (0.52)	0.00 (0.52)	10.56 (18.95)	3.52 (6.32)	0.00 (0.52)	0.00 (0.52)	15.49 (23.14)	5.16 (7.71)
Mean	21.74 (25.21)	27.81 (29.09)	30.00 (32.87)	26.52 (29.06)	13.92 (19.64)	20.77 (24.23)	20.24 (26.26)	18.31 (23.37)	20.11 (24.16)	26.13 (27.97)	26.07 (30.37)	24.10 (27.50)
Comparing the means of	S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)	
A	0.79		3.02		0.70		2.69		0.71		2.71	
B	0.56		2.14		0.49		1.90		0.50		1.92	
A X B	1.36		5.23		1.21		4.65		1.22		4.70	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Among the combinations, the NSKE @ 5% and Dhanuvit @ 1 ml/l resulted significantly higher mortality (56.67%), which was on par with NSKE @ 5% and FORS @ 5 ml/l with an average mortality of 50.67 per cent. However, the combinations NSKE @ 5% + APSA-80 @ 1 ml/l, neem oil @ 2% + Dhanuvit @ 1 ml/l and neem oil @ 2% + FORS @ 5 ml/l performed better in causing mortality of 46.30, 44.34 and 42.28 per cent, respectively as compared to other combinations (Table 27).

Second instar mealybugs

Among the botanicals NSKE @ 5% exerted significantly higher mortality of 49.56 per cent followed by neem oil @ 2% with a mean mortality of 30.22 per cent. Whereas, the botanical PSKE @ 5% and *Pongamia* oil @ 2% showed mortality of 22.65 and 21.00 per cent, respectively. However, the lowest mortality was recorded in the botanical CAKSE @ 5% (13.54%) on second instar mealybugs (Table 27). Among the adjuvants, significantly higher mortality was recorded in FORS @ 5 ml/l (26.20%), followed by Dhanuvit @ 1 ml/l with a mortality of 25.91 per cent. However, the APSA-80 @ 1 ml/l recorded lowest mortality of 18.46 per cent on mealybugs (Table 27).

The interaction of NSKE @ 5% with Dhanuvit @ 1 ml/l was found to be significantly most effective in causing mortality of 62.74 per cent on second instar mealybug. The next better combinations included NSKE @ 5% with FORS @ 5 ml/l and APSA-80 @ 1 ml/l with a mortality of 46.29 and 39.65 per cent, respectively.

Third instar mealybugs

Significantly higher mortality was observed in the botanical NSKE @ 5% with a mean of 56.22 per cent followed by neem oil @ 2% with mortality of 40.97 per cent as compared to rest of the botanicals. The adjuvant FORS @ 5 ml/l exerted significantly higher mortality of 32.92 per cent. The next better adjuvant was Dhanuvit @ 1 ml/l with an average mortality of 31.33 per cent as compared to APSA-80 @ 1 ml/l (24.27%) on third instar mealybugs (Table 27).

Among the interactions of botanicals and adjuvants, the combination of NSKE @ 5% and Dhanuvit @ 1 ml/l resulted significantly higher mortality of 64.29 per cent. However, the next better combinations were NSKE @ 5% with FORS @ 5 ml/l and APSA-80 @ 1 ml/l and neem oil @ 2% with Dhanuvit @ 1 ml/l, which caused mortality of 54.06, 50.30 and 48.05 per cent, respectively as compared to rest of the interactions.

4.3.1.4c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The botanicals NSKE @ 5% and neem oil @ 2% resulted higher mortality of 44.35 and 40.24 per cent, respectively, which were significantly superior over rest of the botanicals. FORS @ 5 ml/l was significantly superior over other adjuvants causing mortality of 28.04 per cent followed by Dhanuvit @ 1 ml/l (27.81%) on first instar mealybug.

The combinations of botanicals with adjuvant were significantly superior over water spray with adjuvant. However, significantly higher mortality was recorded in combination of NSKE @ 5% + Dhanuvit @ 1 ml/l (51.18%), which was on par with neem oil @ 2% with FORS @ 5 ml/l and Dhanuvit @ 1 ml/l with a mean mortality of 44.18 and 43.27 per cent, respectively (Table 28).

Second instar

Significantly higher mortality of mealybug was observed in the botanical NSKE @ 5% (39.01%) followed by neem oil @ 2% with mortality of 25.75 per cent as compared to rest of the botanicals (Table 28). The adjuvant Dhanuvit @ 1 ml/l showed significantly higher mortality, followed by FORS @ 5 ml/l with an average of 20.77 and 20.24 per cent, respectively.

Significantly superior mortality of mealybug was observed in the combination of NSKE @ 5% + Dhanuvit @ 1 ml/l (51.27%) on second instar mealybug as compared to rest of the combinations (Table 28).

Third instar mealybug

The botanical NSKE @ 5% was most effective on third instar mealybug with mortality of 42.90 per cent followed by neem oil @ 2% (34.33%) as compared to other botanicals. The adjuvants FORS @ 5 ml/l and Dhanuvit @ 1 ml/l were most effective on third instar mealybug with an average mortality of 26.07 and 26.13 per cent, respectively (Table 28).

Table 29. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2009-10

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Botanicals (A)												
<i>Pongamia</i> oil @ 2%	22.60 (28.37)	28.02 (31.95)	25.26 (30.13)	25.30 (30.15)	12.97 (21.06)	22.43 (28.25)	20.66 (26.98)	18.69 (25.43)	15.03 (22.79)	18.48 (25.45)	18.46 (25.41)	17.32 (24.55)
Neem oil @ 2%	30.32 (33.35)	38.40 (38.27)	40.65 (39.59)	36.46 (37.07)	19.02 (25.81)	37.12 (37.52)	28.03 (31.95)	28.06 (31.76)	22.35 (28.19)	31.31 (33.99)	22.91 (28.58)	25.53 (30.25)
CASE @ 5%	13.53 (21.51)	18.18 (25.23)	23.58 (29.04)	18.43 (25.26)	6.64 (14.78)	9.10 (17.52)	12.70 (20.87)	9.48 (17.72)	5.67 (13.76)	11.30 (19.55)	9.84 (18.27)	8.94 (17.20)
PSKE @ 5%	25.82 (30.53)	26.12 (30.72)	26.59 (31.03)	26.18 (30.76)	13.47 (21.52)	20.30 (26.76)	21.97 (27.93)	18.58 (25.40)	10.38 (18.78)	18.01 (25.10)	15.87 (23.45)	14.75 (22.44)
NSKE @ 5%	42.11 (40.44)	60.32 (50.96)	43.39 (41.18)	48.61 (44.20)	28.29 (32.11)	48.15 (43.92)	39.52 (38.93)	38.65 (38.32)	18.10 (25.16)	38.60 (38.39)	18.89 (25.73)	25.20 (29.76)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	16.52 (23.86)	5.51 (7.95)	0.00 (0.52)	0.00 (0.52)	17.68 (24.85)	5.89 (8.28)	0.00 (0.52)	0.00 (0.52)	8.85 (17.29)	2.95 (5.76)
Mean	22.40 (25.70)	28.51 (29.52)	29.33 (32.47)	26.75 (29.23)	13.40 (19.21)	22.85 (25.66)	23.43 (28.58)	19.89 (24.49)	11.92 (18.11)	19.62 (23.75)	15.80 (23.12)	15.78 (21.66)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.56		2.14		0.46		1.76		0.38		1.48	
B	0.39		1.51		0.32		1.24		0.27		1.05	
A X B	0.96		3.70		0.79		3.05		0.67		2.56	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASKE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Table 30. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2010-11

Treatments	Corrected per cent mortality of mealybugs											
Botanicals (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	25.53 (30.33)	33.99 (35.64)	32.16 (34.53)	30.56 (33.50)	34.50 (35.95)	45.32 (42.29)	37.59 (37.80)	39.14 (38.68)	37.23 (37.58)	42.61 (40.73)	38.29 (38.21)	39.38 (38.84)
Neem oil @ 2%	48.89 (44.35)	65.67 (54.11)	54.29 (47.45)	56.28 (48.63)	44.44 (41.79)	60.07 (50.80)	52.39 (46.35)	52.30 (46.31)	47.44 (43.51)	68.25 (55.70)	48.82 (44.31)	54.84 (47.84)
CASKE @ 5%	3.96 (11.47)	7.34 (15.61)	17.92 (25.03)	9.74 (17.37)	7.51 (15.70)	14.67 (22.48)	20.77 (27.09)	14.32 (21.76)	6.43 (14.49)	10.35 (18.76)	18.80 (25.68)	11.86 (19.64)
PSKE @ 5%	18.01 (25.10)	21.98 (27.94)	25.56 (30.35)	21.85 (27.80)	25.04 (30.01)	36.76 (37.31)	38.56 (38.35)	33.45 (35.22)	36.03 (36.87)	45.05 (42.14)	43.17 (41.05)	41.42 (40.02)
NSKE @ 5%	62.22 (52.07)	83.81 (66.31)	53.70 (47.11)	66.58 (55.16)	46.97 (43.24)	58.89 (50.15)	55.19 (47.97)	53.68 (47.12)	63.49 (52.84)	75.00 (59.98)	64.44 (53.39)	67.65 (55.40)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	22.92 (28.54)	7.64 (9.51)	0.00 (0.52)	0.00 (0.52)	23.85 (29.21)	7.95 (9.74)	0.00 (0.52)	0.00 (0.52)	23.09 (28.71)	7.70 (9.57)
Mean	26.44 (27.22)	35.46 (33.27)	34.43 (35.50)	32.11 (32.00)	26.41 (27.78)	35.95 (33.84)	38.06 (37.80)	33.47 (33.14)	31.77 (30.88)	40.21 (36.22)	39.44 (38.56)	37.14 (35.22)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.49		1.88		0.62		2.40		0.58		2.24	
B	0.35		1.33		0.44		1.69		0.41		1.58	
A X B	0.85		3.26		1.08		4.15		1.01		3.88	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASKE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Among the interactions of botanicals with different adjuvant, the interaction of NSKE @ 5% + Dhanuvit @ 1 ml/l recorded significantly higher mortality of 49.31 per cent on third instar mealybug, which was on par with NSKE @ 5% with FORS @ 5 ml/l (41.46%). However, the remaining combinations of botanicals with adjuvants were also found superior over water spray (Table 28).

4.3.1.5 Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment (5 DAT)

4.3.1.5a During 2009-10

First instar mealybugs

The botanical NSKE @ 5% resulted significantly higher mortality (48.61 %) among the botanicals. The next better treatment was neem oil @ 2% with a mortality of 36.46 per cent on first instar mealybug. The adjuvant, FORS @ 5 ml/l was significantly superior (29.33%) over other adjuvants. The next better adjuvant was Dhanuvit @ 1 ml/l with a mortality of 28.51 per cent (Table 29).

Among the interaction of botanicals with adjuvants, NSKE @ 5% and Dhanuvit @ 1 ml/l proved significantly superior in causing mortality of 60.32 per cent. However, least mortality was recorded in combination of APSA-80 @ 1 ml/l and CAKSE @ 5% (13.53%).

Second instar mealybugs

NSKE @ 5% recorded significantly higher mortality of 38.65 per cent on second instar mealybugs. The next better botanical was neem oil @ 2% (28.06%). However, among the botanicals the CAKSE @ 5% registered lower mortality of 9.48 per cent. Among the adjuvants, FORS @ 5 ml/l exerted significantly higher mortality of 23.43 per cent on second instar mealybug. The next better treatment was Dhanuvit @ 1 ml/l causing mortality of 22.85 per cent (Table 29).

Significantly superior mortality of mealybug was recorded in the combination of NSKE @ 5% + Dhanuvit @ 1 ml/l (48.15%). However, the next better treatments were NSKE @ 5% + FORS @ 5 ml/l and neem oil @ 2% + Dhanuvit @ 1 ml/l with mortality of 39.52 and 37.12 per cent, respectively (Table 29).

Third instar mealybugs

The botanicals neem oil @ 2% and NSKE @ 5% exerted significantly higher mortality with a mean of 25.53 and 25.20 per cent, respectively. However, among the botanicals the CAKSE @ 5% recorded least mortality (8.94%) on third instar mealybugs (Table 29). The adjuvant Dhanuvit @ 1 ml/l registered higher mortality (19.62%) followed by FORS @ 5 ml/l (18.80%) as compared to remaining adjuvants on third instar mealybug (Table 29).

Among the interaction of botanicals and different adjuvants, the combination of NSKE @ 5% and Dhanuvit @ 1 ml/l showed higher mortality of 38.60 per cent. The next better combination was neem oil @ 2% and Dhanuvit @ 1 ml/l (31.31%) at 5 DAT as compared to rest of the combinations (Table 29).

4.3.1.5b During 2010-11

First instar mealybugs

The botanical NSKE @ 5% resulted significantly higher mortality of 66.60 per cent on first instar mealybug. However, the next best effective botanical was neem oil @ 2% with mortality of 56.28 per cent as compared to other botanicals on mealybugs. The adjuvant FORS @ 5 ml/l showed higher mortality of 34.43 per cent followed by Dhanuvit @ 1 ml/l causing mortality of 35.46 per cent (Table 30).

The combination of NSKE @ 5% with Dhanuvit @ 1 ml/l proved significantly superior over rest of the combinations by causing mortality of 83.81 per cent on first instar mealybugs. However, the next better combinations were neem oil @ 2% + Dhanuvit @ 1 ml/l and NSKE @ 5% + APSA-80 @ 1 ml/l with an average mortality of 65.67 and 62.22 per cent, respectively (Table 30).

Second instar mealybugs

The NSKE @ 5% and neem oil @ 2% recorded significantly higher mortality of second instar mealybug (53.68 and 52.30%) among the botanicals. However, the lower mortality was observed in the botanical CAKSE @ 5% (14.32%). The adjuvant FORS @ 5 ml/l was most effective on the second

instar mealybugs (38.06%) as compared to other adjuvants followed by Dhanuvit @ 1 ml/l by recording 35.95 per cent mortality (Table 30).

The combination of neem oil @ 2% with Dhanuvit @ 1 ml/l was superior by causing significantly higher mortality (60.07%), which was on par with NSKE @ 5% with Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with a mean mortality of 58.89 and 55.19 per cent, respectively.

Third instar mealybugs

Significantly higher mortality was observed in botanical NSKE @ 5% with an average mortality of 67.65 per cent followed by neem oil @ 2% (54.84%). However, the *Pongamia* based botanicals viz., PSKE @ 5% and *Pongamia* oil @ 2% gave 41.42 and 39.38 per cent of mortality, respectively. The adjuvant FORS @ 5 ml/l and Dhanuvit @ 1 ml/l registered higher mortality of 39.44 and 40.21 per cent among the adjuvants on third instar mealybug (Table 30).

The combination of NSKE @ 5% and Dhanuvit @ 1 ml/l resulted higher mortality (75.00%) on third instar mealybug. The next best combinations were neem oil @ 2% + Dhanuvit @ 1 ml/l, NSKE @ 5% + FORS @ 5 ml/l and NSKE @ 5% + APSA-80 @ 1 ml/l with a mean mortality of 68.25, 64.44 and 63.49 per cent, respectively (Table 30).

4.3.1.5a Mean of two years (2009-10 and 2010-11)

First instar mealybug

The botanical NSKE @ 5% was significantly superior over other botanicals with mortality of 57.59 per cent on first instar mealybug followed by neem oil @ 2% (46.37%). However, the botanicals were superior over water spray with different adjuvants on mortality of mealybugs. The adjuvant FORS @ 5 ml/l recorded significantly higher mortality of first instar mealybug with a mean of 32.88 per cent. The next better adjuvant was Dhanuvit @ 1 ml/l with a mortality of 31.99 per cent (Table 31).

The interaction of NSKE @ 5% + Dhanuvit @ 1 ml/l found significantly higher mortality of 72.06 per cent. However, the remaining combinations of botanicals with adjuvants were also found significantly superior as compared to water spray with adjuvants (Table 31).

Second instar mealybug

The botanicals neem oil @ 2% and NSKE @ 5% recorded significantly higher mortality of 38.91 and 39.43 per cent, respectively as compared to remaining botanicals on second instar mealybugs. The adjuvant Dhanuvit @ 1 ml/l registered significantly higher mortality of second instar mealybug with an average of 27.78 per cent followed by FORS @ 5 ml/l (26.93%) as compared to APSA-80 @ ml/l (19.16%) (Table 31).

The combination of neem oil @ 2% and NSKE @ 5% along with Dhanuvit @ 1 ml/l recorded significantly higher mortality with 48.73 and 45.69 per cent, respectively. However, rest of the combinations of botanicals with adjuvants were also found superior in causing mortality on second instar mealybug.

Third instar mealybug

The botanical NSKE @ 5% and neem oil @ 2% recorded significantly higher mortality of 43.98 and 40.18 per cent, respectively. The next better botanicals were *Pongamia* oil @ 2% and PSKE @ 5% with mortality of 28.35 and 26.45, per cent, respectively. Significantly higher mortality was observed in adjuvant FORS @ 5 ml/l (27.14), followed by Dhanuvit @ 1 ml/l with a mortality of 28.68 per cent (Table 31).

The interaction effect of NSKE @ 5% and neem oil @ 2% with Dhanuvit @ 1 ml/l recorded significantly higher mortality of 52.21 and 49.78 per cent, respectively and proved superior over rest of the combinations on third instar mealybugs (Table 31).

4.3.2 Evaluation of different botanicals in combination with entomopathogenic fungus and fish oil rosin soap (FORS) against grapevine mealybug, *Maconellicoccus hirsutus*

4.3.2.1 Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment (12 HAT)

Table 31. Effect of botanicals in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
Botanicals (A)	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
<i>Pongamia</i> oil @ 2%	24.06 (29.35)	31.01 (33.81)	28.71 (32.38)	27.93 (31.85)	24.76 (29.83)	31.89 (34.37)	28.02 (31.94)	28.23 (32.05)	26.13 (30.72)	30.54 (33.53)	28.37 (32.17)	28.35 (32.14)
Neem oil @ 2%	39.60 (38.98)	52.04 (46.15)	47.47 (43.53)	46.37 (42.89)	33.40 (35.29)	45.69 (42.51)	37.65 (37.82)	38.91 (38.54)	34.89 (36.19)	49.78 (44.86)	35.86 (36.76)	40.18 (39.27)
CASE @ 5%	8.75 (17.16)	12.76 (20.92)	20.75 (27.09)	14.09 (21.72)	6.58 (14.85)	12.98 (21.07)	15.31 (23.02)	11.62 (19.65)	6.04 (14.15)	10.83 (19.18)	14.32 (22.22)	10.39 (18.52)
PSKE @ 5%	21.92 (27.89)	24.04 (29.34)	26.07 (30.68)	24.01 (29.31)	17.70 (24.82)	27.39 (31.54)	27.19 (31.42)	24.09 (29.26)	23.19 (28.74)	28.73 (32.38)	27.42 (31.53)	26.45 (30.88)
NSKE @ 5%	52.16 (46.22)	72.06 (58.10)	48.54 (44.15)	57.59 (49.49)	32.53 (34.75)	48.73 (44.24)	37.04 (37.46)	39.43 (38.82)	38.85 (38.54)	52.21 (46.25)	40.90 (39.73)	43.98 (41.51)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	19.72 (26.33)	6.57 (8.78)	0.00 (0.52)	0.00 (0.52)	16.35 (23.83)	5.45 (7.94)	0.00 (0.52)	0.00 (0.52)	15.97 (23.54)	5.32 (7.85)
Mean	24.41 (26.60)	31.99 (31.39)	31.88 (34.03)	29.43 (30.67)	19.16 (23.26)	27.78 (28.96)	26.93 (30.92)	24.62 (27.71)	21.52 (24.72)	28.68 (29.37)	27.14 (30.99)	25.78 (28.36)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.47		1.80		0.51		1.97		0.54		2.07	
B	0.33		1.27		0.36		1.39		0.38		1.46	
A X B	0.81		3.11		0.89		3.42		0.93		3.58	

NSKE- Neem seed kernel extract @ 5%

PSKE- *Pongamia* seed kernel extract @ 5%

Figures in parentheses are Arcsine transformations

CASE- Custard apple kernel seed extract @ 5%

FORS- Fish oil rosin soap @ 5ml/l

Table 32. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment during 2009-10

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	7.19 (15.54)	8.89 (17.27)	3.33 (10.52)	9.33 (17.78)	13.62 (21.65)	8.47 (16.55)	6.67 (14.96)	10.00 (18.43)	6.04 (14.19)	6.67 (14.96)	11.60 (19.90)	8.20 (16.49)	5.56 (13.48)	7.78 (16.11)	3.33 (10.52)	6.67 (14.96)	10.00 (18.43)	6.67 (14.70)
	Without FORS	5.09 (12.96)	8.46 (16.84)	3.33 (10.52)	3.33 (10.52)	9.33 (17.77)	5.91 (13.72)	5.56 (13.48)	6.67 (14.96)	3.32 (10.50)	4.44 (12.00)	9.47 (17.90)	5.89 (13.77)	3.33 (10.52)	3.33 (10.52)	4.44 (12.00)	3.33 (10.52)	6.67 (14.96)	4.22 (11.70)
	Mean	6.14 (14.25)	8.67 (17.06)	3.33 (10.52)	6.33 (14.15)	11.48 (19.71)	7.19 (15.14)	6.11 (14.22)	8.33 (16.69)	4.68 (12.34)	5.56 (13.48)	10.53 (18.90)	7.04 (15.13)	4.44 (12.00)	5.56 (13.31)	3.89 (11.26)	5.00 (12.74)	8.33 (16.69)	5.44 (13.20)
<i>M. anisopliae</i> @ 2 g/l	With FORS	5.56 (13.48)	7.78 (16.11)	4.44 (12.00)	6.21 (14.41)	9.23 (17.68)	6.64 (14.73)	5.56 (13.48)	8.90 (17.34)	4.43 (12.15)	6.82 (15.13)	6.82 (16.56)	6.77 (14.93)	4.44 (12.00)	3.33 (10.52)	4.44 (12.00)	5.56 (13.48)	6.67 (14.96)	4.89 (12.59)
	Without FORS	3.33 (10.52)	5.72 (13.80)	3.33 (10.52)	5.16 (13.05)	8.30 (16.73)	5.17 (12.92)	4.44 (12.00)	5.88 (13.96)	3.32 (10.50)	3.33 (10.52)	3.33 (14.96)	4.73 (12.39)	4.44 (12.00)	3.33 (10.52)	3.33 (10.52)	3.33 (10.52)	3.33 (10.52)	3.56 (10.81)
	Mean	4.44 (12.00)	6.75 (14.96)	3.89 (11.26)	5.68 (13.73)	8.77 (17.20)	5.91 (13.83)	5.00 (12.74)	7.39 (15.65)	3.82 (11.32)	5.08 (12.82)	5.08 (15.76)	5.75 (13.66)	4.44 (12.00)	3.33 (10.52)	3.89 (11.26)	4.44 (12.00)	5.00 (12.74)	4.22 (11.70)
For comparing botanicals (A) and soap solution (C)																			
With FORS		6.37 (14.51)	8.33 (16.69)	3.89 (11.26)	7.77 (16.09)	11.43 (19.66)	7.56 (15.64)	6.11 (14.22)	9.45 (17.88)	5.24 (13.17)	6.74 (15.04)	9.87 (18.23)	7.48 (15.71)	5.00 (12.74)	5.56 (13.31)	3.89 (11.26)	6.11 (14.22)	8.33 (16.69)	5.78 (13.64)
Without FORS		4.21 (11.74)	7.09 (15.32)	3.33 (10.52)	4.24 (11.78)	8.82 (17.25)	5.54 (13.32)	5.00 (12.74)	6.27 (14.46)	3.32 (10.50)	3.89 (11.26)	8.07 (16.43)	5.31 (13.08)	3.89 (11.26)	3.33 (10.52)	3.89 (11.26)	3.33 (10.52)	5.00 (12.74)	3.89 (11.26)
Mean (A)		5.29 (13.12)	7.71 (16.01)	3.61 (10.89)	6.01 (13.94)	10.12 (18.46)		5.56 (13.48)	7.86 (16.17)	4.28 (11.83)	5.32 (13.15)	8.97 (17.33)		4.44 (12.00)	4.44 (11.92)	3.89 (11.26)	4.72 (12.37)	6.67 (14.71)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.38			1.45			0.38			1.45			0.42			1.62		
B		0.24			0.92			0.24			0.92			0.27			1.02		
C		0.24			0.92			0.24			0.92			0.27			1.02		
A X B		0.54			2.05			0.54			2.05			0.60			2.29		
B X C		0.34			1.30			0.34			1.30			0.38			1.45		
A X C		0.54			2.05			0.54			2.05			0.60			2.29		
A X B X C		0.76			2.90			0.76			2.90			0.85			3.24		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

4.3.2.1a During 2009-10

First instar mealybugs

The Botanical NSKE @ 5% exerted significantly higher mortality (10.12%) as compared to other treatments followed by neem oil @ 2% (7.71%). Among the entomopathogens, *L. lecanii* @ 2 g/l caused significantly higher mortality of 7.19 per cent as compared to *M. anisopliae* @ 2 g/l (5.91%). The treatment with FORS @ 5 ml/l resulted significantly higher mortality of 7.56 per cent as compared to without FORS treatment (5.54%) (Table 32).

The interaction of NSKE @ 5% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l caused significantly higher mortality (13.62%) as compared to other combinations.

Second Instar mealybugs

The mortality was significantly higher in NSKE @ 5% (8.97%) followed by neem oil @ 2% (7.86%) as compared to other treatments. The entomopathogen, *L. lecanii* @ 2 g/l showed significantly higher mortality of mealybug (7.04%) as compared to entomopathogen, *M. anisopliae* @ 2 g/l (5.75%). The treatments added with FORS @ 5 ml/l showed higher mortality (7.48%) as compared to treatments of without FORS (5.31%). The addition of adjuvant increased mortality than without adjuvant (Table 32).

Significantly higher per cent mortality was observed in the treatment with NSKE @ 5% and *L. lecanii* @ 2 g/l in combination with adjuvant (11.60%) as compared to other treatments.

Third instars mealybugs

Among the botanicals, NSKE @ 5% was most effective resulting significantly higher mortality (14.71%) as compared to other botanicals. The entomopathogen, *L. lecanii* @ 2 g/l showed significantly higher mortality (5.44 %) as compared to entomopathogen, *M. anisopliae* @ 2 g/l (4.22 %) on third instar mealybugs (Table 32). The treatments with addition of FORS @ 5 ml/l recorded higher mortality of 5.78 per cent compared to without FORS (3.89%).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l recorded significantly higher mortality of mealybugs (10.00%) as compared to other botanicals and entomopathogens with or without FORS @ 5 ml/l (Table 32).

4.3.2.1b During 2010-11

First instar mealybugs

The botanical NSKE @ 5% resulted significantly higher mortality (9.72%) of first instar mealybugs, which was on par with neem oil @ 2% (7.78%). Significant difference was observed in the treatment, *L. lecanii* @ 2 g/l (8.00%) as compared to *M. anisopliae* @ 2 g/l (6.00%). The addition of FORS @ 5 ml/l resulted significantly higher mortality of 9.22 per cent as compared to without adjuvant treatments (4.78%) (Table 33).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l caused significantly higher mortality of first instar of mealybug (15.56%), which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (11.11% each).

Second instar mealybugs

Significantly higher per cent mortality was recorded in NSKE @ 5% (6.94%), which was on par with rest of the botanicals except CAKSE @ 5% (4.72%) (Table 33). There were non-significant differences between the two entomopathogens. However, higher mortality was observed with entomopathogen, *L. lecanii* @ 2 g/l (6.22 %) as compared to *M. anisopliae* @ 2 g/l (4.22%). FORS @ 5 ml/l added treatments showed significantly higher per cent mortality (7.11 %).

The treatment combination with NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality of second instar mealybugs (10.00%) as compared to rest of the combinations. However, least mortality was observed in combination of PSKE @ 5% and *M. anisopliae* @ 2 g/l (3.33%) (Table 33).

Table 32. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment during 2009-10

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	7.19 (15.54)	8.89 (17.27)	3.33 (10.52)	9.33 (17.78)	13.62 (21.65)	8.47 (16.55)	6.67 (14.96)	10.00 (18.43)	6.04 (14.19)	6.67 (14.96)	11.60 (19.90)	8.20 (16.49)	5.56 (13.48)	7.78 (16.11)	3.33 (10.52)	6.67 (14.96)	10.00 (18.43)	6.67 (14.70)
	Without FORS	5.09 (12.96)	8.46 (16.84)	3.33 (10.52)	3.33 (10.52)	9.33 (17.77)	5.91 (13.72)	5.56 (13.48)	6.67 (14.96)	3.32 (10.50)	4.44 (12.00)	9.47 (17.90)	5.89 (13.77)	3.33 (10.52)	3.33 (10.52)	4.44 (12.00)	3.33 (10.52)	6.67 (14.96)	4.22 (11.70)
	Mean	6.14 (14.25)	8.67 (17.06)	3.33 (10.52)	6.33 (14.15)	11.48 (19.71)	7.19 (15.14)	6.11 (14.22)	8.33 (16.69)	4.68 (12.34)	5.56 (13.48)	10.53 (18.90)	7.04 (15.13)	4.44 (12.00)	5.56 (13.31)	3.89 (11.26)	5.00 (12.74)	8.33 (16.69)	5.44 (13.20)
<i>M. anisopliae</i> @ 2 g/l	With FORS	5.56 (13.48)	7.78 (16.11)	4.44 (12.00)	6.21 (14.41)	9.23 (17.68)	6.64 (14.73)	5.56 (13.48)	8.90 (17.34)	4.43 (12.15)	6.82 (15.13)	6.82 (16.56)	6.77 (14.93)	4.44 (12.00)	3.33 (10.52)	4.44 (12.00)	5.56 (13.48)	6.67 (14.96)	4.89 (12.59)
	Without FORS	3.33 (10.52)	5.72 (13.80)	3.33 (10.52)	5.16 (13.05)	8.30 (16.73)	5.17 (12.92)	4.44 (12.00)	5.88 (13.96)	3.32 (10.50)	3.33 (10.52)	3.33 (14.96)	4.73 (12.39)	4.44 (12.00)	3.33 (10.52)	3.33 (10.52)	3.33 (10.52)	3.33 (10.52)	3.56 (10.81)
	Mean	4.44 (12.00)	6.75 (14.96)	3.89 (11.26)	5.68 (13.73)	8.77 (17.20)	5.91 (13.83)	5.00 (12.74)	7.39 (15.65)	3.82 (11.32)	5.08 (12.82)	5.08 (15.76)	5.75 (13.66)	4.44 (12.00)	3.33 (10.52)	3.89 (11.26)	4.44 (12.00)	5.00 (12.74)	4.22 (11.70)
For comparing botanicals (A) and soap solution (C)																			
With FORS		6.37 (14.51)	8.33 (16.69)	3.89 (11.26)	7.77 (16.09)	11.43 (19.66)	7.56 (15.64)	6.11 (14.22)	9.45 (17.88)	5.24 (13.17)	6.74 (15.04)	9.87 (18.23)	7.48 (15.71)	5.00 (12.74)	5.56 (13.31)	3.89 (11.26)	6.11 (14.22)	8.33 (16.69)	5.78 (13.64)
Without FORS		4.21 (11.74)	7.09 (15.32)	3.33 (10.52)	4.24 (11.78)	8.82 (17.25)	5.54 (13.32)	5.00 (12.74)	6.27 (14.46)	3.32 (10.50)	3.89 (11.26)	8.07 (16.43)	5.31 (13.08)	3.89 (11.26)	3.33 (10.52)	3.89 (11.26)	3.33 (10.52)	5.00 (12.74)	3.89 (11.26)
Mean (A)		5.29 (13.12)	7.71 (16.01)	3.61 (10.89)	6.01 (13.94)	10.12 (18.46)		5.56 (13.48)	7.86 (16.17)	4.28 (11.83)	5.32 (13.15)	8.97 (17.33)		4.44 (12.00)	4.44 (11.92)	3.89 (11.26)	4.72 (12.37)	6.67 (14.71)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.38			1.45			0.38			1.45			0.42			1.62		
B		0.24			0.92			0.24			0.92			0.27			1.02		
C		0.24			0.92			0.24			0.92			0.27			1.02		
A X B		0.54			2.05			0.54			2.05			0.60			2.29		
B X C		0.34			1.30			0.34			1.30			0.38			1.45		
A X C		0.54			2.05			0.54			2.05			0.60			2.29		
A X B X C		0.76			2.90			0.76			2.90			0.85			3.24		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Table 33. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at twelve hour after treatment during 2010-11

Treatments		Corrected per cent mortality of mealybugs																		
Entomo pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar						
		Botanicals (A)																		
		Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	
<i>L. lecanii</i> @ 2 g/l	With FORS	8.89 (17.27)	11.11 (19.42)	7.78 (16.11)	7.78 (16.11)	15.56 (23.19)	10.22 (18.42)	6.67 (14.96)	7.78 (16.19)	5.56 (13.48)	8.89 (17.27)	10.00 (18.43)	7.78 (16.06)	5.56 (13.48)	7.78 (16.11)	4.44 (12.00)	5.56 (13.48)	8.89 (17.27)	6.44 (14.47)	
	Without FORS	5.56 (13.48)	6.67 (14.96)	4.44 (12.00)	4.44 (12.00)	7.78 (16.11)	5.78 (13.71)	4.44 (12.16)	4.44 (12.00)	4.44 (12.00)	4.44 (12.00)	5.56 (13.48)	4.67 (12.33)	3.33 (10.52)	5.56 (13.48)	3.33 (10.52)	5.56 (13.48)	6.67 (14.96)	4.89 (12.59)	
	Mean	7.22 (15.37)	8.89 (17.19)	6.11 (14.06)	6.11 (14.06)	11.67 (19.65)	8.00 (16.07)	5.56 (13.56)	6.11 (14.09)	5.00 (12.74)	6.67 (14.63)	7.78 (15.95)	6.22 (14.19)	4.44 (12.00)	6.67 (14.80)	3.89 (11.26)	5.56 (13.48)	7.78 (16.11)	5.67 (13.53)	
<i>M. anisopliae</i> @ 2 g/l	With FORS	7.78 (16.11)	8.89 (17.27)	5.56 (13.48)	7.78 (16.11)	11.11 (19.42)	8.22 (16.48)	6.67 (14.96)	5.56 (13.48)	4.44 (12.00)	7.78 (16.11)	7.78 (16.11)	6.44 (14.53)	4.44 (12.00)	5.56 (13.48)	4.44 (12.00)	4.44 (12.00)	5.56 (13.48)	4.89 (12.59)	
	Without FORS	3.33 (10.52)	4.44 (12.00)	3.33 (10.52)	3.33 (10.52)	4.44 (12.00)	3.78 (11.11)	4.44 (12.16)	4.44 (12.00)	4.44 (12.00)	3.33 (10.52)	4.44 (12.00)	4.22 (11.73)	3.33 (10.52)	4.44 (12.00)	4.44 (12.00)	4.44 (12.00)	4.44 (12.00)	4.22 (11.70)	
	Mean	5.56 (13.31)	6.67 (14.63)	4.44 (12.00)	5.56 (13.31)	7.78 (15.71)	6.00 (13.79)	5.56 (13.56)	5.00 (12.74)	4.44 (12.00)	5.56 (13.31)	6.11 (14.06)	5.33 (13.13)	3.89 (11.26)	5.00 (12.74)	4.44 (12.00)	4.44 (12.00)	5.00 (12.74)	4.56 (12.14)	
For comparing botanicals (A) and soap solution (C)																				
With FORS		8.33 (16.69)	10.00 (18.35)	6.67 (14.80)	7.78 (16.11)	13.33 (21.31)	9.22 (17.45)	6.67 (14.96)	6.67 (14.83)	5.00 (12.74)	8.33 (16.69)	8.89 (17.27)	7.11 (15.30)	5.00 (12.74)	6.67 (14.80)	4.444 (12.00)	5.00 (12.74)	7.22 (15.37)	5.67 (13.53)	
Without FORS		4.44 (12.00)	5.56 (13.48)	3.89 (11.26)	3.89 (11.26)	6.11 (14.06)	4.78 (12.41)	4.44 (12.16)	4.44 (12.00)	4.44 (12.00)	3.89 (11.26)	5.00 (12.74)	4.44 (12.03)	3.33 (10.52)	5.00 (12.74)	3.89 (11.26)	5.00 (12.74)	5.56 (13.48)	4.56 (12.14)	
Mean (A)		6.39 (14.34)	7.78 (15.91)	5.28 (13.03)	5.83 (13.68)	9.72 (17.68)		5.56 (13.56)	5.56 (13.41)	4.72 (12.37)	6.11 (13.97)	6.94 (15.00)		4.17 (11.63)	5.83 (13.77)	4.17 (11.63)	5.00 (12.74)	6.39 (14.43)		
Comparing the means of		S.Em.±				C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.58				2.21			0.58			2.23			0.66			2.52		
B		0.36				1.40			0.37			1.41			0.42			1.60		
C		0.36				1.40			0.37			1.41			0.42			1.60		
A X B		0.82				3.13			0.82			3.15			0.93			3.57		
B X C		0.52				1.98			0.52			1.99			0.59			2.26		
A X C		0.82				3.13			0.82			3.15			0.93			3.57		
A X B X C		1.15				4.42			1.16			4.46			1.32			5.05		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Third instar mealybugs

The botanical NSKE @ 5% recorded significantly more mortality of 6.39 per cent, which was on par with rest of the botanicals *Pongamia* oil @ 2% and CAKSE @ 5% (4.17% each). Non-significant differences were observed between entomopathogens with respect to mortality of mealybug (Table 33). There were no significant difference between with or without FORS @ 5 ml/l with respect to mortality of mealybugs.

The treatment combination with NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality of third instar mealybugs (8.89%) as compared to other treatment combinations. However, the least mortality was observed in the combination of botanical *Pongamia* oil @ 2% with *L. lecanii* @ 2 g/l and *M. anisopliae* @ 2 g/l alone and CAKSE @ 5% with *L. lecanii* @ 2 g/l alone (3.33) (Table 33).

4.3.2.1c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The mortality of first instar mealybug, *M. hirsutus* was superior in NSKE @ 5% (9.17%). The least mortality was observed in CAKSE @ 5% (4.44%). Among the entomopathogens, *L. lecanii* @ 2 g/l resulted significantly higher mortality (7.28 %) as compared to *M. anisopliae* @ 2 g/l (5.72%) on first instar mealybug. FORS @ 5 ml/l exerted significantly higher mortality of 8.11 per cent as compared to without FORS @ 5 ml/l (4.89%) (Table 34).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l exerted significantly higher mortality of first instar mealybugs (10.83 %), which was on par with neem oil @ 2% with *L. lecanii* @ 2 g/l (8.61 %). However, least mortality was observed in the combination of CAKSE @ 5% with *M. anisopliae* @ 2 g/l (4.17 %). Among the two entomopathogens, the combination of *L. lecanii* @ 2 g/l and FORS @ 5 ml/l resulted higher mortality (9.00%) of mealybug, *M. hirsutus* (Table 34). The interaction of botanical NSKE @ 5% and FORS resulted significantly higher mortality of 11.67 per cent, which was superior over rest of the treatment combinations. However, least per cent mortality was registered in the combination of CAKSE @ 5% without FORS @ 5 ml/l (3.61 %).

Significantly higher mortality was recorded in the combination of NSKE @ 5% and entomopathogen, *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (13.89%). The next better treatments were neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l with a mortality of 10.00 and 9.44 per cent, respectively as compared to other treatment combinations.

Second instar mealybugs

Neem oil @ 2% and NSKE @ 5% registered significantly higher mortality of 6.39 and 6.25 per cent, respectively, which were on par with PSKE @ 5% and *Pongamia* oil @ 2% (5.69% each) on second instar mealybugs at twelve hours after treatment (Table 34). Among the two entomopathogens, no significant difference was observed with respect to mortality of second instar mealybug. Similarly, there was non-significant difference between with and without FORS @ 5 ml/l on the mortality of second instar mealybugs.

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l showed significantly higher mortality (7.78%), which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l (6.67 %), neem oil @ 2% + *M. anisopliae* @ 2 g/l (6.11 %) and *Pongamia* oil @ 2% and PSKE @ 5% with *L. lecanii* @ 2 g/l (5.83%, each) on second instar mealybugs. There was no significant difference among the treatments of entomopathogens, *L. lecanii* @ 2 g/l and *M. anisopliae* @ 2 g/l either with or without FORS @ 5 ml/l. However, higher and lower mortality was observed with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (6.22%) and *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (5.33%). The interaction of NSKE @ 5% with FORS @ 5 ml/l resulted significantly higher mortality of 6.94 per cent, which was on par with rest of the combination except CAKSE @ 5% with or without FORS @ 5 ml/l (4.72 and 4.22 %, respectively).

The interaction of NSKE @ 5% and entomopathogen, *L. lecanii* @ 2 g/l with or without FORS @ 5 ml/l recorded significantly higher mortality (7.78%, each), followed by neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (7.22%) as compared to other treatment combinations. However, least mortality was observed in the treatment combination with CAKSE @ 5% + *L. lecanii* @ 2 g/l (3.33%).

Third instar mealybugs

Significantly higher mortality was exerted by botanical NSKE @ 5% (6.53%) which was superior to rest of the botanicals. Among the entomopathogens, the *L. lecanii* @ 2 g/l exerted significantly higher mortality of 5.56 per cent on third instar mealybugs. The addition of FORS @ 5 ml/l registered significantly higher mortality (5.72%).

The interaction of botanical NSKE @ 5% and entomopathogen, *L. lecanii* @ 2 g/l showed significantly higher mortality of 8.06 per cent, which was superior over rest of the treatments. The least mortality was observed in the treatment combination of CAKSE @ 5% + *L. lecanii* @ 2 g/l (3.89 %). Among the entomopathogens, with or without FORS, the entomopathogen, *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (6.56%) was significantly superior over other combinations with respect to mortality of third instar mealybugs (Table 34). The combination of NSKE @ 5% with FORS @ 5 ml/l recorded significantly higher mortality of 7.78 per cent, which was on par with combination of neem oil @ 2% and FORS @ 5 ml/l (6.11 %) (Table 34).

The interaction of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality (9.44%) of mealybugs, which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l alone causing mortality of 7.78 and 6.67 per cent.

4.3.2.2 Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at one day after treatments (1 DAT)

4.3.2.2a During 2009-10

First instar mealybugs

Significantly higher mortality was recorded by NSKE @ 5% (15.86%) as compared to other botanicals. There was no significant difference between *L. lecanii* @ 2 g/l and *M. anisopliae* @ 2 g/l on per cent mortality of mealybugs. However, the *L. lecanii* @ 2 g/l registered highest mortality of 11.77 per cent. The adjuvant FORS @ 5 ml/l added treatments resulted significantly higher per cent mortality (12.75 %) as compared to treatments without FORS @ 5 ml/l (Table 35).

The botanical neem oil @ 2% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l combination caused highly significant mortality of mealybugs (19.53%) followed by the combination of NSKE @ 5% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l (18.27%), which were on par with NSKE @ 5% + *L. lecanii* @ 2 g/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS with respect to mortality of 16.42 and 16.84 per cent, respectively, as compared to other combinations (Table 35).

Second instar mealybugs

The mortality of second instar mealybugs recorded significantly higher in PSKE @ 5% treatment (14.80%), the next best treatments included neem oil @ 2% and NSKE @ 5% having 11.54 and 9.97 per cent mortality, respectively (Table 35). Among the entomopathogens, the *L. lecanii* @ 2 g/l registered significantly higher mortality of mealybugs (10.02 %) followed by *M. anisopliae* @ 2 g/l with mortality of 9.41 per cent. The mortality of mealybug was significantly higher in treatments with FORS @ 5 ml/l (11.01 %) as compared to without FORS (8.43 %).

The botanical NSKE @ 5% in combination with *L. lecanii* @ 2 g/l and FORS @ 5 ml/l resulted significantly higher mortality (11.38%), which was on par with NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l (15.04 and 13.96 per cent, respectively) as compared to other combinations.

Third instar mealybugs

Among the botanicals, the NSKE @ 5% exerted significantly higher mortality of mealybug (11.67%) followed by PSKE @ 5%, neem oil @ 2% and *Pongamia* oil @ 2% with mortality of 10.82, 10.62 and 9.90 per cent, respectively. The least mortality was observed in CSKSE @ 5% (5.21%) (Table 35). There was no significant difference between entomopathogens on the mortality of third instar mealybugs. However, *L. lecanii* @ 2 g/l added treatments recorded highest mortality of 10.23 per cent followed by *M. anisopliae* @ 2 g/l (9.05%). The mortality of 10.98 per cent was registered in the treatments with adjuvant FORS @ 5 ml/l, which was highly significant as compared to without FORS.

Table 35. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2009-10

Treatments		Corrected per cent mortality of mealybugs																	
Entomo pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	11.90 (20.13)	19.53 (26.19)	6.90 (15.22)	10.31 (18.70)	18.27 (25.29)	13.38 (21.11)	9.50 (17.94)	13.50 (21.54)	4.70 (12.49)	11.90 (20.13)	17.31 (24.56)	11.38 (19.33)	11.83 (20.08)	13.07 (21.16)	5.75 (13.71)	12.17 (20.40)	15.14 (22.88)	11.59 (19.65)
	Without FORS	9.32 (17.69)	10.85 (19.22)	5.75 (13.71)	8.43 (16.86)	16.42 (23.88)	10.15 (18.27)	7.06 (15.40)	9.50 (17.92)	4.56 (12.14)	8.17 (16.51)	13.96 (21.93)	8.65 (16.78)	9.17 (17.62)	10.34 (18.59)	4.64 (12.27)	9.86 (18.29)	10.5 (18.64)	8.87 (17.08)
	Mean	10.61 (18.91)	15.19 (22.71)	6.32 (14.47)	9.37 (17.78)	17.35 (24.59)	11.77 (19.69)	8.28 (16.67)	11.50 (19.73)	4.63 (12.32)	10.04 (18.32)	15.63 (23.25)	10.02 (18.06)	10.50 (18.85)	11.71 (19.88)	5.19 (12.99)	11.01 (19.35)	12.74 (20.76)	10.23 (18.36)
<i>M. anisopliae</i> @ 2 g/l	With FORS	11.78 (20.02)	13.23 (21.29)	9.30 (17.75)	9.40 (17.78)	16.84 (24.20)	12.11 (20.21)	9.43 (17.88)	13.43 (21.48)	4.64 (12.27)	10.59 (18.98)	15.04 (22.81)	10.63 (18.68)	9.30 (17.75)	10.70 (19.08)	7.00 (15.32)	11.74 (20.00)	13.10 (21.17)	10.37 (18.66)
	Without FORS	9.20 (17.58)	8.25 (16.60)	4.67 (12.47)	11.47 (19.74)	11.90 (20.13)	9.10 (17.30)	5.80 (13.93)	9.71 (18.15)	3.41 (10.64)	9.20 (17.58)	12.89 (20.97)	8.20 (16.25)	9.2 (17.69)	8.37 (16.80)	3.45 (10.70)	9.50 (17.94)	8.05 (16.40)	7.74 (15.91)
	Mean	10.49 (18.80)	10.74 (18.95)	6.98 (15.11)	10.43 (18.76)	14.37 (22.17)	10.60 (18.76)	7.62 (15.90)	11.57 (19.82)	4.02 (11.45)	9.89 (18.28)	13.96 (21.89)	9.41 (17.47)	9.31 (17.72)	9.53 (17.94)	5.22 (13.01)	10.62 (18.97)	10.57 (18.78)	9.05 (17.28)
For comparing botanicals (A) and soap solution (C)																			
With FORS	11.84 (20.07)	16.38 (23.74)	8.10 (16.48)	9.85 (18.24)	17.56 (24.75)	12.75 (20.66)	9.47 (17.91)	13.47 (21.51)	4.67 (12.38)	11.25 (19.56)	16.17 (23.69)	11.01 (19.01)	10.57 (18.91)	11.88 (20.12)	6.37 (14.52)	11.95 (20.20)	14.12 (22.02)	10.98 (19.15)	
Without FORS	9.26 (17.63)	9.55 (17.91)	5.21 (13.09)	9.95 (18.30)	14.16 (22.01)	9.63 (17.79)	6.43 (14.67)	9.61 (18.04)	3.98 (11.39)	8.68 (17.04)	13.42 (21.45)	8.43 (16.52)	9.24 (17.65)	9.36 (17.70)	4.04 (11.48)	9.68 (18.11)	9.20 (17.52)	8.30 (16.49)	
Mean (A)	10.55 (18.85)	12.96 (20.83)	6.65 (14.79)	9.90 (18.27)	15.86 (23.38)		7.95 (16.29)	11.54 (19.77)	4.33 (11.88)	9.97 (18.30)	14.80 (22.57)		9.90 (18.28)	10.62 (18.91)	5.21 (13.00)	10.82 (19.16)	11.66 (19.77)		
Comparing the means of	S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			
A	0.46			1.75			0.40			1.55			0.45			1.72			
B	0.29			1.10			0.26			0.98			0.28			1.09			
C	0.29			1.10			0.26			0.98			0.28			1.09			
A X B	0.64			2.47			0.57			2.19			0.63			2.43			
B X C	0.41			1.56			0.36			1.39			0.40			1.54			
A X C	0.64			2.47			0.57			2.19			0.63			2.43			
A X B X C	0.91			3.49			0.81			3.10			0.90			3.44			

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Table 36. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2010-11

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	18.34 (25.26)	23.74 (29.14)	9.66 (18.02)	20.46 (26.88)	27.69 (31.69)	19.98 (26.20)	19.05 (25.78)	21.69 (27.70)	10.59 (18.98)	17.06 (24.36)	19.73 (26.35)	17.62 (24.63)	15.31 (22.99)	20.21 (26.70)	12.61 (20.77)	15.31 (22.99)	19.49 (26.17)	16.59 (23.92)
	Without FORS	12.97 (20.95)	19.05 (25.85)	8.13 (16.49)	16.30 (23.77)	15.83 (23.43)	14.45 (22.10)	11.62 (19.88)	12.77 (20.89)	8.13 (16.49)	12.77 (20.89)	12.93 (21.03)	11.64 (19.84)	11.49 (19.77)	15.35 (22.91)	7.93 (16.29)	14.08 (21.94)	15.48 (23.13)	12.87 (20.81)
	Mean	15.66 (23.11)	21.39 (27.49)	8.89 (17.25)	18.38 (25.32)	21.76 (27.56)	17.22 (24.15)	15.33 (22.83)	17.23 (24.30)	9.36 (17.74)	14.92 (22.63)	16.33 (23.69)	14.63 (22.24)	13.40 (21.38)	17.78 (24.80)	10.27 (18.53)	14.70 (22.47)	17.48 (24.65)	14.73 (22.37)
<i>M. anisopliae</i> @ 2 g/l	With FORS	15.65 (23.27)	22.20 (27.90)	10.59 (18.98)	18.03 (25.12)	21.23 (27.41)	17.50 (24.54)	15.48 (22.95)	18.84 (25.69)	9.32 (17.69)	16.84 (24.20)	16.84 (24.20)	15.46 (22.95)	13.96 (21.93)	15.31 (22.99)	11.62 (19.88)	15.11 (22.84)	19.99 (26.53)	15.20 (22.83)
	Without FORS	10.34 (18.59)	12.80 (20.95)	6.90 (15.22)	13.79 (21.79)	14.94 (22.73)	11.75 (19.86)	10.43 (18.68)	11.62 (19.88)	6.98 (15.31)	9.20 (17.58)	11.62 (19.88)	9.97 (18.27)	11.34 (19.64)	100.47 (18.87)	9.28 (17.67)	9.32 (17.69)	13.92 (21.81)	10.86 (19.13)
	Mean	13.00 (20.93)	17.40 (24.42)	8.74 (17.10)	15.91 (23.45)	18.08 (25.07)	14.63 (22.20)	12.95 (20.82)	15.23 (22.79)	8.15 (16.50)	13.02 (20.89)	14.23 (22.04)	12.72 (20.61)	12.65 (20.78)	12.89 (20.93)	10.45 (18.77)	12.21 (20.26)	16.95 (24.17)	13.03 (20.98)
For comparing botanicals (A) and soap solution (C)																			
With FORS		17.00 (24.27)	22.87 (28.52)	10.12 (18.50)	19.25 (26.00)	24.46 (29.55)	18.74 (25.37)	17.26 (24.36)	20.27 (26.69)	9.95 (18.34)	16.95 (24.28)	18.28 (25.27)	16.54 (23.79)	14.63 (22.46)	17.76 (24.84)	12.12 (20.32)	15.21 (22.92)	19.74 (26.35)	15.89 (23.38)
Without FORS		11.66 (19.77)	15.92 (23.40)	7.51 (15.85)	15.04 (22.78)	15.38 (23.08)	13.10 (20.98)	11.02 (19.28)	12.19 (20.39)	7.55 (15.90)	10.98 (19.24)	12.27 (20.46)	10.80 (19.05)	11.42 (19.70)	12.91 (20.89)	8.60 (16.98)	11.70 (19.82)	14.70 (22.47)	11.87 (19.97)
Mean (A)		14.33 (22.02)	19.40 (25.96)	8.82 (17.18)	17.15 (24.39)	19.92 (26.32)		14.14 (21.82)	16.23 (23.54)	8.75 (17.12)	13.97 (21.76)	15.28 (22.87)		13.03 (21.08)	15.34 (22.87)	10.36 (18.65)	13.45 (21.37)	17.22 (24.41)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.53			2.02			0.58			2.24			0.47			1.82		
B		0.33			1.28			0.37			1.42			0.30			1.15		
C		0.33			1.28			0.37			1.42			0.30			1.15		
A X B		0.74			2.85			0.83			3.17			0.67			2.57		
B X C		0.47			1.81			0.52			2.01			0.42			1.62		
A X C		0.74			2.85			0.83			3.17			0.67			2.57		
A X B X C		1.05			4.04			1.17			4.49			0.95			3.63		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

The interaction of NSKE @ 5% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l resulted significantly higher mortality, (15.14%) which was, on par with NSKE @ 5% and *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (13.10%), neem oil @ 2% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (13.07%), PSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (12.17%) and PSKE @ 5% and *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (11.74%) as compared to other interactions.

4.3.2.2b During 2010-11

First instar mealybugs

The botanicals NSKE @ 5%, neem oil @ 2% and PSKE @ 5% caused significantly higher mortality of 19.92, 19.40 and 17.15 per cent, respectively. The least mortality was observed in the botanical CAKSE @ 5% (8.82%). The entomopathogen, *L. lecanii* @ 2 g/l showed significantly higher mortality (17.22 %) on first instar mealybug as compared to *M. anisopliae* @ 2 g/l (14.63 %). The adjuvant FORS @ 5 ml/l added to botanicals and entomopathogen caused significantly highest mortality of 18.74 per cent as compared to without FORS (Table 36).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality of mealybug (27.69%), which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, neem oil @ 2% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l with mortality of 23.74, 22.00 and 21.23 per cent, respectively. However, least mortality was observed in combination of CAKSE @ 5% + *M. anisopliae* @ 2 g/l (6.90%).

Second instar mealybugs

Significantly higher per cent mortality was observed in botanical, neem oil @ 2% (16.23%), which was on par with rest of the botanical treatments except CAKSE @ 5% (8.75%) (Table 36). Significantly higher mortality was recorded in entomopathogen,

L. lecanii @ 2 g/l (14.63 %) as compared to *M. anisopliae* @ 2 g/l (12.72 %). The adjuvant FORS @ 5 ml/l addition increased the mortality (16.54 %) as compared to without FORS.

The interaction of neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l resulted significantly higher mortality (21.69%), which was on par with NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, *Pongamia* oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, neem oil @ 2% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l, PSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, PSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l, NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l with mortality of 19.73, 19.05, 18.84, 17.06, 16.84 and 16.84 per cent, respectively. However, least per cent mortality of second instar mealybug was observed in CAKSE @ 5% + *M. anisopliae* @ 2 g/l alone (6.98%).

Third instar mealybugs

Among the botanicals, NSKE @ 5% resulted significantly higher mortality (17.22%) on third instar mealybugs, which was on par with neem oil @ 2% (15.34%). However, least mortality was observed in botanical CAKSE @ 5% (10.36%) (Table 36). Significantly higher mortality was recorded in the treatments with entomopathogen, *L. lecanii* @ 2 g/l (14.73 %) as compared to other *M. anisopliae* @ 2 g/l (13.03%). The adjuvant FORS @ 5 ml/l resulted significantly higher mortality of 15.89 per cent on third instar mealybug as compared to treatments without FORS.

The combination of *L. lecanii* @ 2 g/l + FORS @ 5 ml/l with botanical neem oil @ 2% recorded significantly higher mortality (20.21%) followed by botanical NSKE @ 5% in combination with entomopathogen, *M. anisopliae* @ 2 g/l and *L. lecanii* @ 2 g/l with FORS producing mortality of 19.99 and 19.49 per cent, respectively. However, least mortality was observed with CAKSE @ 5% along with *L. lecanii* @ 2 g/l without FORS (7.93%) (Table 36).

4.3.2.2c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The botanicals NSKE @ 5% and neem oil @ 2% were significantly superior over rest of the botanicals with mortality of 17.12 and 16.18 per cent, respectively. The entomopathogen, *L. lecanii* @ 2 g/l recorded higher per cent mortality (14.25 %) as compared to *M. anisopliae* @ 2 g/l. The adjuvant FORS @ 5 ml/l registered significantly higher mortality (15.50 %) (Table 37).

Table 37. Effect of botanicals in combination with entomopathogens different instars of *Maconellicoccus hirsutus* at one day after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	15.12 (22.84)	21.64 (27.71)	8.28 (16.69)	15.06 (22.77)	22.06 (27.99)	16.43 (23.60)	10.57 (18.92)	14.18 (22.08)	6.42 (14.64)	12.34 (20.53)	14.42 (22.24)	11.86 (19.94)	13.57 (21.54)	16.15 (23.66)	9.18 (17.57)	13.61 (21.60)	17.15 (24.42)	13.93 (21.76)
	Without FORS	11.15 (19.48)	14.95 (22.73)	6.94 (15.27)	12.17 (20.37)	15.12 (22.83)	12.07 (20.14)	11.27 (19.53)	12.56 (20.72)	6.94 (15.18)	12.51 (20.67)	13.87 (21.80)	11.15 (19.32)	10.34 (18.71)	12.85 (20.85)	6.28 (14.48)	11.64 (19.86)	14.29 (22.09)	11.08 (19.20)
	Mean	13.13 (21.16)	18.29 (25.22)	7.61 (15.98)	13.61 (21.57)	18.59 (25.41)	14.25 (21.87)	10.92 (19.22)	13.37 (21.40)	6.68 (14.91)	12.42 (20.60)	14.15 (22.02)	11.51 (19.63)	11.96 (20.12)	14.50 (22.26)	7.73 (16.03)	12.62 (20.73)	15.72 (23.26)	12.51 (20.48)
<i>M. anisopliae</i> @ 2 g/l	With FORS	13.72 (21.72)	17.61 (24.80)	9.95 (18.37)	13.72 (21.70)	17.87 (24.95)	14.57 (22.31)	9.93 (18.31)	12.53 (20.69)	5.81 (13.91)	9.89 (18.31)	11.85 (20.12)	10.00 (18.27)	11.62 (19.91)	12.25 (20.45)	9.32 (17.74)	13.42 (21.46)	16.54 (23.99)	12.63 (20.71)
	Without FORS	9.77 (18.19)	10.51 (18.86)	5.75 (13.83)	12.13 (20.34)	13.42 (21.47)	10.32 (18.54)	13.74 (21.68)	10.00 (18.41)	10.24 (18.64)	14.46 (22.34)	5.95 (13.96)	10.88 (19.01)	10.33 (18.70)	9.26 (17.69)	6.36 (14.58)	9.26 (17.63)	10.98 (19.27)	9.24 (17.57)
	Mean	11.74 (19.96)	14.06 (21.83)	7.85 (16.10)	12.92 (21.02)	15.64 (23.21)	12.44 (20.42)	11.84 (20.00)	11.26 (19.55)	8.02 (16.28)	12.18 (20.33)	8.90 (17.04)	10.44 (18.64)	10.97 (19.30)	10.76 (19.07)	7.84 (16.16)	11.34 (19.54)	13.76 (21.63)	10.93 (19.14)
For comparing botanicals (A) and soap solution (C)																			
With FORS		14.42 (22.28)	19.63 (26.25)	9.12 (17.53)	14.39 (22.24)	19.96 (26.47)	15.50 (22.95)	10.25 (18.62)	12.54 (20.70)	6.12 (14.28)	13.48 (21.51)	12.86 (20.96)	11.37 (19.47)	12.59 (20.72)	14.20 (22.05)	9.25 (17.66)	13.52 (21.53)	16.85 (24.20)	13.28 (21.23)
Without FORS		10.46 (18.84)	12.73 (20.80)	6.34 (14.55)	12.13 (20.36)	14.27 (22.15)	11.19 (19.34)	12.50 (20.60)	12.09 (20.25)	8.59 (16.91)	11.11 (19.42)	10.19 (18.10)	10.58 (18.79)	10.34 (18.71)	11.05 (19.27)	6.32 (14.53)	10.45 (18.75)	12.63 (20.68)	10.16 (18.39)
Mean (A)		12.44 (20.56)	16.18 (23.52)	7.73 (16.04)	13.27 (21.30)	17.12 (24.31)		11.38 (19.61)	12.32 (20.47)	7.35 (15.59)	12.30 (20.46)	11.52 (19.53)		11.46 (19.71)	12.63 (20.66)	7.79 (16.10)	11.98 (20.14)	14.74 (22.44)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.38			1.45			0.48			1.84			0.44			1.71		
B		0.24			0.92			0.30			1.17			0.28			1.08		
C		0.24			0.92			0.30			1.17			0.28			1.08		
A X B		0.53			2.05			0.68			2.61			0.63			2.41		
B X C		0.34			1.30			0.43			1.65			0.40			1.53		
A X C		0.53			2.05			0.68			2.61			0.63			2.41		
A X B X C		0.76			2.90			0.96			3.69			0.89			3.41		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Table 38. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2009-10

Treatments		Corrected per cent mortality of mealybugs																	
Entomopathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	24.33 (29.49)	22.69 (28.37)	9.88 (18.24)	17.35 (24.57)	23.61 (29.03)	19.57 (25.94)	21.08 (27.29)	26.48 (30.93)	11.12 (19.47)	21.08 (27.29)	23.16 (28.74)	20.58 (26.74)	16.24 (23.64)	15.01 (22.77)	10.07 (18.45)	16.73 (24.09)	29.51 (32.83)	17.51 (24.35)
	Without FORS	15.21 (22.83)	21.61 (27.67)	10.98 (19.34)	13.96 (21.88)	22.58 (28.33)	16.87 (24.01)	19.66 (26.26)	18.27 (25.25)	5.79 (13.78)	10.98 (19.34)	19.22 (25.95)	14.78 (22.12)	7.60 (15.99)	8.94 (16.94)	4.85 (12.56)	19.04 (25.78)	15.09 (22.81)	11.10 (18.81)
	Mean	19.77 (26.16)	22.15 (28.02)	10.43 (18.79)	15.66 (23.23)	23.10 (28.68)	18.22 (24.98)	20.37 (26.78)	22.37 (28.09)	8.45 (16.62)	16.03 (23.32)	21.19 (27.35)	17.68 (24.43)	11.92 (19.82)	11.98 (19.85)	7.46 (15.50)	17.89 (24.93)	22.30 (27.82)	14.31 (21.58)
<i>M. anisopliae</i> @ 2 g/l	With FORS	10.54 (18.86)	19.44 (26.13)	10.22 (18.58)	15.54 (23.11)	18.21 (25.07)	14.79 (22.35)	16.05 (23.58)	20.92 (27.16)	12.17 (20.38)	19.74 (26.30)	19.01 (25.68)	17.58 (24.62)	11.54 (19.68)	13.96 (21.88)	8.75 (17.13)	18.41 (25.37)	22.31 (28.13)	14.99 (22.44)
	Without FORS	12.68 (20.80)	9.97 (18.34)	10.85 (19.22)	12.54 (20.67)	22.94 (28.55)	13.80 (21.52)	17.28 (24.53)	12.63 (20.77)	8.33 (16.70)	15.45 (23.01)	16.44 (23.80)	14.03 (21.76)	7.70 (16.10)	16.24 (23.55)	8.62 (17.01)	16.43 (23.88)	16.48 (23.90)	13.09 (20.89)
	Mean	11.61 (19.83)	14.71 (22.23)	10.53 (18.90)	14.04 (21.89)	20.58 (26.81)	14.29 (21.93)	16.67 (24.05)	16.77 (23.96)	10.25 (18.54)	17.60 (24.65)	17.73 (24.74)	15.80 (23.19)	9.62 (17.89)	15.10 (22.72)	8.69 (17.07)	17.42 (24.63)	19.39 (26.02)	14.04 (21.66)
For comparing botanicals (A) and soap solution (C)																			
With FORS		17.44 (24.18)	21.07 (27.25)	10.05 (18.41)	16.44 (23.84)	20.91 (27.05)	17.18 (24.15)	18.56 (25.44)	23.70 (29.04)	11.64 (19.92)	20.41 (26.79)	21.08 (27.21)	19.08 (25.68)	13.89 (21.66)	14.49 (22.32)	9.41 (17.79)	17.57 (24.73)	25.91 (30.48)	16.25 (23.40)
Without FORS		13.94 (21.82)	15.79 (23.01)	10.91 (19.28)	13.25 (21.27)	22.76 (28.44)	15.33 (22.76)	18.47 (25.39)	15.45 (23.01)	7.06 (15.24)	13.21 (21.18)	17.83 (24.88)	14.41 (21.94)	7.65 (16.05)	12.59 (20.25)	6.73 (14.78)	17.74 (24.83)	15.78 (23.36)	12.10 (19.85)
Mean (A)		15.69 (23.00)	18.43 (25.13)	10.48 (18.84)	14.85 (22.56)	21.84 (27.74)		18.52 (25.42)	19.57 (26.02)	9.35 (17.58)	16.81 (23.99)	19.46 (26.05)		10.77 (18.85)	13.54 (21.28)	8.07 (16.29)	17.65 (24.78)	20.85 (26.92)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.64			2.46			0.66			2.53			0.71			2.72		
B		0.41			1.56			0.42			1.60			0.45			1.72		
C		0.41			1.56			0.42			1.60			0.45			1.72		
A X B		0.91			3.48			0.93			3.58			1.00			3.84		
B X C		0.57			2.20			0.59			2.27			0.63			2.43		
A X C		0.91			3.48			0.93			3.58			1.00			3.84		
A X B X C		1.28			4.92			1.32			5.07			1.42			5.44		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

The NSKE @ 5% with entomopathogen, *L. lecanii* @ 2 g/l combination registered significantly higher mortality of 18.59 per cent, which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l (18.29 %) as compared to rest of the combinations. The entomopathogens, *L. lecanii* @ 2 g/l and *M. anisopliae* @ 2 g/l with adjuvant FORS @ 5 ml/l was found significantly superior in causing per cent mortality of 16.43 and 14.47, respectively as compared to entomopathogens without FORS). Among the combination of botanicals with or without adjuvant FORS, the combination of NSKE @ 5% and neem oil @ 2% with FORS @ 5 ml/l resulted significantly higher mortality of 19.96 and 19.63 per cent, respectively, which were superior over rest of the treatment combinations (Table 37).

The interaction of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l registered significantly higher mortality (22.06%) of first instar mealybug, which was on par with neem oil @ 2% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (21.64%). However, least mortality was observed in combination of CAKSE @ 5% and *M. anisopliae* @ 2 g/l (5.75%) (Table 37).

Second instar mealybugs

There was no significant mortality between the botanicals except CAKSE @ 5% (7.35%). However, highest mortality was resulted in PSKE @ 5% (12.30%). There was no significant difference between the entomopathogens on the mortality. Non significant difference was observed between mortality of second instar mealybug with or without FORS @ 5 ml/l (Table 37).

The interaction of botanicals and entomopathogen was effective on mortality of mealybugs. Among these, the combination of NSKE @ 5% and *L. lecanii* @ 2 g/l recorded significantly higher mortality of second instar mealybug (14.15 %) as compared to rest of the combinations. However, least mortality was registered in the combination of CAKSE @ 5% with *L. lecanii* @ 2 g/l (5.81 %). The effect of combination of entomopathogens along with or without FORS @ 5 ml/l was found non-significant. Significantly higher mortality was recorded in the combination of NSKE @ 5% with FORS @ 5 ml/l (12.86 %) as compared to rest of the combinations. It was on par with rest of the combinations except NSKE @ 5% without FORS and CAKSE @ 5% with or without FORS @ 5 ml/l (10.19, 8.59 and 6.12 per cent, respectively).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l without FORS recorded significantly higher mortality (14.42%). However, least mortality was observed in CAKSE @ 5% and *M. anisopliae* @ 2 g/l with FORS @ 5 ml/l (5.81%) (Table 37).

Third instar mealybugs

The effect of botanical NSKE @ 5% was significant with higher mortality (14.74%) on third instar mealybugs as compared to rest of the botanicals. However, it was on par with neem oil @ 2% (12.63%). Among the entomopathogens, the *L. lecanii* @ 2 g/l exerted significantly higher mortality of 12.51 per cent. The addition of FORS @ 5 ml/l resulted significantly higher mortality (13.28%).

The combination of NSKE @ 5% with entomopathogen, *L. lecanii* @ 2 g/l registered significantly higher mortality (15.72%), which was on par with combination of neem oil @ 2% + *L. lecanii* @ 2 g/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l causing mortality of 14.50 and 13.76 per cent, respectively. Among the combinations, the combination of *L. lecanii* @ 2 g/l + FORS @ 5 ml/l exerted significantly higher mortality (13.93%) on third instar mealybugs, which was on par with *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (12.63%) as compared to entomopathogens without FORS. The interaction of botanicals with adjuvant FORS @ 5 ml/l was most effective on mortality of third instar mealybugs. Among these, the combination of NSKE @ 5% with FORS @ 5 ml/l resulted significantly higher mortality, which was on par with neem oil @ 2% and FORS @ 5 ml/l (14.20 %) as compared to rest of the combinations (Table 37).

The interaction of botanical NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l resulted higher mortality (17.15%) of mealybugs as compared to other interactions. However, the least per cent mortality was recorded in the interaction of CAKSE @ 5% + *L. lecanii* @ 2 g/l without FORS (6.28%) on third instar mealybug (Table 47).

4.3.2.3 Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at two days after treatment (2 DAT)

4.3.2.3a During 2009-10

First instar mealybugs

The mortality of first instar mealybug was significantly higher in NSKE @ 5% (21.84%) as compared to other botanicals. However, the least mortality was observed in CSKSE @ 5% (10.48%). Among the entomopathogens, the *L. lecanii* @ 2 g/l showed significantly higher mortality (18.22 %) as compared to *M. anisopliae* @ 2 g/l (14.29%). The addition of FORS @ 5 ml/l increased mortality (17.18%) significantly as compared to without FORS treatments (Table 38).

Among the combination of botanicals and entomopathogen, with or without FORS, the combination of *Pongamia* oil @ 2% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l was most effective (24.33%), which was on par with the combinations of NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, NSKE @ 5% + *M. anisopliae*, neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, NSKE @ 5% + *L. lecanii*, neem oil @ 2% + *L. lecanii* @ 2 g/l, neem oil @ 2% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l with mortality of 23.61, 22.94, 22.69, 22.58, 21.61, 19.44 and 18.21 per cent, respectively.

Second instar mealybugs

The botanical NSKE @ 5% exerted significantly higher mortality of second instar mealybug (19.46%), which was on par with rest of the treatments except CAKSE @ 5% (9.35%). There was non-significant differences among the entomopathogens. However, higher mortality was recorded with entomopathogen, *L. lecanii* @ 2 g/l (17.68%). The FORS @ 5 ml/l treatments were highly significant by causing mortality of 19.08 per cent as compared to without FORS.

The combination of botanical, neem oil @ 2% and entomopathogen, *L. lecanii* @ 2 g/l with FORS @ 5 ml/l recorded significantly higher mortality (26.48%) as compared to other combinations, which was on par with NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (23.16 %), *Pongamia* oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (21.08 %), PSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (21.08%), neem oil @ 2% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (20.92 %), PSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (19.74 %), *Pongamia* oil @ 2% + *L. lecanii* @ 2 g/l (19.66 %) and NSKE @ 5% + *L. lecanii* @ 2 g/l (19.22 %). However, the least mortality was recorded in botanical, CAKSE @ 5% and entomopathogen, *L. lecanii* @ 2 g/l (5.79%) (Table 38).

Third instar mealybugs

The NSKE @ 5% recorded significantly higher mortality (20.85%) followed by PSKE @ 5% (17.65%) as compared to other botanicals. No significant difference was observed between entomopathogens, *L. lecanii* @ 2 g/l (14.31 %) and *M. anisopliae* @ 2 g/l (14.04 %) on per cent mortality. Significantly higher mortality was found in the treatments added with FORS @ 5 ml/l (16.25 %) as compared to without FORS on mealybugs (Table 38).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality of 29.51 per cent, which was on par with NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (22.31%) as compared to rest of the combinations.

4.3.2.3b During 2010-11

First instar mealybugs

Among the botanicals, the NSKE @ 5% exerted significantly higher mortality (34.79%) on first instar mealybugs as compared to other botanicals. Among the entomopathogens, the *L. lecanii* @ 2 g/l registered significantly higher mortality of 26.07 per cent as compared to treatments with *M. anisopliae* @ 2 g/l (22.83%). The adjuvant FORS @ 5 ml/l registered significantly higher mortality of mealybug (28.42 %) as compared to without FORS (20.47%) (Table 39).

The combination of botanical NSKE @ 5% with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l resulted significantly higher mortality (47.35%). The next better combination was neem oil @ 2% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (37.70%). However, least mortality was observed in CAKSE @ 5% and *M. anisopliae* @ 2 g/l without FORS (7.41) on first instar mealybugs (Table 39).

Table 39. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2010-11

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	31.24 (33.96)	37.70 (37.86)	14.74 (22.50)	22.76 (28.48)	47.35 (43.46)	30.76 (33.25)	17.68 (24.85)	23.12 (28.72)	14.46 (22.30)	23.52 (28.98)	27.71 (31.75)	21.30 (27.32)	22.19 (28.08)	28.39 (32.17)	15.85 (23.32)	33.43 (35.27)	28.79 (32.42)	25.73 (30.25)
	Without FORS	22.94 (28.60)	23.52 (28.98)	8.88 (17.24)	20.60 (26.98)	30.96 (33.79)	21.38 (27.12)	13.18 (21.23)	18.67 (25.56)	8.88 (17.24)	20.00 (26.48)	18.94 (25.76)	15.93 (23.25)	16.87 (24.22)	24.92 (29.91)	9.88 (18.24)	24.67 (29.77)	19.75 (26.34)	19.22 (25.69)
	Mean	27.09 (31.28)	30.61 (33.42)	11.81 (19.87)	21.68 (27.73)	39.15 (38.63)	26.07 (30.18)	15.43 (23.04)	20.89 (27.14)	11.67 (19.77)	21.76 (27.73)	23.33 (28.75)	18.62 (25.29)	19.53 (26.15)	26.65 (31.04)	12.86 (20.78)	29.05 (32.52)	24.27 (29.38)	22.47 (27.97)
<i>M. anisopliae</i> @ 2 g/l	With FORS	30.07 (33.19)	31.26 (33.97)	10.51 (18.84)	22.07 (28.01)	36.51 (37.15)	26.08 (30.23)	18.46 (25.37)	24.67 (29.75)	12.83 (20.94)	20.29 (26.73)	23.19 (28.75)	19.89 (26.31)	23.00 (28.62)	22.19 (28.08)	15.79 (23.41)	27.44 (31.56)	25.03 (29.98)	22.69 (28.33)
	Without FORS	21.77 (27.79)	24.03 (29.34)	7.41 (15.45)	20.32 (26.78)	24.33 (29.54)	19.57 (25.78)	14.26 (22.14)	19.74 (26.37)	9.97 (18.34)	12.63 (20.78)	19.74 (26.37)	15.27 (22.80)	17.95 (25.03)	16.87 (24.22)	10.26 (18.60)	14.17 (22.04)	18.89 (25.73)	15.63 (23.12)
	Mean	25.92 (30.49)	27.64 (31.65)	8.96 (17.15)	21.20 (27.39)	30.42 (33.35)	22.83 (28.01)	16.36 (23.76)	22.21 (28.06)	11.40 (19.64)	16.46 (23.75)	21.47 (27.56)	17.58 (24.55)	20.47 (26.82)	19.53 (26.15)	13.03 (21.00)	20.80 (26.80)	21.96 (27.86)	19.16 (25.73)
For comparing botanicals (A) and soap solution (C)																			
With FORS		30.66 (33.58)	34.48 (35.91)	12.62 (20.67)	22.41 (28.24)	41.93 (40.31)	28.42 (31.74)	18.07 (25.11)	23.90 (29.23)	13.65 (21.62)	21.90 (27.86)	25.45 (30.25)	20.59 (26.81)	22.60 (28.35)	25.29 (30.12)	15.82 (23.37)	30.44 (33.41)	26.91 (31.20)	24.21 (29.29)
Without FORS		22.35 (28.19)	23.77 (29.16)	8.14 (16.35)	20.46 (26.88)	27.64 (31.67)	20.47 (26.45)	13.72 (21.68)	19.21 (25.96)	9.43 (17.79)	16.32 (23.63)	19.34 (26.06)	15.60 (23.03)	17.41 (24.62)	20.89 (27.06)	10.07 (18.42)	19.42 (25.90)	19.32 (26.03)	17.42 (24.41)
Mean (A)		26.50 (30.89)	29.12 (32.54)	10.38 (18.51)	21.44 (27.56)	34.79 (35.99)		15.89 (23.40)	21.55 (27.60)	11.54 (19.71)	19.11 (25.74)	22.40 (28.16)		20.00 (26.49)	23.09 (28.59)	12.94 (20.89)	24.93 (29.66)	23.11 (28.62)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.51			1.96			0.49			1.88			0.55			2.09		
B		0.32			1.24			0.31			1.19			0.34			1.32		
C		0.32			1.24			0.31			1.19			0.34			1.32		
A X B		0.72			2.78			0.69			2.66			0.77			2.96		
B X C		0.46			1.76			0.44			1.68			0.49			1.87		
A X C		0.72			2.78			0.69			2.66			0.77			2.96		
A X B X C		1.02			3.93			0.98			3.76			1.09			4.18		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Table 40. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	27.79 (31.80)	30.19 (33.31)	12.31 (20.46)	20.35 (26.58)	35.48 (36.54)	25.16 (29.74)	17.13 (24.42)	22.57 (28.33)	10.00 (18.41)	20.54 (26.93)	21.05 (27.30)	18.26 (25.08)	19.22 (25.97)	21.70 (27.74)	12.96 (21.07)	25.08 (30.02)	29.15 (32.65)	21.62 (27.49)
	Without FORS	19.07 (25.88)	22.56 (28.35)	9.93 (18.34)	17.28 (24.53)	26.77 (31.14)	19.12 (25.65)	19.06 (25.87)	21.47 (27.58)	9.31 (17.76)	15.63 (23.27)	21.21 (27.39)	17.34 (24.37)	12.23 (20.45)	16.93 (24.27)	7.36 (15.66)	21.85 (27.84)	17.42 (24.62)	15.16 (22.57)
	Mean	23.43 (28.84)	26.38 (30.83)	11.12 (19.40)	18.67 (25.56)	31.13 (33.84)	22.14 (27.69)	18.09 (25.15)	22.02 (27.95)	9.65 (18.08)	18.09 (25.10)	21.13 (27.34)	17.80 (24.73)	15.72 (23.21)	19.32 (26.00)	10.16 (18.37)	23.47 (28.93)	23.28 (28.63)	18.39 (25.03)
<i>M. anisopliae</i> @ 2 g/l	With FORS	20.30 (26.75)	25.35 (30.22)	10.36 (18.75)	18.80 (25.67)	27.36 (31.49)	20.44 (26.58)	15.15 (22.88)	20.33 (26.78)	11.07 (19.43)	16.19 (23.70)	19.38 (26.06)	16.42 (23.77)	17.27 (24.51)	18.08 (25.15)	12.27 (20.49)	22.93 (28.59)	23.67 (29.10)	18.84 (25.57)
	Without FORS	17.22 (24.49)	17.00 (24.34)	9.13 (17.51)	16.43 (23.90)	23.64 (29.06)	16.68 (23.86)	20.20 (26.69)	13.54 (21.56)	15.93 (23.48)	21.58 (27.65)	8.22 (16.57)	15.89 (23.19)	12.82 (20.96)	16.56 (23.92)	9.44 (17.84)	15.30 (23.01)	17.68 (24.86)	14.36 (22.12)
	Mean	18.76 (25.62)	21.17 (27.28)	9.75 (18.13)	17.62 (24.78)	25.50 (30.28)	18.56 (25.22)	17.68 (24.79)	16.94 (24.17)	13.50 (21.45)	18.88 (25.67)	13.80 (21.32)	16.16 (23.48)	15.05 (22.74)	17.32 (24.53)	10.86 (19.17)	19.11 (25.80)	20.68 (26.98)	16.60 (23.84)
For comparing botanicals (A) and soap solution (C)																			
With FORS		24.05 (29.27)	27.77 (31.77)	11.34 (19.61)	19.43 (26.12)	31.42 (34.02)	22.80 (28.16)	16.14 (23.65)	21.45 (27.55)	10.53 (18.92)	18.36 (25.32)	20.21 (26.68)	17.34 (24.42)	18.24 (25.24)	19.89 (26.44)	12.62 (20.78)	24.01 (29.31)	26.41 (30.88)	20.23 (26.53)
Without FORS		18.15 (25.18)	19.78 (26.34)	9.53 (17.93)	16.86 (24.22)	25.20 (30.10)	17.90 (24.75)	19.63 (26.28)	17.51 (24.57)	12.62 (20.62)	18.61 (25.46)	14.71 (21.98)	16.62 (23.78)	12.53 (20.71)	16.74 (24.09)	8.40 (16.75)	18.58 (25.43)	17.55 (24.74)	14.76 (22.34)
Mean (A)		21.10 (27.23)	23.78 (29.05)	10.43 (18.77)	18.14 (25.17)	28.31 (32.06)		17.89 (24.97)	19.48 (26.06)	11.58 (19.77)	18.48 (25.39)	17.46 (24.33)		15.39 (22.97)	18.32 (25.27)	10.51 (18.77)	21.29 (27.37)	21.98 (27.81)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.38			1.47			0.37			1.43			0.38			1.44		
B		0.24			0.93			0.24			0.91			0.24			0.91		
C		0.24			0.93			0.24			0.91			0.24			0.91		
A X B		0.54			2.07			0.53			2.03			0.53			2.04		
B X C		0.34			1.31			0.33			1.28			0.34			1.29		
A X C		0.54			2.07			0.53			2.03			0.53			2.04		
A X B X C		0.76			2.93			0.75			2.86			0.75			2.89		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Second instar mealybugs

The botanical NSKE @ 5% recorded significantly higher mortality (22.40%), which was on par with neem oil @ 2% (21.55%) as compared to rest of the botanicals. There was no significant effect between both the entomopathogens on mortality of second instar mealybug. The treatments with FORS @ 5 ml/l recorded significantly higher mortality of 20.59 per cent as compared to without FORS (15.60%) (Table 39).

Significantly higher mortality was observed in the combination of NSKE @ 5% with entomopathogen, *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (27.71%), which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l (23.12%) and *M. anisopliae* @ 2 g/l (24.67%) with FORS @ 5 ml/l and PSKE @ 5% with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (23.52%) and NSKE @ 5% with *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (23.19%) as compared to rest of the combinations (Table 39).

Third instar mealybugs

The botanical PSKE @ 5% exerted significantly higher mortality (24.93%), which was on par with NSKE @ 5% and neem oil @ 2% with mortality of 23.11 and 23.09 per cent, respectively as compared to rest of the botanicals on third instar mealybug. Among the entomopathogens, the *L. lecanii* @ 2 g/l resulted significantly higher mortality of 22.47 per cent as compared to *M. anisopliae* @ 2 g/l (19.16%). The addition of FORS @ 5 ml/l recorded significantly higher mortality (24.21 %) as compared to without FORS treatments (17.42%).

The interaction of botanical PSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l caused significantly higher mortality (33.43%) on third instar mealybug, which was on par with combinations of NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l with mortality of 28.79, 28.39 and 27.44 per cent, respectively. However, least per cent mortality was observed in treatment combination CAKSE + *L. lecanii* @ 2 g/l (9.88%) (Table 39).

4.3.2.3c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The botanical, NSKE @ 5% exerted significantly higher mortality (28.31%), which was superior over other botanicals. However, the lower mortality was recorded in botanical CAKSE @ 5% (10.43%). Among the entomopathogens, the *L. lecanii* @ 2 g/l registered significantly higher mortality of 22.14 per cent as compared to *M. anisopliae* @ 2 g/l (18.56 %). The presence of FORS @ 5 ml/l exerted significantly higher mortality of 22.80 per cent (Table 40).

The combination of NSKE @ 5% with entomopathogen, *L. lecanii* @ 2 g/l showed significantly superior mortality of 31.13 per cent as compared to rest of the combinations. The least mortality was observed in the combination of CAKSE @ 5% + *M. anisopliae* @ 2 g/l (9.75 %). Among the combinations, the combination of *L. lecanii* @ 2 g/l with FORS exerted significantly superior mortality (25.16 %) of mealybugs as compared to other combinations (Table 40). Significantly superior mortality of first instar mealybug was recorded in the combination of NSKE @ 5% with FORS @ 5 ml/l (31.42 %) as compared to rest of the combinations.

The combination of NSKE @ 5% with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l registered significantly higher mortality (35.48%) of first instar mealybug, which was superior over other combinations.

Second instar mealybugs

The neem oil @ 2% on second instar mealybug was found most effective in causing higher mortality (19.48%), which was on par with PSKE @ 5% and *Pongamia* oil @ 2% with mortality of 18.48 and 17.89 per cent, respectively as compared to other botanicals. Among the entomopathogens, the *L. lecanii* @ 2 g/l resulted higher mortality of 17.80 per cent as compared to *M. anisopliae* @ 2 g/l (16.16%). There was no significant difference between with or without FORS @ 5 ml/l (Table 40).

The combination of neem oil @ 2% with FORS resulted significantly higher per cent mortality (21.45 %), which was on par with NSKE @ 5% with FORS @ 5 ml/l (20.21 %) and *Pongamia* oil @ 2% + without FORS @ 5 ml/l (19.63 %) as compared to rest of the combinations. The combination of *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality (18.26%), which was on par with *L. lecanii* @ 2 g/l (17.34%) as compared to other combination of entomopathogens with FORS @

5 ml/l. Significantly higher mortality was recorded in the combination of neem oil @ 2% with *L. lecanii* @ 2 g/l (22.02 %), which was on par with the treatment combination of NSKE @ 5% with *L. lecanii* @ 2 g/l as compared to rest of the combinations (Table 40).

The botanical neem oil @ 2% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded higher mortality (22.57%), followed by combination of NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, neem oil @ 2% + *L. lecanii* @ 2 g/l, NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l with a mean mortality of 21.58, 21.47, 21.21 and 21.05 per cent, respectively as compared to rest of the combinations (Table 40).

Third instar mealybugs

The botanicals, NSKE @ 5% and PSKE @ 5% exerted significantly higher mortality of 21.98 and 21.29 per cent, respectively on third instar mealybugs as compared to other botanicals. The entomopathogen, *L. lecanii* @ 2 g/l resulted significantly higher mortality of 18.39 per cent on third instar mealybugs. Significantly higher mortality was recorded in the treatments added with adjuvant FORS @ 5 ml/l (20.23 %) as compared to without FORS (14.76%) (Table 40).

Among the combinations of botanicals and entomopathogens, the combinations of PSKE @ 5% and NSKE @ 5% with *L. lecanii* @ 2 g/l resulted significantly higher mortality of 23.47 and 23.38 per cent, respectively, which were on par with combinations of NSKE @ 5% with *M. anisopliae* @ 2 g/l (20.68%). Significantly higher and superior mortality of mealybugs was registered in the combination of *L. lecanii* @ 2 g/l + FORS (21.62%). However, least mortality was observed in combination of *M. anisopliae* @ 2 g/l (14.36%). The combination of NSKE @ 5% with FORS @ 5 ml/l showed significantly higher mortality of 26.41 per cent, which was on par with PSKE @ 5% with FORS @ 5 ml/l (24.01%) as compared to rest of the combination on third instar mealybugs (Table 40).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality (29.15%), which was on par with combination of PSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (25.08%) as compared to rest of the combinations (Table 40).

4.3.2.4 Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at three days after treatment (3 DAT)

4.3.2.4a 2009-10

First instar mealybugs

The botanical NSKE @ 5% exerted significantly higher mortality of first instar mealybug (26.39%), which was superior over other botanicals. The least mortality was observed in botanical CAKSE @ 5% (6.44%). Significantly higher mortality was recorded in the entomopathogen, *L. lecanii* @ 2 g/l (23.62 %) as compared to *M. anisopliae* @ 2 g/l (17.47 %). The adjuvant FORS @ 5 ml/l recorded significantly higher mortality (23.64 %) as compared to without FORS (Table 41).

Among the combinations, the combination of NSKE @ 5% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l registered significantly higher mortality of first instar mealybug (36.63%), which was on par with PSKE @ 5% + *L. lecanii* @ 2 g/l with FORS @ 5 ml/l (35.45%). The least mortality was observed in the combination of CAKSE @ 5% and *L. lecanii* @ 2 g/l (3.90%) (Table 41).

Second instar mealybugs

Significantly higher mortality was exerted in botanical, NSKE @ 5% (27.69%), which was superior over other botanical treatments. The least mortality was observed in CAKSE @ 5% (11.40%). The addition of adjuvant FORS @ 5 ml/l showed significantly higher mortality (24.17 %) as compared to without FORS treatments (16.43%). Among the entomopathogens, the *L. lecanii* @ 2 g/l treatments recorded significantly higher mortality (21.17 %) as compared to treatments with *M. anisopliae* @ 2 g/l (18.90 %).

The botanical NSKE @ 5% with a combination of *L. lecanii* @ 2 g/l and FORS @ 5 ml/l recorded significantly higher mortality (41.39%) and was superior over other combinations. The next better treatments included NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l with mortality of 31.76 and 27.59 per cent, respectively (Table 41).

Table 41. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2009-10

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	28.52 (32.26)	27.16 (31.38)	8.17 (16.27)	35.45 (36.50)	36.63 (37.22)	27.19 (30.72)	24.05 (29.33)	27.59 (31.66)	15.13 (22.82)	24.24 (29.39)	41.39 (40.01)	26.48 (30.64)	17.96 (24.93)	16.69 (24.05)	7.72 (16.12)	25.54 (30.31)	28.45 (32.09)	19.27 (25.50)
	Without FORS	26.97 (31.25)	29.30 (32.74)	3.90 (11.39)	17.89 (24.85)	22.26 (28.09)	20.06 (25.66)	16.19 (23.65)	19.97 (26.52)	10.19 (18.57)	16.80 (24.04)	21.50 (27.54)	16.93 (24.06)	14.32 (22.18)	15.85 (23.28)	10.26 (18.60)	16.35 (23.81)	21.18 (27.32)	15.59 (23.04)
	Mean	27.74 (31.76)	28.23 (32.06)	6.03 (13.83)	26.67 (30.67)	29.44 (32.66)	23.62 (28.19)	20.12 (26.49)	23.78 (29.09)	12.66 (20.69)	20.52 (26.72)	31.45 (33.78)	21.71 (27.35)	16.14 (23.56)	16.27 (23.66)	8.99 (17.36)	20.95 (27.06)	24.81 (29.70)	17.43 (24.27)
<i>M. anisopliae</i> @ 2 g/l	With FORS	17.90 (24.98)	24.30 (29.49)	4.35 (12.03)	27.71 (31.69)	26.56 (30.99)	20.16 (25.84)	20.30 (26.75)	22.56 (28.35)	11.11 (19.39)	23.56 (28.97)	31.76 (34.28)	21.86 (27.54)	20.25 (26.72)	20.38 (26.78)	8.02 (16.44)	21.79 (27.73)	22.20 (28.09)	18.53 (25.15)
	Without FORS	16.03 (23.56)	16.97 (24.32)	9.33 (17.70)	11.47 (19.70)	20.08 (26.39)	14.78 (22.33)	19.43 (26.11)	19.10 (25.88)	9.16 (17.51)	15.87 (23.46)	16.09 (23.61)	15.93 (23.31)	12.35 (20.56)	13.85 (21.84)	6.22 (14.29)	19.07 (25.87)	14.67 (22.48)	13.23 (21.01)
	Mean	16.97 (24.27)	20.63 (26.91)	6.84 (14.86)	19.59 (25.70)	23.32 (28.69)	17.47 (24.09)	19.87 (26.43)	20.83 (27.11)	10.13 (18.45)	19.72 (26.21)	23.93 (28.94)	18.90 (25.43)	16.30 (23.64)	17.12 (24.31)	7.12 (15.37)	20.43 (26.80)	18.43 (25.29)	15.88 (23.08)
For comparing botanicals (A) and soap solution (C)																			
With FORS		23.21 (28.62)	25.73 (30.44)	6.26 (14.15)	31.58 (34.09)	31.60 (34.10)	23.67 (28.28)	22.17 (28.04)	25.08 (30.00)	13.12 (21.11)	23.90 (29.18)	36.58 (37.14)	24.17 (29.09)	19.11 (25.83)	18.53 (25.41)	7.87 (16.28)	23.67 (29.02)	25.32 (30.09)	18.90 (25.33)
Without FORS		21.50 (27.41)	23.13 (28.53)	6.62 (14.54)	14.68 (22.28)	21.17 (27.24)	17.42 (24.00)	17.81 (24.88)	19.54 (26.20)	9.67 (18.04)	16.34 (23.75)	18.79 (25.58)	16.43 (23.69)	13.33 (21.37)	14.85 (22.56)	8.24 (16.45)	17.71 (24.84)	17.92 (24.90)	14.41 (22.02)
Mean (A)		22.36 (28.01)	24.43 (29.48)	6.44 (14.35)	23.13 (28.18)	26.38 (30.67)		19.99 (26.46)	22.31 (28.10)	11.40 (19.57)	20.12 (26.46)	27.69 (31.36)		16.22 (23.60)	16.69 (23.99)	8.05 (16.36)	20.69 (26.93)	21.62 (27.50)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.73			2.79			0.66			2.54			0.61			2.32		
B		0.46			1.76			0.42			1.60			0.38			1.47		
C		0.46			1.76			0.42			1.60			0.38			1.47		
A X B		1.03			3.94			0.94			3.59			0.86			3.29		
B X C		0.65			2.49			0.59			2.27			0.54			2.08		
A X C		1.03			3.94			0.94			3.59			0.86			3.29		
A X B X C		1.45			5.58			1.32			5.07			1.21			4.65		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Table 42. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2010-11

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	52.22 (46.26)	63.25 (52.67)	28.22 (32.07)	41.27 (39.95)	65.66 (54.11)	50.12 (45.01)	25.00 (29.97)	34.03 (35.66)	13.85 (21.84)	28.87 (32.48)	38.33 (38.24)	28.02 (31.64)	21.44 (27.57)	31.07 (33.83)	14.11 (22.05)	29.13 (32.65)	34.03 (35.66)	25.96 (30.35)
	Without FORS	42.18 (40.48)	46.19 (42.80)	23.58 (29.03)	36.35 (37.06)	36.76 (37.31)	37.01 (37.33)	18.21 (25.24)	24.60 (29.72)	12.51 (20.71)	23.39 (28.83)	23.29 (28.83)	20.38 (26.67)	18.76 (25.65)	24.12 (29.37)	12.33 (20.55)	25.54 (30.30)	26.36 (30.88)	21.42 (27.35)
	Mean	47.20 (43.37)	54.72 (47.73)	25.90 (30.55)	38.81 (38.51)	51.21 (45.71)	43.57 (41.17)	21.60 (27.60)	29.32 (32.69)	13.18 (21.27)	26.08 (30.66)	30.81 (33.53)	24.20 (29.15)	20.10 (26.61)	27.60 (31.60)	13.22 (21.30)	27.33 (31.47)	30.20 (33.27)	23.69 (28.85)
<i>M. anisopliae</i> @ 2 g/l	With FORS	49.26 (44.56)	54.76 (47.72)	26.48 (30.96)	39.65 (39.01)	60.07 (50.80)	46.05 (42.61)	29.33 (32.77)	32.64 (34.82)	13.26 (21.34)	32.75 (34.89)	30.17 (33.29)	27.63 (31.42)	19.24 (25.98)	21.44 (27.57)	14.07 (22.02)	24.46 (29.62)	29.48 (32.87)	21.74 (27.61)
	Without FORS	39.37 (38.84)	40.33 (39.41)	20.02 (26.57)	33.89 (35.59)	32.16 (34.53)	33.15 (34.99)	21.21 (27.38)	24.60 (29.72)	12.50 (20.70)	24.64 (29.73)	24.60 (29.72)	21.51 (27.45)	17.17 (24.43)	15.66 (23.24)	12.86 (21.01)	19.48 (26.14)	21.67 (27.70)	17.37 (24.50)
	Mean	44.31 (41.70)	47.55 (43.56)	23.25 (28.76)	36.77 (37.30)	46.12 (42.67)	39.60 (38.80)	25.27 (30.08)	28.62 (32.27)	12.88 (21.02)	28.69 (32.31)	27.39 (31.51)	24.57 (29.44)	18.21 (25.21)	18.55 (25.41)	13.47 (21.51)	21.97 (27.88)	25.57 (30.28)	19.55 (26.06)
For comparing botanicals (A) and soap solution (C)																			
With FORS		50.74 (45.41)	59.00 (50.19)	27.35 (31.51)	40.46 (39.48)	62.86 (52.45)	48.08 (43.81)	27.16 (31.37)	33.33 (35.24)	13.56 (21.59)	30.81 (33.69)	34.25 (35.76)	27.82 (31.53)	20.34 (26.78)	26.26 (30.70)	14.09 (22.03)	26.79 (31.14)	31.75 (34.26)	23.85 (28.98)
Without FORS		40.77 (39.66)	43.26 (41.10)	21.80 (27.80)	35.12 (36.32)	34.46 (35.92)	35.08 (36.16)	19.71 (26.31)	24.60 (29.72)	12.51 (20.70)	23.96 (29.28)	23.95 (29.28)	20.95 (27.06)	17.97 (25.04)	19.89 (26.30)	12.60 (20.78)	22.51 (28.22)	24.02 (29.29)	19.40 (25.93)
Mean (A)		45.76 (42.53)	51.13 (45.65)	24.58 (29.66)	37.79 (37.90)	48.66 (44.19)		23.44 (28.84)	28.97 (32.48)	13.03 (21.15)	27.39 (31.48)	29.10 (32.52)		19.15 (25.91)	23.07 (28.50)	13.34 (21.41)	24.65 (29.68)	27.88 (31.77)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.36			1.39			0.32			1.24			0.46			1.76		
B		0.23			0.88			0.20			0.78			0.29			1.11		
C		0.23			0.88			0.20			0.78			0.29			1.11		
A X B		0.51			1.97			0.46			1.75			0.65			2.49		
B X C		0.32			1.25			0.29			1.11			0.41			1.57		
A X C		0.51			1.97			0.46			1.75			0.65			2.49		
A X B X C		0.73			2.78			0.65			2.48			0.92			3.52		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Third instar mealybugs

The mortality of third instar mealybug was significantly higher in botanical NSKE @ 5% (21.62%) followed by PSKE @ 5% (20.69%) as compared to other botanicals (Table 41). No significant difference was observed between the entomopathogens. However, highest mortality was recorded with *L. lecanii* @ 2 g/l treatments (17.43 %). Significantly higher mortality was observed in the treatments with FORS @ 5 ml/l (18.90%) as compared to without FORS treatments.

The combination of botanical NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l showed significantly higher (28.45%), which was on par with PSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l, PSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l causing mortality of 25.54, 22.20, 21.79 and 21.18 per cent, respectively (Table 41).

4.3.2.4b 2010-11

First instar mealybugs

Significantly higher mortality of first instar mealybug was observed with botanical neem oil @ 2% (51.13%). The next best treatment was NSKE @ 5% (48.67%) as compared to rest of the botanical treatments. The entomopathogen, *L. lecanii* @ 2 g/l recorded significantly higher mortality (43.57 %) as compared to *M. anisopliae* @ 2 g/l (39.60%). The adjuvant FORS @ 5 ml/l resulted significantly higher mortality of (48.08 %) as compared to without FORS (35.08%)(Table 42).

The combination of botanical NSKE @ 5% with entomopathogen, *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (65.66%) was more effective as compared to other combinations except neem oil @ 2% in combination with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (63.25%). The least mortality was observed in the combination of CAKSE @ 5% with *M. anisopliae* @ 2 g/l (20.02%) (Table 42).

Second instar mealybugs

The botanicals NSKE @ 5%, neem oil @ 2% and PSKE @ 5% caused higher mortality of 29.10, 28.97 and 27.39 per cent, respectively as compared to rest of the botanicals. There was no significant mortality between both entomopathogens. The addition of FORS @ 5 ml/l with the botanical treatments increased the mortality of second instar mealybug (27.82 %) as compared to without FORS treatments (Table 42).

Significantly higher mortality recorded in the treatment combination of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (38.33%), which was superior over all other combination of botanicals with entomopathogens with or without FORS (Table 42).

Third instar mealybugs

Among botanicals, the NSKE @ 5% recorded significantly higher mortality (27.88%) which was superior over other botanicals. Significantly higher mortality was observed with entomopathogen, *L. lecanii* @ 2 g/l (23.69 %) as compared to *M. anisopliae* @ 2 g/l (19.55 %). Addition of adjuvant FORS @ 5 ml/l resulted higher mortality (23.85 %) as compared to without FORS (19.40%) (Table 42).

The combination of *L. lecanii* @ 2 g/l + FORS @ 5 ml/l along with botanical NSKE @ 5% resulted significantly higher mortality (34.03%), which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and PSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l with a mortality of 31.07, 29.48 and 29.13 per cent, respectively (Table 42).

4.3.2.4c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

The botanicals, neem oil @ 2% and NSKE @ 5% exerted significantly higher mortality (37.78 and 37.53 %) of first instar mealybug as compared to other botanicals. The entomopathogen, *L. lecanii* @ 2 g/l caused significantly higher mortality (33.60 %) as compared to other entomopathogen, *M. anisopliae* @ 2 g/l (28.54 %). The addition of adjuvant FORS @ 5 ml/l increased the mortality (35.88%) as compared to without FORS (26.25%) (Table 43).

The combination of neem oil @ 2% and NSKE @ 5% with entomopathogen, *L. lecanii* @ 2 g/l registered significantly higher mortality of 41.47 and 40.33 per cent, respectively, as compared to rest of the combinations which was on par with combination of *Pongamia* oil @ 2% + *L. lecanii* @ 2 g/l

Table 43. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments		Corrected per cent mortality of mealybugs																	
Entomo pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	40.37 (39.41)	45.21 (42.22)	18.19 (25.22)	38.36 (38.25)	51.14 (45.64)	38.66 (38.15)	21.13 (27.35)	26.10 (30.71)	13.82 (21.79)	23.76 (29.14)	32.34 (34.64)	23.43 (28.73)	19.70 (26.31)	23.88 (29.22)	10.91 (19.28)	27.34 (31.50)	31.24 (33.96)	22.61 (28.06)
	Without FORS	34.57 (35.96)	37.74 (37.88)	13.74 (21.74)	27.12 (31.33)	29.51 (32.89)	28.54 (31.96)	22.76 (28.48)	26.31 (30.84)	11.72 (20.01)	24.78 (29.81)	25.84 (30.53)	22.28 (27.93)	16.54 (23.97)	19.99 (26.46)	11.29 (19.61)	20.94 (27.19)	23.77 (29.14)	18.51 (25.28)
	Mean	37.47 (37.69)	41.47 (40.05)	15.97 (23.48)	32.74 (34.79)	40.33 (39.26)	33.60 (35.06)	21.94 (27.91)	26.30 (30.77)	12.77 (20.90)	24.27 (29.48)	29.09 (32.59)	22.86 (28.33)	18.12 (25.14)	21.93 (27.84)	11.10 (19.44)	24.14 (29.35)	27.51 (31.55)	20.56 (26.67)
<i>M. anisopliae</i> @ 2 g/l	With FORS	33.58 (35.40)	39.53 (38.93)	15.42 (23.07)	33.68 (35.45)	43.33 (41.15)	33.11 (34.80)	20.76 (27.09)	23.58 (29.04)	11.81 (20.07)	24.10 (29.39)	28.18 (32.05)	21.69 (27.53)	18.75 (26.35)	20.91 (27.19)	11.05 (19.40)	23.12 (28.72)	25.84 (30.54)	20.13 (26.44)
	Without FORS	27.70 (31.70)	28.65 (32.33)	14.68 (22.50)	22.68 (28.43)	26.12 (30.69)	23.97 (29.13)	26.73 (31.11)	16.48 (23.93)	19.01 (25.83)	27.10 (31.36)	8.04 (16.45)	19.47 (25.74)	14.76 (22.57)	14.75 (22.57)	9.54 (17.97)	19.27 (26.01)	18.17 (25.21)	15.30 (22.86)
	Mean	30.64 (33.55)	34.06 (35.63)	15.05 (22.79)	28.18 (31.94)	34.73 (35.92)	28.54 (31.97)	23.74 (29.10)	20.03 (26.49)	15.41 (22.95)	25.60 (30.37)	18.11 (24.25)	20.58 (26.63)	17.25 (24.46)	17.83 (24.88)	10.29 (18.69)	21.20 (27.36)	22.00 (27.88)	17.72 (24.65)
For comparing botanicals (A) and soap solution (C)																			
With FORS		36.98 (37.40)	42.37 (40.58)	16.80 (24.15)	36.02 (36.85)	47.24 (43.39)	35.88 (36.47)	20.94 (27.22)	24.84 (29.87)	12.81 (20.93)	23.93 (29.26)	30.26 (33.34)	22.56 (28.13)	19.72 (26.33)	22.40 (28.21)	10.98 (19.34)	25.23 (30.11)	28.54 (32.25)	21.27 (27.25)
Without FORS		31.14 (33.83)	33.20 (35.11)	14.21 (22.12)	24.90 (29.88)	27.82 (31.79)	26.25 (30.55)	24.74 (29.79)	21.39 (27.39)	15.37 (22.92)	25.94 (30.59)	16.94 (23.49)	20.88 (26.84)	15.65 (23.27)	17.37 (24.51)	10.42 (18.79)	20.11 (26.60)	20.97 (27.18)	16.90 (24.07)
Mean (A)		34.06 (35.62)	37.78 (37.84)	15.51 (23.14)	30.46 (33.36)	37.53 (37.59)		22.84 (28.51)	23.12 (28.63)	14.09 (21.93)	24.94 (29.93)	23.60 (28.42)		17.69 (24.80)	19.88 (26.36)	10.70 (19.07)	22.67 (28.35)	24.75 (29.71)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.57			2.17			0.30			1.15			0.39			1.49		
B		0.36			1.37			0.19			0.73			0.25			0.94		
C		0.36			1.37			0.19			0.73			0.25			0.94		
A X B		0.80			3.07			0.43			1.63			0.55			2.11		
B X C		0.51			1.94			0.27			1.03			0.35			1.34		
A X C		0.80			3.07			0.43			1.63			0.55			2.11		
A X B X C		1.13			4.34			0.60			2.31			0.78			2.99		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

(37.47 %). The combination of entomopathogen, *L. lecanii* @ 2 g/l + FORS @ 5 ml/l proved significantly superior over other combinations with mortality of 38.66 per cent. The next best combination was *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l causing mortality of 33.11 per cent. Significantly higher mortality was recorded in the interaction of NSKE @ 5% and neem oil @ 2% with FORS @ 5 ml/l (47.24 and 42.37 %, respectively) as compared to rest of the combinations (Table 43).

The combination of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality (51.14%) of second instar mealybugs, which was on par with neem oil @ 2% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l causing mortality of 45.21 per cent as compared to remaining combinations of botanicals with entomopathogens.

Second instar mealybugs

Significantly higher mortality was recorded in PSKE @ 5% with a mortality of 24.94 per cent on second instar mealybug as compared to rest of the botanicals. The entomopathogen, *L. lecanii* @ 2 g/l showed significantly higher mortality (22.86 %) as compared to *M. anisopliae* @ 2 g/l (20.58%). The addition of adjuvant FORS @ 5 ml/l showed higher mortality of (22.56 %) as compared to treatments of without FORS @ 5 ml/l (20.88%).

The combination of NSKE @ 5% with entomopathogen, *L. lecanii* @ 2 g/l resulted significantly higher mortality (29.09%), which was superior over rest of the treatments. The entomopathogen, *L. lecanii* @ 2 g/l in combination with FORS @ 5 ml/l recorded significantly higher mortality (23.43%), which was on par with entomopathogen, *L. lecanii* @ 2 g/l (22.28%) as compared to others. Similarly, the combination of NSKE @ 5% with FORS @ 5 ml/l registered significantly higher mortality (30.26 %) which was superior over rest of the combinations (Table 43).

Significantly higher and superior mortality was registered in the combination of NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (32.34%) as compared to remaining combinations. However, least mortality (8.04%) was observed with combination of NSKE @ 5% and *M. anisopliae* @ 2 g/l.

Third instar mealybugs

The botanicals NSKE @ 5% and PSKE @ 5% exerted significantly higher mortality of 24.75 and 22.67 per cent, respectively as compared to rest of the botanicals (Table 43). The entomopathogen, *L. lecanii* @ 2 g/l showed significantly higher mortality (20.56 %). FORS @ 5 ml/l recorded significantly higher mortality (21.27%) as compared to without FORS (16.90%).

The combination of NSKE @ 5% with *L. lecanii* @ 2 g/l recorded significantly higher mortality (27.51%) which was superior over rest of the combination of botanicals with entomopathogens. The entomopathogen, *L. lecanii* @ 2 g/l + FORS @ 5 ml/l registered significantly higher mortality (22.61%) as compared to rest of the combinations (Table 43). The combination of NSKE @ 5% with FORS @ 5 ml/l registered significantly higher mortality (28.54%) and was superior over rest of the treatments.

Among, the combinations, NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l proved significantly superior by causing higher mortality (31.34%) as compared to other combinations. However, least mortality was observed in combination of CAKSE @ 5% + *M. anisopliae* @ 2 g/l (9.54%) (Table 43).

4.3.2.5 Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at five days after treatment (5 DAT)

4.3.2.5a During 2009-10

First instar mealybugs

Significantly higher mortality was registered in the botanical NSKE @ 5% (37.88%) followed by *Pongamia* oil @ 2% and neem oil @ 2% with a mortality of 36.50 and 35.38 per cent, respectively. The entomopathogen, *L. lecanii* @ 2 g/l added treatments caused significantly higher mortality (31.11%) as compared to *M. anisopliae* @ 2 g/l (26.67%). The FORS @ 5 ml/l registered significantly higher mortality (34.89 %) as compared to without FORS (25.90%) (Table 44).

Among the combinations, *Pongamia* oil @ 2% and *L. lecanii* @ 2 g/l with FORS @ 5 ml/l exerted significantly higher mortality of mealybug (49.75%). But it was found on par with neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l and neem oil @ 2% + *L. lecanii* @ 2 g/l with a mean mortality of 45.71, 43.33 and 42.26 per cent, respectively (Table 44).

Table 44. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2009-10

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	Pongamia oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	49.75 (44.84)	45.71 (42.51)	16.47 (23.87)	36.23 (36.93)	40.28 (39.37)	37.69 (37.51)	24.96 (29.92)	25.40 (30.13)	14.29 (22.20)	26.84 (31.15)	27.98 (31.92)	23.89 (29.06)	12.86 (21.01)	17.24 (24.52)	9.68 (18.06)	25.23 (30.07)	25.62 (30.27)	18.13 (24.78)
	Without FORS	36.35 (37.06)	42.26 (40.52)	13.46 (21.49)	25.12 (30.05)	35.52 (36.56)	30.54 (33.14)	17.30 (24.41)	15.73 (23.26)	8.36 (16.80)	16.62 (24.03)	14.67 (22.48)	14.53 (22.20)	11.54 (19.80)	14.49 (22.32)	8.06 (16.47)	12.48 (20.96)	13.83 (21.74)	12.15 (20.26)
	Mean	43.05 (40.95)	43.98 (41.52)	14.97 (22.68)	30.68 (33.49)	37.90 (37.97)	34.11 (35.32)	21.13 (27.17)	20.56 (26.69)	11.32 (19.50)	21.73 (27.59)	21.32 (27.20)	19.21 (25.63)	12.20 (20.40)	15.86 (23.42)	8.87 (17.26)	19.04 (25.51)	19.72 (26.00)	15.14 (22.52)
<i>M. anisopliae</i> @ 2 g/l	With FORS	41.31 (39.97)	30.81 (33.68)	13.26 (21.34)	31.75 (34.27)	43.33 (41.14)	32.09 (34.08)	16.76 (24.15)	19.64 (26.29)	11.69 (19.94)	28.69 (32.30)	25.66 (30.38)	20.49 (26.61)	1.41 (21.39)	16.44 (23.90)	10.76 (19.08)	23.90 (29.16)	21.50 (27.59)	17.20 (24.22)
	Without FORS	18.58 (25.52)	22.75 (28.47)	13.44 (21.50)	19.08 (25.88)	32.40 (34.66)	21.25 (27.21)	15.68 (23.32)	12.21 (20.39)	3.03 (5.85)	13.70 (21.67)	17.66 (24.66)	11.85 (18.01)	9.39 (17.84)	10.24 (18.64)	8.11 (16.54)	14.52 (22.32)	12.04 (20.22)	10.86 (19.11)
	Mean	29.94 (32.74)	26.78 (31.08)	13.35 (21.42)	25.41 (30.07)	37.87 (37.90)	26.67 (30.64)	16.22 (23.73)	15.93 (23.34)	5.84 (9.97)	21.20 (26.99)	21.66 (27.52)	16.17 (22.31)	11.40 (19.61)	13.34 (21.27)	9.43 (17.81)	19.21 (25.74)	16.77 (23.91)	14.03 (21.67)
For comparing botanicals (A) and soap solution (C)																			
With FORS		45.53 (42.41)	38.26 (38.10)	14.86 (22.61)	33.99 (35.60)	41.81 (40.26)	34.89 (35.79)	20.86 (27.03)	22.52 (28.21)	12.99 (21.07)	27.76 (31.73)	26.82 (31.15)	22.19 (27.84)	13.14 (21.20)	16.84 (24.21)	10.22 (18.57)	24.56 (29.61)	23.56 (28.93)	17.66 (24.50)
Without FORS		27.47 (31.29)	32.50 (34.50)	13.45 (21.49)	22.10 (27.97)	33.96 (35.61)	25.90 (30.17)	16.49 (23.86)	13.97 (21.83)	4.18 (8.40)	15.16 (22.85)	16.16 (23.57)	13.19 (20.10)	10.47 (18.82)	12.37 (20.48)	8.08 (16.50)	13.68 (21.64)	12.93 (20.98)	11.51 (19.68)
Mean (A)		36.50 (36.85)	35.38 (36.30)	14.16 (22.05)	28.04 (31.78)	37.88 (37.93)		18.68 (25.45)	18.24 (25.02)	8.58 (14.73)	21.46 (27.29)	21.49 (27.36)		11.80 (20.01)	14.60 (22.34)	9.15 (17.54)	19.12 (25.63)	18.25 (24.95)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.60			2.29			0.92			3.51			0.64			2.45		
B		0.38			1.45			0.58			2.22			0.40			1.55		
C		0.38			1.45			0.58			2.22			0.40			1.55		
A X B		0.84			3.24			1.30			4.97			0.90			3.46		
B X C		0.53			2.05			0.82			3.14			0.57			2.19		
A X C		0.84			3.24			1.30			4.97			0.90			3.46		
A X B X C		1.19			4.58			1.83			7.03			1.28			4.90		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Table 45. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2010-11

Treatments		Corrected per cent mortality of mealybugs																					
Entomo pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar									
		Botanicals (A)																					
		<i>Pongamia oil @ 2%</i>	<i>Neem oil @ 2%</i>	CAKSE	PSKE	NSKE	Mean	<i>Pongamia oil @ 2%</i>	<i>Neem oil @ 2%</i>	CAKSE	PSKE	NSKE	Mean	<i>Pongamia oil @ 2%</i>	<i>Neem oil @ 2%</i>	CAKSE	PSKE	NSKE	Mean				
<i>L. lecanii</i> @ 2 g/l	With FORS	45.24 (42.25)	43.33 (41.14)	21.65 (27.71)	36.57 (37.18)	69.44 (56.47)	43.25 (40.95)	35.48 (36.75)	42.37 (40.59)	16.08 (23.63)	26.92 (31.22)	41.48 (40.07)	32.54 (34.45)	34.13 (35.73)	36.36 (37.07)	16.44 (23.90)	29.44 (32.81)	38.79 (38.50)	31.3 (33.60)				
	Without FORS	36.57 (37.18)	32.22 (34.57)	16.37 (23.86)	24.57 (29.67)	48.48 (44.11)	31.64 (33.88)	22.27 (28.14)	32.64 (34.82)	9.54 (17.98)	19.58 (26.25)	26.11 (30.71)	22.03 (27.58)	21.24 (27.37)	24.27 (29.49)	10.97 (19.24)	22.05 (27.98)	21.50 (27.61)	20.01 (26.34)				
	Mean	40.90 (39.71)	37.78 (37.85)	19.01 (25.78)	30.57 (33.43)	58.96 (50.29)	37.44 (37.41)	29.05 (32.44)	37.51 (37.71)	12.81 (20.80)	23.25 (28.73)	33.80 (35.39)	27.28 (31.02)	27.68 (31.55)	30.32 (33.28)	13.70 (21.57)	25.75 (30.40)	30.14 (33.05)	25.52 (29.97)				
<i>M. anisopliae</i> @ 2 g/l	With FORS	44.29 (41.69)	34.72 (36.08)	9.93 (18.19)	34.24 (35.78)	62.22 (52.07)	37.08 (36.76)	31.75 (34.27)	39.90 (39.15)	15.29 (23.00)	24.36 (29.56)	40.60 (39.56)	30.38 (33.11)	26.11 (30.71)	27.30 (31.49)	16.37 (23.86)	30.04 (33.22)	33.49 (35.33)	26.66 (30.92)				
	Without FORS	32.48 (34.73)	32.32 (34.60)	10.02 (18.44)	23.17 (28.75)	31.62 (34.20)	25.92 (30.14)	23.09 (28.71)	28.33 (32.11)	9.52 (17.97)	11.55 (19.86)	26.11 (30.71)	19.72 (25.87)	18.85 (25.68)	22.27 (28.14)	11.51 (19.72)	16.76 (24.15)	19.17 (25.95)	17.71 (24.73)				
	Mean	38.38 (38.21)	33.52 (35.34)	9.97 (18.32)	28.17 (32.27)	46.92 (43.14)	31.50 (33.45)	27.42 (31.49)	34.12 (35.63)	12.41 (20.49)	17.95 (24.71)	33.35 (35.14)	25.05 (29.49)	22.48 (28.20)	24.78 (29.81)	13.94 (21.79)	23.40 (28.68)	26.33 (30.64)	22.19 (27.82)				
For comparing botanicals (A) and soap solution (C)																							
With FORS		44.76 (41.97)	39.03 (38.61)	15.79 (22.95)	35.40 (36.48)	65.83 (54.27)	40.16 (38.86)	33.79 (35.51)	41.14 (39.87)	15.69 (23.32)	25.64 (30.39)	41.04 (39.82)	31.46 (33.78)	30.12 (33.22)	31.83 (34.28)	16.41 (23.88)	29.74 (33.01)	36.14 (36.92)	28.85 (32.26)				
Without FORS		34.52 (35.95)	32.27 (34.58)	13.20 (21.15)	23.87 (29.21)	40.05 (39.16)	28.78 (32.01)	22.68 (28.42)	30.49 (33.47)	9.53 (17.97)	15.57 (23.05)	26.11 (30.71)	20.46 (26.73)	20.04 (26.52)	23.27 (28.82)	11.24 (19.48)	19.41 (26.06)	20.33 (26.78)	18.86 (25.53)				
Mean (A)		39.64 (38.96)	35.6 (36.60)	14.49 (22.05)	29.64 (32.85)	52.94 (46.71)		28.24 (31.97)	35.81 (36.67)	12.61 (20.65)	20.60 (26.72)	33.58 (35.27)		25.08 (29.87)	27.55 (31.55)	13.82 (21.68)	24.57 (29.54)	28.24 (31.85)					
Comparing the means of		S.Em.±				C.D. (0.01)				S.Em.±				C.D. (0.01)				S.Em.±				C.D. (0.01)	
A		0.61				2.34				0.36				1.37				0.45				1.72	
B		0.39				1.48				0.23				0.87				0.28				1.09	
C		0.39				1.48				0.23				0.87				0.28				1.09	
A X B		0.86				3.30				0.51				1.94				0.63				2.43	
B X C		0.54				2.09				0.32				1.23				0.40				1.54	
A X C		0.86				3.30				0.51				1.94				0.63				2.43	
A X B X C		1.22				4.67				0.72				2.75				0.90				3.44	

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Second instar mealybugs

The botanical NSKE @ 5%, PSKE @ 5%, *Pongamia* oil @ 2% and neem oil @ 2% caused significantly higher mortality (21.49, 21.46, 18.68 and 18.24 per cent, respectively) except CAKSE @ 5% (8.58%). Significantly higher mortality was recorded in the treatments mixed with *L. lecanii* @ 2 g/l (19.21 %) compared to *M. anisopliae* @ 2 g/l (16.17%). The FORS @ 5 ml/l registered significantly higher mortality (22.19 %) of second instar mealybug as compared to without FORS (13.19%) (Table 44).

The combination of PSKE @ 5% with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l was more effective with mortality of 28.69 per cent followed by the combination of NSKE @ 5% and PSKE @ 5% along with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l with mortality of 27.98 and 26.84 per cent, respectively (Table 44).

Third instar mealybugs

The botanical, PSKE @ 5% resulted significantly higher mortality (19.12%) of mealybug followed by NSKE @ 5% (18.25%) as compared to other botanicals. Non-significant difference was observed between both the entomopathogens. Significantly higher mortality was registered in the treatments mixed with FORS @ 5 ml/l (17.66 %) on third instar mealybug.

The combination of botanical NSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality (25.62%), followed by PSKE @ 5% and *L. lecanii* @ 2 g/l + FORS @ 5 ml/l (25.23%), which were on par with PSKE @ 5% and NSKE @ 5% in combination with *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (23.90 and 21.50%, respectively) as compared to rest of the combinations (Table 44).

4.3.2.5b During 2010-11

First instar mealybugs

The botanical NSKE @ 5% exerted significantly higher mortality (52.94%), which was superior over rest of the botanicals. However, least mortality (14.49 %) was observed in the treatment of CAKSE @ 5%. The entomopathogen, *L. lecanii* @ 2 g/l registered significantly higher mortality (37.44 %). FORS @ 5 ml/l resulted higher mortality (40.16%) (Table 45).

The combination of botanical, NSKE @ 5% and entomopathogens, *L. lecanii* @ 2 g/l and *M. anisopliae* @ 2 g/l with FORS @ 5 ml/l resulted higher mortality (69.44 and 62.22%, respectively) (Table 45).

Second instar mealybugs

The botanical, neem oil @ 2% was significantly superior over all other botanical treatments with of 35.81 per cent mortality. The next better treatment was NSKE @ 5% (33.58%) (Table 45). The entomopathogen, *L. lecanii* @ 2 g/l resulted significantly higher mortality (27.28 %) as compared to *M. anisopliae* @ 2 g/l (25.05 %). The FORS @ 5 ml/l resulted significantly higher mortality (31.46 %) as compared to without FORS (20.46%).

The combination of entomopathogen, *L. lecanii* @ 2 g/l + FORS @ 5 ml/l with neem oil @ 2% and NSKE @ 5% and *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l with NSKE @ 5% proved most effective against with 42.37, 41.48 and 40.60 per cent mortality, respectively. However, least mortality was observed in CAKSE @ 5% in combination with *L. lecanii* @ 2 g/l and *M. anisopliae* @ 2 g/l (9.54 and 9.52 %, respectively).

Third instar mealybugs

The botanical, NSKE @ 5% recorded significantly higher mortality (28.24%) of mealybug, which was on par with neem oil @ 2% (27.55%) as compared to rest of the botanicals. Significantly higher mortality was exerted by entomopathogen, *L. lecanii* @ 2 g/l (25.52 %). The FORS @ 5 ml/l added treatments exerted significantly higher mortality (28.85 %).

The combination of NSKE @ 5% and neem oil @ 2% in combination with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l registered significantly higher mortality (38.79 and 36.36%, respectively). However, they were on par with *Pongamia* oil @ 2% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (33.49%) (Table 45).

Table 46. Effect of botanicals in combination with entomopathogens on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatments		Corrected per cent mortality of mealybugs																	
Entomo- pathogens (B)	Soap (C)	1 st Instar						2 nd Instar						3 rd Instar					
		Botanicals (A)																	
		<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean	<i>Pongamia</i> oil @ 2%	Neem oil @ 2%	CAKSE	PSKE	NSKE	Mean
<i>L. lecanii</i> @ 2 g/l	With FORS	47.50 (43.54)	44.52 (41.84)	19.06 (25.85)	36.40 (37.09)	54.86 (47.77)	40.47 (39.22)	23.61 (29.05)	29.02 (32.55)	11.91 (20.18)	23.21 (28.78)	27.05 (31.32)	22.96 (28.38)	23.49 (28.98)	26.80 (31.16)	13.06 (21.15)	27.34 (31.51)	32.20 (34.55)	24.58 (29.47)
	Without FORS	36.46 (37.13)	37.24 (37.59)	14.92 (22.71)	24.84 (29.87)	42.00 (40.38)	31.09 (33.53)	24.52 (29.64)	27.81 (31.81)	11.83 (20.11)	20.49 (26.90)	27.63 (31.70)	22.46 (28.03)	16.39 (23.81)	19.38 (26.09)	9.51 (17.92)	17.45 (24.68)	17.66 (24.83)	16.08 (23.46)
	Mean	41.98 (40.34)	40.88 (39.71)	16.99 (24.28)	30.62 (33.48)	48.43 (44.08)	35.78 (36.38)	24.07 (29.35)	28.42 (32.18)	11.87 (20.14)	21.85 (27.84)	27.34 (31.51)	22.71 (28.20)	19.94 (26.40)	23.09 (28.63)	11.28 (19.53)	22.39 (28.09)	24.93 (29.69)	20.33 (26.47)
<i>M. anisopliae</i> @ 2 g/l	With FORS	42.80 (40.84)	32.77 (34.90)	11.59 (19.87)	32.99 (35.03)	52.78 (46.57)	34.59 (35.44)	19.93 (26.50)	23.99 (29.30)	10.61 (18.99)	20.12 (26.60)	25.89 (30.56)	20.11 (26.39)	19.76 (26.38)	21.87 (27.87)	13.56 (21.59)	26.97 (31.25)	27.49 (31.60)	21.93 (27.74)
	Without FORS	25.53 (30.34)	27.54 (31.63)	11.73 (20.02)	21.12 (27.35)	32.01 (34.44)	34.59 (28.75)	29.03 (32.59)	14.15 (22.08)	13.46 (21.49)	27.59 (31.67)	8.83 (17.14)	18.61 (24.99)	14.12 (22.05)	16.26 (23.77)	9.81 (18.21)	15.64 (23.25)	15.60 (23.24)	14.29 (22.10)
	Mean	34.16 (35.59)	30.15 (33.27)	11.66 (19.95)	27.06 (31.19)	42.39 (40.51)	29.09 (32.10)	24.48 (29.54)	19.07 (25.69)	12.03 (20.24)	23.85 (29.14)	17.36 (23.85)	19.36 (25.69)	16.94 (24.21)	19.06 (25.82)	11.69 (19.90)	21.31 (27.25)	21.55 (27.42)	18.11 (24.92)
For comparing botanicals (A) and soap solution (C)																			
With FORS		45.15 (42.19)	38.64 (38.37)	15.33 (22.86)	34.70 (36.06)	53.82 (47.17)	37.53 (37.33)	21.77 (27.78)	26.50 (30.93)	11.26 (19.58)	21.66 (27.69)	26.47 (30.94)	21.53 (27.38)	21.63 (27.68)	24.33 (29.52)	13.31 (21.37)	27.15 (31.38)	29.85 (33.07)	23.26 (28.60)
Without FORS		30.99 (33.73)	32.39 (34.61)	13.32 (21.36)	22.98 (28.61)	37.01 (37.41)	27.34 (31.14)	26.78 (31.11)	20.98 (26.94)	12.64 (20.80)	24.04 (29.29)	18.23 (24.42)	20.53 (26.51)	15.26 (22.93)	17.82 (24.93)	9.66 (18.07)	16.55 (23.97)	16.63 (24.03)	15.18 (22.78)
Mean (A)		38.07 (37.96)	35.52 (36.49)	14.32 (22.11)	28.84 (32.33)	45.41 (42.29)		24.27 (29.45)	23.74 (28.94)	11.95 (20.19)	22.85 (28.49)	22.35 (27.68)		18.44 (25.30)	21.08 (27.22)	11.49 (19.72)	21.85 (27.67)	23.24 (28.55)	
Comparing the means of		S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A		0.38			1.47			0.38			1.44			0.37			1.44		
B		0.24			0.93			0.24			0.91			0.24			0.91		
C		0.24			0.93			0.24			0.91			0.24			0.91		
A X B		0.54			2.08			0.53			2.04			0.53			2.03		
B X C		0.34			1.32			0.34			1.29			0.33			1.28		
A X C		0.54			2.08			0.53			2.04			0.53			2.03		
A X B X C		0.77			2.95			0.75			2.88			0.75			2.87		

NSKE - Neem seed kernel extract @ 5% **CAKSE** - Custard apple kernel seed extract @ 5% **PSKE** - *Pongamia* seed kernel extract @ 5% **FORS** - Fish oil rosin soap @ 5 ml/l The figures in parentheses are arcsine transformations

Table 47. Effect of insecticides in combination with adjuvants on different instars of *Macronellus hirsutus* at twelve hours after treatment during 2009-10

Treatment		Corrected per cent mortality of mealybugs											
Insecticides (A)	Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
		APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l		15.56 (23.19)	20.00 (26.55)	12.22 (20.41)	15.9 (23.39)	11.11 (19.42)	12.22 (20.41)	13.33 (21.31)	12.22 (20.38)	4.44 (11.99)	7.78 (16.11)	4.46 (12.01)	5.56 (13.37)
Thiamethoxam 25 WG @ 0.3 g/l		11.10 (19.25)	16.67 (24.02)	12.22 (20.31)	13.33 (21.19)	12.22 (20.41)	13.33 (21.41)	12.22 (20.41)	12.59 (20.75)	4.44 (11.99)	7.79 (16.13)	4.46 (12.01)	5.56 (13.38)
Acetamiprid 20 SP @ 0.3 g/l		5.56 (13.48)	6.67 (14.63)	7.79 (16.13)	6.67 (14.75)	5.56 (13.48)	10.00 (18.26)	6.67 (14.63)	7.41 (15.46)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Imidacloprid 70 WG @ 0.3 g/l		27.78 (31.78)	37.79 (37.91)	28.89 (32.49)	31.49 (34.06)	15.56 (23.19)	18.89 (25.73)	16.67 (24.09)	17.04 (24.34)	7.79 (16.13)	12.21 (20.41)	8.89 (17.27)	9.63 (17.93)
Imidacloprid 17.8 SL @ 0.3 ml/l		24.44 (29.61)	31.11 (33.88)	23.3 (28.84)	26.30 (30.78)	12.22 (20.41)	15.56 (23.19)	11.11 (19.42)	12.96 (21.01)	3.33 (8.49)	6.67 (14.96)	5.56 (13.48)	5.19 (12.31)
Chlorfenapyr 10 SC @ 1ml/l		4.44 (12.00)	2.22 (7.01)	7.78 (16.11)	4.81 (11.71)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Emamectin benzoate 5 SG @ 0.3 g/l		4.44 (12.00)	7.78 (16.11)	6.67 (14.96)	6.30 (14.36)	4.44 (12.00)	4.44 (12.00)	4.44 (12.00)	4.44 (12.00)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Buprofezin 25 EC @ 2.00 ml/l		20.02 (26.43)	26.67 (31.05)	18.89 (25.73)	21.86 (27.74)	8.89 (17.11)	12.22 (20.41)	5.56 (13.48)	8.89 (17.00)	4.44 (12.00)	10.00 (18.43)	6.68 (14.65)	7.04 (15.02)
Bifenthrin 10 EC @ 1 ml/l		24.43 (29.60)	26.67 (31.05)	21.10 (27.32)	24.07 (29.32)	15.56 (23.19)	17.78 (24.91)	15.56 (23.19)	16.30 (23.76)	5.57 (13.49)	11.10 (19.41)	5.57 (13.49)	7.41 (15.46)
Profenophos 50 EC @ 2ml/l		11.11 (19.42)	15.56 (23.19)	12.22 (20.31)	12.96 (20.98)	8.89 (17.27)	10.00 (18.26)	11.11 (19.16)	10.00 (18.23)	3.33 (10.52)	5.56 (13.48)	4.42 (11.96)	4.44 (11.98)
Diafenthiuron 50 WP @ 1.2 g/l		12.21 (20.41)	13.32 (21.40)	11.10 (19.41)	12.21 (20.41)	6.67 (14.96)	7.78 (16.11)	7.78 (16.11)	7.41 (15.73)	3.33 (10.52)	4.44 (12.00)	3.33 (10.52)	3.70 (11.01)
Dimethoate 30 EC @ 1.7 ml/l		10.00 (18.26)	17.78 (24.84)	12.22 (20.41)	13.33 (21.17)	8.89 (17.27)	8.89 (17.27)	5.56 (13.48)	7.78 (16.01)	3.33 (10.52)	5.56 (13.48)	3.33 (10.52)	4.07 (11.50)
Dichlorvos 76 EC @ 0.5 ml/l		17.78 (24.91)	23.33 (28.84)	18.89 (25.73)	20.00 (26.49)	8.89 (17.27)	14.44 (22.20)	10.00 (18.43)	11.11 (19.30)	4.44 (12.00)	7.78 (16.11)	4.44 (12.00)	5.56 (13.37)
Adjuvant alone		0.00 (0.52)	0.00 (0.52)	11.11 (19.42)	3.70 (6.47)	0.00 (0.52)	0.00 (0.52)	1.11 (3.51)	0.37 (1.17)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Mean		13.49 (20.02)	17.54 (22.89)	14.60 (21.97)	15.21 (21.63)	8.49 (15.43)	10.40 (17.16)	8.65 (15.66)	9.18 (16.08)	3.18 (8.40)	5.63 (11.46)	3.65 (9.13)	4.15 (9.67)
Comparing the means of		S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)		S.E.m.±		C.D. (0.01)	
A		0.76		2.85		0.77		2.88		0.72		2.67	
B		0.35		1.32		0.36		1.33		0.33		1.23	
A X B		1.32		4.93		1.34		4.98		1.24		4.62	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

4.3.2.5c Mean of Two years (2009-10 and 2010-11)

First instar mealybugs

The botanical NSKE @ 5% recorded higher mortality (45.41 %) which was superior over rest of the botanicals. The next better treatments were *Pongamia* oil @ 2% and neem oil @ 2% with mortality of 38.07 and 35.52 per cent, respectively. The entomopathogen, *L. lecanii* @ 2 g/l showed significantly higher mortality of 35.78 per cent. The FORS @ 5 ml/l resulted significantly higher mortality of 37.53 per cent (Table 46).

Significantly higher mortality was recorded in the combination of NSKE @ 5% and *L. lecanii* @ 2 g/l (48.43%) which was superior over rest of the combinations. Significantly higher mortality was registered in combination of *L. lecanii* @ 2 g/l + FORS @ 5 ml/l with 40.47 per cent as compared to rest of the combinations. The combination of NSKE @ 5% with FORS registered higher mortality of first instar mealybugs (53.82 %) which was superior over rest of the combinations (Table 46).

Among the combination, the botanical NSKE @ 5% in combination with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality of 54.86 and 52.78 per cent, respectively as compared to rest of the combinations (Table 46).

Second instar mealybugs

The botanical, *Pongamia* oil @ 2% was most effective by causing mortality of 24.27 per cent, which was on par with neem oil @ 2% (23.74%) and PSKE @ 5% (22.85%). Among the entomopathogens, *L. lecanii* @ 2 g/l showed significantly higher mortality (22.71 %) of second instar mealybugs as compared to *M. anisopliae* @ 2 g/l (19.36 %). There was no significant difference between with or without FORS. However, highest mortality was recorded in the presence of FORS @ 5 ml/l (21.53 %).

The combination of neem oil @ 2% with *L. lecanii* @ 2 g/l showed significantly higher mortality (28.42 %) which was on par with NSKE @ 5% with *L. lecanii* @ 2 g/l as compared to rest of the combinations. Among the combinations, *L. lecanii* @ 2 g/l with FORS @ 5 ml/l resulted significantly higher mortality (22.96%) of mealybugs, followed by *L. lecanii* @ 2 g/l (22.46%) as compared to remaining combinations. The combinations of *Pongamia* oil @ 2% without FORS, neem oil @ 2% with FORS @ 5 ml/l and NSKE @ 5% with FORS @ 5 ml/l resulted significantly higher mortality of 26.78, 26.50 and 26.47 per cent, respectively which were on par with NSKE @ 5% without FORS (24.04 %) (Table 46).

The combination of *Pongamia* oil @ 2% + *M. anisopliae* @ 2 g/l and neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded significantly higher mortality of 29.03 and 29.02 per cent, respectively, which was on par with neem oil @ 2% + *L. lecanii* @ 2 g/l, NSKE @ 5% + *L. lecanii* @ 2 g/l NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l with mortality of 27.81, 27.63, 27.05 and 25.89 per cent, respectively (Table 46).

Third instar mealybugs

The botanicals, NSKE @ 5%, PSKE @ 5% and neem oil @ 2% recorded significantly higher mortality (23.24, 21.85 and 21.08%, respectively) as compared to rest of the botanicals. The *L. lecanii* @ 2 g/l registered significantly higher mortality (20.33 %) as compared to other entomopathogen, *M. anisopliae* @ 2 g/l (18.11%). The addition of FORS @ 5 ml/l recorded significantly higher mortality (23.26 %) than the treatments without FORS @ 5 ml/l (15.18 %) (Table 46).

The combination of NSKE @ 5% with *L. lecanii* @ 2 g/l resulted for higher mortality of 24.93 per cent, which was on par with neem oil @ 2% and PSKE @ 5% with *L. lecanii* @ 2 g/l causing mortality of 23.09 and 22.39 per cent, respectively. The combination of entomopathogen, *L. lecanii* @ 2 g/l with FORS @ 5 ml/l recorded significantly higher mortality (24.58%) on third instar mealybugs as compared to other combinations. The combination of botanical NSKE @ 5% with FORS @ 5 ml/l showed significantly higher mortality of 29.85 per cent, which was on par with PSKE @ 5% with FORS @ 5 ml/l causing mortality of 27.15 per cent as compared to rest of the combinations.

The combination of entomopathogen, *L. lecanii* @ 2 g/l with FORS @ 5 ml/l with NSKE @ 5% registered significantly higher mortality (32.20 %) which was superior over other combinations (Table 46).

4.3.3 Evaluation of newer chemical insecticides against grapevine mealybug, *Maconellicoccus hirsutus* along with different adjuvants

4.3.3.1 Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at twelve hour after treatment (12 HAT)

4.3.3.1a During 2009-10

First instar mealybug

The insecticide imidacloprid 70 WG @ 0.3 g/l recorded significantly higher mortality (31.49%), which was on par with the imidacloprid 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l with mortality of 26.30 and 24.07 per cent, respectively. However, lowest mortality was observed in insecticides viz., acetamiprid 20 SP @ 0.3 g/l, emamectin benzoate 5 SG @ 0.3 g/l and chlorfenapyr 10 SC @ 1 ml/l with mortality of 6.67, 6.30 and 4.81 per cent, respectively. The adjuvant Dhanuvit @ 1 ml/l and FORS @ 5 ml/l registered significantly higher mortality of 17.54 and 14.60 per cent, respectively (Table 47).

The combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l registered significantly higher mortality (37.79 %). It was on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (31.11%), followed by combination of imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l, 25 EC @ 0.12 ml/l and bifenthrin 10 EC @ 1 ml/l with Dhanuvit @ 1 ml/l causing mortality of 28.89, and 26.67 and 26.67 per cent, respectively.

Second instar mealybug

Imidacloprid 70 WG @ 0.3 g/l caused significantly higher mortality of 17.04 per cent, which was on par with bifenthrin 10 EC @ 1 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l, thiamethoxam 25 WG @ 0.3g/l, thiacloprid 240 SC @ 0.2 ml/l and dichlorvos 76 EC @ 0.5 ml/l with mortality of 16.30, 12.96, 12.59, 12.22 and 11.11 per cent, respectively. The Dhanuvit @ 1 ml/l recorded significantly higher mortality (10.40%) as compared to other adjuvants viz., FORS @ 5 ml/l (8.65%) and APSA-80 (8.49%) (Table 47).

Significantly higher mortality was observed in the treatment combinations of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l with mortality of 18.89 per cent. It was on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l, imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + APSA-80 @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + FORS @ 5 ml/l and dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l with a mean mortality of 17.78, 16.67, 15.56, 15.56, 15.56, 15.56 and 14.44 per cent, respectively as compared to other treatment combinations of insecticides and adjuvants (Table 47).

Third instar mealybug

Imidacloprid 70 WG @ 0.3g/l resulted significantly higher mortality of 9.63 per cent, which was on par with bifenthrin 10 EC @ 1 ml/l, buprofezin 25 SC @ 2.00 ml/l. (7.41 and 7.04 per cent, respectively), dichlorvos 76 EC @ 0.5 ml/l, thiamethoxam @ 25 WG @ 0.3g/l and thiacloprid 240 SC @ 0.2 ml/l with mortality of 5.56 per cent, each (Table 47). Among the adjuvants, Dhanuvit @ 1 ml/l resulted higher mortality (5.63%) as compared to other adjuvants viz., FORS @ 5 ml/l (3.65%) and APSA-80 @ 1 ml/l (3.18%).

Among the remaining treatment combinations, imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l recorded significantly higher mortality (12.21 %), which was on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l, buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l, imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l, and thiamethoxam + Dhanuvit @ 1 ml/l, thiacloprid 240 SC @ 0.2 ml/l and dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l with mortality of 11.10, 10.00, 8.89, 7.79, and 7.78 per cent, respectively as compared to other combinations. However, all the combinations of insecticides and adjuvants were found effective against third instar mealybugs.

4.3.3.1b During 2010-11

First instar mealybug

The insecticide imidacloprid 70 WG @ 0.3g/l showed significantly higher mortality (12.22 %) which was on par with bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l as compared to

Table 48. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment during 2010-11

Treatment	Corrected per cent mortality of mealybugs											
	1 st Instar				2 nd Instar				3 rd Instar			
Insecticides (A)	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l	7.78 (16.11)	10.00 (18.43)	12.23 (20.46)	10.00 (18.33)	3.34 (10.52)	5.56 (13.60)	5.56 (13.48)	4.82 (12.53)	3.23 (10.33)	4.10 (11.67)	3.63 (10.96)	3.66 (10.99)
Thiamethoxam 25 WG @ 0.3 g/l	3.32 (10.50)	5.57 (13.49)	4.43 (11.98)	4.44 (11.99)	2.23 (8.57)	1.10 (6.01)	3.34 (10.52)	2.23 (8.37)	4.44 (12.00)	6.66 (14.94)	7.80 (16.21)	6.30 (14.38)
Acetamiprid 20 SP @ 0.3 g/l	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	1.00 (5.74)	1.43 (6.80)	1.20 (6.28)	1.21 (6.27)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Imidacloprid 70 WG @ 0.3 g/l	10.00 (18.43)	16.67 (24.07)	10.00 (18.43)	12.22 (20.31)	7.77 (16.17)	0.00 (18.43)	5.56 (13.48)	7.77 (16.02)	6.66 (14.94)	8.90 (17.35)	8.90 (17.35)	8.15 (16.55)
Imidacloprid 17.8 SL @ 0.3 ml/l	8.89 (17.27)	8.90 (17.35)	7.36 (15.70)	8.38 (16.77)	6.23 (14.42)	8.90 (17.33)	6.80 (15.11)	7.31 (15.62)	4.44 (12.00)	7.80 (16.21)	4.44 (12.00)	5.56 (13.40)
Chlorfenapyr 10 SC @ 1ml/l	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	1.10 (6.01)	1.77 (7.60)	6.67 (14.93)	3.17 (9.51)	1.10 (6.01)	0.00 (0.52)	0.00 (0.52)	0.37 (2.00)
Emamectin benzoate 5 SG @ 0.3 g/l	0.00 (0.52)	2.20 (8.48)	1.10 (6.01)	1.10 (4.83)	1.27 (6.43)	1.87 (7.84)	3.07 (10.07)	2.07 (8.11)	0.00 (0.52)	0.00 (0.52)	3.32 (10.50)	1.11 (3.50)
Buprofezin 25 EC @ 2.00 ml/l	5.56 (13.48)	6.67 (14.94)	4.44 (12.00)	5.55 (13.47)	3.34 (10.52)	3.34 (10.52)	6.66 (14.94)	4.45 (12.00)	5.54 (13.46)	5.57 (13.64)	2.20 (8.52)	4.44 (11.87)
Bifenthrin 10 EC @ 1 ml/l	7.78 (16.11)	11.11 (19.42)	8.90 (17.35)	9.26 (17.63)	7.23 (15.58)	8.90 (17.28)	7.32 (15.68)	7.82 (16.18)	6.54 (14.82)	8.00 (16.41)	5.67 (13.76)	6.74 (14.99)
Profenophos 50 EC @ 2ml/l	2.20 (8.52)	5.56 (13.48)	3.34 (10.52)	3.70 (10.84)	3.34 (10.52)	5.56 (13.60)	3.34 (10.52)	4.08 (11.55)	2.20 (8.52)	2.23 (8.57)	3.34 (10.52)	2.59 (9.20)
Diafenthiuron 50 WP @ 1.2 g/l	3.13 (10.18)	4.91 (12.68)	3.58 (10.83)	3.87 (11.23)	1.10 (6.01)	1.10 (6.01)	2.23 (8.57)	1.48 (6.86)	2.10 (8.32)	2.77 (9.55)	2.20 (8.52)	2.36 (8.80)
Dimethoate 30 EC @ 1.7 ml/l	2.21 (8.32)	4.43 (11.98)	4.44 (12.00)	3.70 (10.77)	2.23 (8.58)	6.66 (14.94)	3.34 (10.52)	4.08 (11.35)	4.43 (12.15)	4.44 (12.00)	4.53 (12.28)	4.47 (12.14)
Dichlorvos 76 EC @ 0.5 ml/l	5.56 (13.48)	8.87 (17.22)	7.76 (16.07)	7.39 (15.59)	4.44 (12.00)	7.22 (15.57)	7.76 (16.14)	6.47 (14.57)	3.34 (10.52)	7.80 (16.21)	6.66 (14.94)	5.93 (13.89)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	6.67 (14.94)	2.22 (4.98)	0.00 (0.52)	0.00 (0.52)	4.43 (11.98)	1.48 (3.99)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Mean	4.03 (9.46)	6.06 (12.25)	5.30 (11.88)	5.13 (11.20)	3.19 (9.36)	4.53 (11.11)	4.80 (12.30)	4.17 (10.92)	3.15 (8.79)	4.16 (9.75)	3.76 (9.68)	3.69 (9.41)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.51		1.89		0.36		1.34		0.32		1.21	
B	0.23		0.87		0.17		0.62		0.15		0.56	
A X B	0.88		3.27		0.62		2.32		0.56		2.09	

FORS - Fish oil rosin soap -Figures in parentheses are Arcsine transformations

Table 49. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at twelve hours after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatment	Corrected per cent mortality of mealybugs											
	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Insecticides (A)												
Thiacloprid 240 SC @ 0.2 ml/l	11.67 (19.93)	15.00 (22.78)	12.23 (20.44)	12.96 (21.05)	7.23 (15.57)	8.89 (17.31)	9.44 (17.88)	8.52 (16.92)	3.84 (11.21)	5.94 (14.08)	4.04 (11.56)	4.61 (12.28)
Thiamethoxam 25 WG @ 0.3 g/l	7.21 (15.48)	11.12 (19.39)	8.33 (16.71)	8.89 (17.19)	7.23 (15.56)	7.22 (15.58)	7.78 (16.17)	7.41 (15.77)	4.44 (11.99)	7.22 (15.56)	6.13 (14.30)	5.93 (13.95)
Acetamiprid 20 SP @ 0.3 g/l	2.78 (9.48)	3.33 (10.28)	3.89 (11.32)	3.34 (10.36)	3.28 (10.34)	5.72 (13.76)	3.93 (11.24)	4.31 (11.78)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Imidacloprid 70 WG @ 0.3 g/l	18.89 (25.74)	27.22 (31.43)	19.44 (26.15)	21.85 (27.78)	11.66 (19.95)	13.89 (21.86)	11.11 (19.45)	12.22 (20.42)	7.22 (15.56)	10.56 (18.94)	8.89 (17.33)	8.89 (17.28)
Imidacloprid 17.8 SL @ 0.3 ml/l	16.67 (24.09)	20.01 (26.55)	15.34 (23.02)	17.34 (24.55)	9.23 (17.67)	12.23 (20.46)	8.96 (17.39)	10.14 (18.51)	3.89 (11.08)	7.23 (15.60)	5.00 (12.80)	5.37 (13.16)
Chlorfenapyr 10 SC @ 1ml/l	2.22 (8.45)	1.11 (4.94)	3.89 (11.32)	2.41 (8.24)	0.55 (4.24)	0.88 (5.37)	3.33 (10.50)	1.59 (6.70)	0.55 (4.24)	0.00 (0.52)	0.00 (0.52)	0.18 (1.41)
Emamectin benzoate 5 SG @ 0.3 g/l	2.22 (8.45)	4.99 (12.88)	3.88 (11.36)	3.70 (10.90)	2.30 (8.17)	3.16 (10.15)	3.76 (10.80)	3.07 (9.71)	0.00 (0.52)	0.00 (0.52)	1.66 (7.40)	0.55 (2.47)
Buprofezin 25 EC @ 2.00 ml/l	12.79 (20.84)	16.66 (24.07)	11.67 (19.93)	13.71 (21.61)	3.89 (11.03)	5.01 (12.78)	4.99 (12.80)	4.63 (12.20)	4.99 (12.78)	7.78 (16.19)	4.44 (12.02)	5.74 (13.67)
Bifenthrin 10 EC @ 1 ml/l	16.11 (23.63)	18.89 (25.72)	15.00 (22.77)	16.67 (24.04)	10.84 (19.21)	13.34 (21.41)	11.44 (19.76)	11.87 (20.12)	6.06 (14.21)	9.55 (17.97)	5.62 (13.67)	7.07 (15.29)
Profenophos 50 EC @ 2ml/l	6.66 (14.92)	10.56 (18.94)	7.78 (16.12)	8.33 (16.66)	5.01 (12.82)	7.78 (16.10)	7.23 (15.46)	6.67 (14.79)	2.77 (9.57)	3.89 (11.34)	3.88 (11.32)	3.51 (10.74)
Diafenthiuron 50 WP @ 1.2 g/l	7.67 (16.05)	9.12 (17.56)	7.34 (15.70)	8.04 (16.43)	2.77 (9.50)	3.88 (11.20)	5.01 (12.89)	3.89 (11.20)	2.72 (9.48)	3.61 (10.88)	2.77 (9.57)	3.03 (9.98)
Dimethoate 30 EC @ 1.7 ml/l	6.11 (14.23)	11.11 (19.45)	8.33 (16.77)	8.51 (16.82)	4.45 (12.01)	7.77 (16.15)	4.45 (12.11)	5.56 (13.42)	3.88 (11.36)	5.00 (12.80)	3.93 (11.43)	4.27 (11.86)
Dichlorvos 76 EC @ 0.5 ml/l	11.67 (19.96)	16.10 (23.60)	13.32 (21.37)	13.70 (21.64)	5.56 (13.40)	9.72 (18.09)	7.77 (16.14)	7.68 (15.88)	3.89 (11.31)	7.79 (16.18)	5.55 (13.58)	5.74 (13.69)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	8.88 (17.32)	2.96 (5.77)	0.00 (0.52)	0.00 (0.52)	2.77 (9.24)	0.92 (3.08)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)
Mean	8.76 (15.80)	11.80 (18.40)	9.95 (17.88)	10.17 (17.36)	5.28 (12.11)	7.11 (14.30)	6.57 (14.42)	6.32 (13.61)	3.16 (8.77)	4.90 (10.68)	3.71 (9.64)	3.92 (9.70)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.52		1.92		0.61		2.26		0.41		1.52	
B	0.24		0.89		0.28		1.05		0.19		0.70	
A X B	0.89		3.33		1.05		3.91		0.71		2.63	

FORS - Fish oil rosin soap

-Figures in parentheses are Arcsine transformations

rest of the insecticides. The adjuvant, Dhanuvit @ 1 ml/l and FORS @ 5 ml/l recorded significantly highest mortality of 6.06 and 5.30 per cent, respectively (Table 48).

The combinations of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l resulted higher mortality (16.67 %) followed by combinations of thiacloprid 240 SC @ 0.2 ml/l + FORS @ 5 ml/l (12.23%), bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (11.11%) and imidacloprid 70 SG + FORS (10.00%) (Table 48).

Second instar mealybug

The insecticide bifenthrin 10 EC @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l, imidacloprid 17.8 SL @ 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l recorded significantly higher mortality of 7.82, 7.77, 7.31 and 6.47 per cent, respectively as compared to other treatments (Table 48). The adjuvant FORS @ 5 ml/l was significantly superior over other adjuvants causing mortality of 4.80 per cent.

The combination of imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l recorded significantly highest mortality of (10.00 %). However, it was on par with combinations of imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (8.90%), imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l (7.77%) and dichlorvos 76 EC @ 0.5 ml/l + FORS @ 5 ml/l (7.76%) (Table 48).

Third instar mealybug

Imidacloprid 70 WG @ 0.3 g/l recorded significantly higher mortality of 8.15 per cent, which was on par with bifenthrin 10 EC @ 1 ml/l and thiamethoxam 20 WG @ 0.3 g/l with mortality of 6.74 and 6.30 per cent, respectively (Table 48). The adjuvants Dhanuvit @ 1 ml/l and FORS @ 5 ml/l recorded significantly higher mortality of 4.16 and 3.76 per cent, respectively as compared to APSA-80 (3.15%).

The combinations of imidacloprid 70 WG @ 0.3 g/l with Dhanuvit @ 1 ml/l and FORS @ 5 ml/l were significantly effective with mortality of 8.90, per cent, each. However, they were on par with the combinations of bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (8.00%), dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l (7.80) and thiamethoxam 25 WG @ 0.3 g/l+ FORS @ 5 ml/l (7.80) (Table 48).

4.3.3.1c Mean of two years (During 2009-10 and 2010-11)

First instar mealybugs

Imidacloprid 70 WG @ 0.3g/l registered significantly higher mortality of 21.85 per cent. It was on par with imidacloprid 17.8 SL @ 0.3 ml/l with mortality of 17.34 per cent. The adjuvant Dhanuvit @ 1 ml/l and FORS @ 5 ml/l were on par with each other with mean of 11.80 and 9.95 per cent mortality, respectively as compared to adjuvant APSA-80 (8.76%) (Table 49).

Significantly superior was recorded in combination of imidacloprid 70 WG @ 0.3g/l with adjuvant Dhanuvit @ 1 ml/l (27.22%) as compared to rest of the combinations (Table 49).

Second instar mealybugs

Imidacloprid 70 WG @ 0.3 g/l showed significantly higher mortality of (12.22%) of mealybugs. It was on par with bifenthrin 10 EC @ 1ml/l, imidacloprid 17.8 SL @ 0.3 ml/l and thiacloprid 240 SC @ 0.2 ml/l with mortality of 11.87, 10.14 and 8.52 per cent, respectively (Table 49). Dhanuvit @ 1 ml/l and FORS @ 5 ml/l recorded higher mortality of 7.11 and 6.57 per cent, respectively as compared to APSA-80 @ 1 ml/l (5.28%).

The mortality was lower among the combinations. However, the combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l resulted significantly higher mortality of 13.89 and 13.34 per cent, respectively (Table 49).

Third instar mealybugs

The insecticide imidacloprid 70 WG @ 0.3 g/l registered significantly higher mortality of mealybugs (8.89 %) which was on par with bifenthrin 10 EC @ 1 ml/l (7.07%) as compared to rest of the insecticide treatments. The adjuvant Dhanuvit @ 1 ml/l enhanced the mortality to 4.90 per cent as compared to rest of the adjuvants (Table 49).

The combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l recorded significantly higher mortality of 10.56 per cent, which was on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l, dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l

and buprofezin 2.00 ml/l + Dhanuvit @ 1 ml/l, with mean mortality of 9.55, 8.89, 7.79 and 7.78 per cent, respectively.

4.3.3.2 Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment (1 DAT)

4.3.3.2a During 2009-10

First instar mealybug

The insecticide bifenthrin 10 EC @ 1 ml/l and imidacloprid 70 WG @ 0.3g/l were significantly superior over rest of the treatments with mortality of 69.20 and 67.21 per cent, respectively, which was on par with imidacloprid 17.8 SL @ 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l with mortality of 64.89 and 60.91 per cent. The Dhanuvit @ 1 ml/l and FORS @ 5 ml/l resulted higher mortality of 50.53 and 48.71 per cent, respectively as compared to APSA-80 (41.57%) (Table 50).

The interaction effect of insecticides with adjuvants was significant on the mortality of mealybugs as compared to water spray. However, the combination of bifenthrin 10 EC @ 1 ml/l with Dhanuvit @ 1 ml/l was significantly superior with higher mortality of 78.00 per cent, which was on par with imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l with mortality of 75.36 and 74.64 per cent, respectively as compared to rest of the combinations (Table 50).

Second instar mealybug

Among the insecticides, the imidacloprid 70 WG @ 0.3g/l registered superiority over other insecticides with mortality of 56.10 per cent. However, all the insecticides were effective, but least mortality was observed in acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 SC @ 1 ml/l and emamectin benzoate 5 SG @ 0.3 g/l with mortality of 16.44, 13.95 and 11.44 per cent, respectively. The adjuvant Dhanuvit @ 1 ml/l was significantly superior over other adjuvants with mortality of 36.42 per cent followed by FORS @ 5 ml/l and APSA-80 @ 1 ml/l with mortality of 31.04 and 29.33 per cent, respectively (Table 50).

Among the combination of insecticides with adjuvants, the combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l showed significantly higher mortality (67.41 %) as compared to other combinations followed by imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l with mortality of 56.51, 56.07 and 52.38 per cent, respectively. However, all the combinations of insecticides with adjuvants were effective on mealybug except the combinations of chlorfenapyr 10 SC @ 1 ml/l, acetamiprid 20 SP @ 0.3 g/l and emamectin benzoate 5 SG 0.3 g/l with adjuvants (Table 50).

Third instar mealybug

The insecticides imidacloprid 70 WG @ 0.3g/l and bifenthrin 10 EC @ 1 ml/l showed highest mortality of mealybugs (37.33 and 36.00%, respectively) as compared to other insecticides. However, former insecticide was on par with dichlorvos 76 EC @ 0.5 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l with mortality of 31.60 and 30.98 per cent. Dhanuvit @ 1 ml/l and FORS @ 5 ml/l were most effective with of 25.52 and 24.73 per cent mortality, respectively as compared to APSA-80 @ 1 ml/l (21.29%) (Table 50).

Among the combinations, the imidacloprid 70 WG + Dhanuvit @ 1 ml/l recorded significantly higher mortality (42.91%), which was on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l with mortality of 40.95 per cent. However, remaining combinations were also effective as compared to water spray (Table 50).

4.3.3.2b During 2010-11

First instar mealybugs

Among the treatments, the bifenthrin 10 EC @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l resulted significantly higher mortality of 42.11, 42.00 and 38.83 per cent, respectively. The next better treatments were profenophos 50 EC @ 2 ml/l and dichlorvos 76 EC @ 0.5 ml/l with mortality of 26.95 and 26.93 per cent, respectively as compared to rest of the treatments. Among the adjuvant, the Dhanuvit @ 1 ml/l registered significantly higher mortality of 26.06 per cent, which was followed by FORS @ 5 ml/l with 22.15 per cent mortality (Table 51).

The combination of imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l resulted significantly higher mortality (49.38 %).

Table 50. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2009-10

Treatment	Corrected per cent mortality of mealybugs											
Insecticides (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l	45.91 (42.63)	59.47 (50.45)	55.78 (48.30)	53.72 (47.13)	35.00 (36.25)	43.07 (41.00)	30.34 (33.39)	36.14 (36.88)	18.97 (25.79)	23.97 (29.30)	19.08 (25.87)	20.67 (26.99)
Thiamethoxam 25 WG @ 0.3 g/l	51.81 (46.02)	58.75 (50.06)	59.62 (50.55)	56.73 (48.88)	30.03 (33.18)	37.69 (37.85)	33.87 (35.54)	33.86 (35.52)	19.00 (25.81)	25.15 (30.07)	21.34 (27.49)	21.83 (27.79)
Acetamiprid 20 SP @ 0.3 g/l	27.71 (31.63)	33.33 (35.24)	39.38 (38.78)	33.44 (35.22)	11.78 (20.02)	18.79 (25.60)	18.75 (25.58)	16.44 (23.73)	17.78 (24.91)	18.89 (25.73)	20.00 (26.50)	18.89 (25.71)
Imidacloprid 70 WG @ 0.3 g/l	63.77 (52.99)	75.36 (60.27)	62.49 (52.21)	67.21 (55.16)	52.38 (46.35)	67.41 (55.19)	48.50 (44.12)	56.10 (48.56)	35.02 (36.25)	42.91 (40.90)	34.05 (35.68)	37.33 (37.61)
Imidacloprid 17.8 SL @ 0.3 ml/l	55.56 (48.18)	74.64 (59.80)	64.47 (53.41)	64.89 (53.80)	44.14 (41.61)	56.51 (48.73)	45.11 (42.15)	48.58 (44.16)	28.83 (32.45)	33.81 (35.53)	30.29 (33.36)	30.98 (33.78)
Chlorfenapyr 10 SC @ 1ml/l	21.10 (27.32)	25.24 (30.34)	21.11 (27.33)	22.59 (28.33)	11.49 (19.77)	15.90 (23.47)	14.46 (22.34)	13.95 (21.86)	15.56 (23.19)	18.89 (25.73)	21.11 (27.33)	18.52 (25.42)
Emamectin benzoate 5 SG @ 0.3 g/l	20.00 (26.55)	22.35 (28.19)	24.01 (29.30)	22.12 (28.02)	10.47 (18.87)	12.08 (20.28)	11.77 (20.00)	11.44 (19.72)	14.44 (22.30)	17.78 (24.79)	17.78 (24.91)	16.67 (24.00)
Buprofezin 25 EC @ 2.00 ml/l	46.59 (43.02)	54.85 (47.77)	48.36 (44.04)	49.93 (44.94)	44.15 (41.62)	46.96 (43.24)	39.43 (38.88)	43.51 (41.25)	20.51 (26.86)	27.86 (31.81)	27.67 (31.69)	25.34 (30.12)
Bifenthrin 10 EC @ 1 ml/l	63.82 (53.03)	78.00 (62.12)	65.78 (54.18)	69.20 (56.44)	44.98 (42.10)	56.07 (48.47)	40.56 (39.54)	47.20 (43.37)	32.97 (34.99)	40.95 (39.76)	34.08 (35.69)	36.00 (36.81)
Profenophos 50 EC @ 2ml/l	47.75 (43.69)	60.08 (50.82)	55.23 (48.00)	54.35 (47.50)	34.31 (35.82)	38.72 (38.46)	35.45 (36.52)	36.16 (36.93)	27.05 (31.30)	30.71 (33.64)	28.17 (32.04)	28.64 (32.32)
Diafenthiuron 50 WP @ 1.2 g/l	36.78 (37.30)	40.52 (39.50)	42.86 (40.87)	40.05 (39.23)	24.98 (29.96)	33.79 (35.52)	28.95 (32.53)	29.24 (32.67)	20.19 (26.64)	22.81 (28.50)	21.38 (27.51)	21.46 (27.55)
Dimethoate 30 EC @ 1.7 ml/l	46.43 (42.93)	56.08 (48.48)	52.38 (46.35)	51.63 (45.92)	30.47 (33.49)	39.32 (38.79)	32.05 (34.46)	33.94 (35.58)	19.12 (25.90)	19.40 (26.10)	21.34 (27.49)	19.95 (26.50)
Dichlorvos 76 EC @ 0.5 ml/l	54.77 (47.72)	68.44 (55.82)	59.51 (50.48)	60.91 (51.34)	36.50 (37.15)	43.53 (41.27)	35.61 (36.62)	38.55 (38.35)	28.60 (32.31)	34.12 (35.72)	32.09 (34.48)	31.60 (34.17)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	31.03 (33.84)	10.34 (11.28)	0.00 (0.52)	0.00 (0.52)	19.73 (26.35)	6.58 (8.78)	0.00 (0.52)	0.00 (0.52)	17.78 (24.91)	5.93 (8.30)
Mean	41.57 (38.79)	50.53 (44.20)	48.71 (44.12)	46.94 (42.37)	29.33 (31.16)	36.42 (35.56)	31.04 (33.43)	32.26 (33.38)	21.29 (26.34)	25.52 (29.11)	24.73 (29.64)	23.84 (28.36)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.78		2.89		0.60		2.24		0.57		2.12	
B	0.36		1.34		0.28		1.04		0.26		0.98	
A X B	1.34		5.00		1.04		3.88		0.99		3.68	

FORS - Fish oil rosin soap

-Figures in parentheses are Arcsine transformations

Table 51. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2010-11

Treatment	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
Insecticides (A)	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l	16.89 (24.25)	21.07 (27.31)	19.07 (25.87)	19.01 (25.81)	12.69 (20.81)	23.11 (28.72)	21.14 (27.32)	18.98 (25.62)	10.07 (18.49)	13.74 (21.75)	10.00 (18.26)	11.27 (19.50)
Thiamethoxam 25 WG @ 0.3 g/l	20.43 (26.85)	23.28 (28.83)	18.42 (25.40)	20.71 (27.03)	10.13 (18.55)	17.97 (25.05)	18.45 (25.39)	15.52 (23.00)	10.47 (18.70)	15.70 (23.32)	9.61 (17.83)	11.93 (19.95)
Acetamiprid 20 SP @ 0.3 g/l	8.89 (17.27)	10.00 (18.26)	6.67 (14.63)	8.52 (16.72)	6.68 (14.97)	6.67 (14.63)	6.67 (14.63)	6.67 (14.75)	7.76 (16.14)	7.78 (16.11)	7.79 (16.13)	7.77 (16.13)
Imidacloprid 70 WG @ 0.3 g/l	39.45 (38.89)	49.38 (44.63)	37.16 (37.52)	42.00 (40.34)	30.31 (33.39)	33.95 (35.61)	27.03 (31.30)	30.43 (33.43)	18.95 (25.79)	23.38 (28.89)	17.67 (24.84)	20.00 (26.51)
Imidacloprid 17.8 SL @ 0.3 ml/l	33.01 (35.05)	45.15 (42.20)	38.34 (38.23)	38.83 (38.50)	26.73 (31.12)	31.64 (34.21)	27.09 (31.35)	28.49 (32.22)	17.40 (24.64)	21.85 (27.86)	15.41 (23.09)	18.22 (25.19)
Chlorfenapyr 10 SC @ 1ml/l	6.66 (14.94)	10.00 (18.43)	7.76 (16.14)	8.14 (16.50)	5.56 (13.15)	5.63 (13.56)	9.57 (17.93)	6.92 (14.88)	6.70 (14.69)	8.89 (17.27)	13.37 (21.43)	9.65 (17.80)
Emamectin benzoate 5 SG @ 0.3 g/l	6.64 (14.66)	11.37 (19.68)	10.11 (18.37)	9.38 (17.57)	4.43 (11.98)	4.44 (12.00)	6.68 (14.65)	5.19 (12.87)	5.54 (13.14)	6.68 (14.65)	6.75 (15.06)	6.33 (14.28)
Buprofezin 25 EC @ 2.00 ml/l	31.69 (34.20)	38.07 (38.08)	33.71 (35.48)	34.49 (35.92)	13.80 (21.80)	13.80 (21.80)	13.06 (21.15)	13.56 (21.58)	9.37 (17.77)	11.74 (19.83)	9.12 (17.32)	10.08 (18.31)
Bifenthrin 10 EC @ 1 ml/l	40.99 (39.79)	46.25 (42.83)	39.10 (38.68)	42.11 (40.44)	20.23 (26.72)	25.64 (30.40)	21.22 (27.41)	22.36 (28.18)	15.33 (23.03)	22.68 (28.42)	16.12 (23.66)	18.04 (25.04)
Profenophos 50 EC @ 2ml/l	24.95 (29.95)	30.54 (33.51)	25.35 (30.20)	26.95 (31.22)	17.26 (24.53)	19.98 (26.53)	18.45 (25.39)	18.56 (25.49)	9.12 (17.49)	12.47 (20.65)	9.21 (17.60)	10.27 (18.58)
Diafenthiuron 50 WP @ 1.2 g/l	15.54 (23.17)	21.36 (27.51)	17.29 (24.55)	18.06 (25.08)	12.34 (20.52)	13.49 (21.54)	10.24 (18.65)	12.02 (20.24)	5.63 (13.56)	9.00 (17.38)	11.41 (19.73)	8.68 (16.89)
Dimethoate 30 EC @ 1.7 ml/l	21.30 (27.39)	27.66 (31.72)	22.18 (28.07)	23.71 (29.06)	10.24 (18.49)	15.45 (23.12)	13.76 (21.68)	13.15 (21.09)	11.65 (19.93)	13.90 (21.88)	15.09 (22.84)	13.55 (21.55)
Dichlorvos 76 EC @ 0.5 ml/l	24.75 (29.71)	30.74 (33.65)	25.31 (30.19)	26.93 (31.18)	18.64 (25.54)	21.22 (27.41)	15.64 (23.27)	18.50 (25.41)	16.02 (23.58)	16.84 (24.20)	19.35 (26.07)	17.40 (24.61)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	9.57 (17.93)	3.19 (5.98)	0.00 (0.52)	0.00 (0.52)	8.01 (16.38)	2.67 (5.46)	0.00 (0.52)	0.00 (0.52)	5.57 (13.48)	1.86 (4.49)
Mean	20.80 (25.44)	26.06 (29.05)	22.15 (27.23)	23.00 (21.73)	13.50 (20.11)	16.64 (22.47)	15.50 (22.61)	15.21 (21.73)	10.29 (17.64)	13.19 (20.16)	11.89 (19.81)	11.79 (19.20)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.62		2.32		0.64		2.40		0.69		2.56	
B	0.29		1.08		0.30		1.11		0.32		1.19	
A X B	1.08		4.03		1.12		4.16		1.19		4.44	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

However, it was on par with combinations of bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l along with Dhanuvit @ 1 ml/l with mortality of 46.25 and 45.15 per cent, respectively (Table 51).

Second instar mealybugs

The insecticide imidacloprid 70 WG @ 0.3g/l was significantly effective with mortality of 30.43 per cent, which was on par with imidacloprid 17.8 SL @ 0.3 ml/l (28.49%). However, it was found that all the insecticides were effective in causing mortality of mealybugs except acetamiprid 20 SP @ 0.3 g/l (6.67%), chlorfenapyr 10 SC @ 1 ml/l (6.92%) and emamectin benzoate 5 SG @ 0.3 g/l (5.19%). Non-significant effect was registered between the adjuvants Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with mortality of 16.64 and 15.50 per cent, respectively except adjuvant APSA-80 @ 1 ml/l (13.50%) (Table 51).

The combination of imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l along with adjuvants registered significantly higher mortality as compared to rest of the combinations. However, the combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l registered higher mortality (33.95%) of second instar mealybugs, which was on par with imidacloprid 70 WG @ 0.3 g/l with adjuvant APSA-80 @ 1 ml/l and FORS @ 5 ml/l, and imidacloprid 17.8 SL @ 0.3 ml/l with Dhanuvit @ 1 ml/l, FORS @ 5 ml/l and APSA-80 @ 1 ml/l causing mortality of 30.31, 27.03, 31.64, 27.09 and 26.73 per cent, respectively (Table 51).

Third instar mealybugs

The insecticides imidacloprid 70 WG @ 0.3g/l, imidacloprid 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l recorded significantly superior and higher mortality of 20.00, 18.22 and 18.04 per cent, respectively as compared to rest of the insecticides. However, they were on par with dichlorvos 76 EC @ 0.5 ml/l and dimethoate 30 EC @ 1.7 ml/l as compared to rest of insecticides. Non-significant difference was recorded between the adjuvants Dhanuvit @ 1 ml/l and FORS @ 5 ml/l on mortality of mealybugs with 13.19 and 11.89 per cent, respectively (Table 51).

The adjuvant Dhanuvit @ 1 ml/l in combination with insecticide imidacloprid 70 WG @ 0.3g/l registered highest mortality of 23.28 per cent as compared to rest of the combinations. However, it was on par with the combinations of bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (22.68%), imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (21.85%), dichlorvos 76 EC @ 0.5 ml/l + FORS @ 5 ml/l (19.35%), imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l (18.95%) imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l (17.67%), imidacloprid 17.8 SL @ 0.3 ml/l + APSA-80 @ 1 ml/l (17.40%) and dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l (16.84%) on third instar mealybugs (Table 51).

4.3.3.2c Mean of two years (During 2009-10 and 2010-11)

First instar mealybugs

The insecticides bifenthrin 10 EC @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l caused significantly superior mortality of 55.66, 54.60 and 51.86 per cent, respectively over rest of the insecticides. There was significant difference between adjuvants Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with mortality of 38.30 and 35.43 per cent, respectively (Table 52).

Among the combination of insecticides and adjuvants, imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l recorded significantly superior over rest of the combinations by causing mortality of 63.37, 62.13 and 59.90 per cent, respectively of first instar mealybugs (Table 52).

Second instar mealybugs

Among the insecticides, imidacloprid 70 WG @ 0.3g/l recorded significantly higher mortality of 43.26 per cent, which was on par with imidacloprid 17.8 SL @ 0.3 ml/l with mortality of 38.54 per cent of mealybugs. The adjuvant Dhanuvit @ 1 ml/l recorded significantly higher mortality of 26.53 per cent as compared to other adjuvants (Table 52).

The highest mortality was observed in the combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l (50.68 %), which was significantly superior over rest of the combinations. The next better treatments were imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (44.08%), imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l (46.35%) and bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (40.86%) (Table 52).

Table 52. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at one day after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatment		Corrected per cent mortality of mealybugs											
Insecticides (A)	Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
		APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l		31.40 (34.06)	40.27 (39.37)	37.42 (37.69)	36.36 (37.04)	23.85 (29.20)	33.09 (35.10)	25.74 (30.46)	27.56 (31.58)	14.52 (22.38)	18.86 (25.73)	14.54 (22.40)	15.97 (23.50)
Thiamethoxam 25 WG @ 0.3 g/l		36.12 (36.93)	41.02 (39.80)	39.02 (38.63)	38.72 (38.45)	20.08 (26.59)	27.83 (31.82)	26.16 (30.74)	24.69 (29.72)	14.74 (22.54)	20.42 (26.84)	15.48 (23.10)	16.88 (24.16)
Acetamiprid 20 SP @ 0.3 g/l		18.30 (25.27)	21.66 (27.72)	22.97 (28.61)	20.98 (27.20)	9.23 (17.66)	12.73 (20.76)	12.71 (20.83)	11.56 (19.75)	12.77 (20.92)	13.33 (21.38)	13.89 (21.82)	13.33 (21.38)
Imidacloprid 70 WG @ 0.3 g/l		51.61 (45.91)	62.37 (52.15)	49.83 (44.88)	54.60 (47.65)	41.35 (40.00)	50.68 (45.37)	37.76 (37.90)	43.26 (41.09)	26.98 (31.28)	33.15 (35.14)	25.86 (30.55)	28.66 (32.32)
Imidacloprid 17.8 SL @ 0.3 ml/l		44.29 (41.70)	59.90 (50.69)	51.40 (45.79)	51.86 (46.06)	35.43 (36.51)	44.08 (41.58)	36.10 (36.91)	38.54 (38.33)	23.12 (28.72)	27.83 (31.82)	22.85 (28.53)	24.60 (29.69)
Chlorfenapyr 10 SC @ 1ml/l		13.88 (21.85)	17.77 (24.92)	14.43 (22.31)	15.36 (23.03)	8.52 (16.92)	10.77 (19.14)	12.02 (20.26)	10.44 (18.77)	11.13 (19.40)	13.89 (21.86)	17.24 (24.51)	14.09 (21.93)
Emamectin benzoate 5 SG @ 0.3 g/l		13.32 (21.38)	16.86 (24.22)	17.06 (24.33)	15.75 (23.31)	7.45 (15.82)	8.26 (16.62)	9.22 (17.56)	8.31 (16.66)	9.99 (18.38)	12.23 (20.39)	12.27 (20.48)	11.50 (19.75)
Buprofezin 25 EC @ 2.00 ml/l		39.14 (38.70)	46.46 (42.95)	41.03 (39.82)	42.21 (40.49)	28.98 (32.56)	30.38 (33.43)	26.25 (30.81)	28.54 (32.27)	14.94 (22.72)	19.80 (26.38)	18.39 (25.38)	17.71 (24.83)
Bifenthrin 10 EC @ 1 ml/l		52.40 (46.36)	62.13 (52.00)	52.44 (46.38)	55.66 (48.25)	32.61 (34.80)	40.86 (39.71)	30.89 (33.75)	34.78 (36.09)	24.15 (29.41)	31.81 (34.32)	25.10 (30.05)	27.02 (31.26)
Profenophos 50 EC @ 2ml/l		36.35 (37.05)	45.31 (42.29)	40.29 (39.36)	40.65 (39.57)	25.78 (30.49)	29.35 (32.78)	26.95 (31.25)	27.36 (31.51)	18.08 (25.13)	21.59 (27.67)	18.69 (25.59)	19.46 (26.13)
Diafenthiuron 50 WP @ 1.2 g/l		26.16 (30.74)	30.94 (33.77)	30.07 (33.23)	29.06 (32.58)	18.66 (25.58)	23.64 (29.08)	19.59 (26.26)	20.63 (26.97)	12.91 (20.99)	15.91 (23.49)	16.40 (23.87)	15.07 (22.78)
Dimethoate 30 EC @ 1.7 ml/l		33.86 (35.55)	41.87 (40.31)	37.28 (37.61)	37.67 (37.82)	20.35 (26.78)	27.38 (31.52)	22.91 (28.56)	23.55 (28.95)	15.38 (23.08)	16.65 (24.07)	18.22 (25.24)	16.75 (24.13)
Dichlorvos 76 EC @ 0.5 ml/l		39.76 (39.07)	49.59 (44.75)	42.41 (40.61)	43.92 (41.48)	27.57 (31.66)	32.38 (34.66)	25.62 (30.40)	28.52 (32.24)	22.31 (28.17)	25.48 (30.30)	25.72 (30.45)	24.50 (29.64)
Adjuvant alone		0.00 (0.52)	0.00 (0.52)	20.30 (26.77)	6.77 (8.92)	0.00 (0.52)	0.00 (0.52)	13.87 (21.83)	4.62 (7.28)	0.00 (0.52)	0.00 (0.52)	11.67 (19.94)	3.89 (6.65)
Mean		31.19 (32.47)	38.30 (36.78)	35.43 (36.15)	34.97 (35.13)	21.42 (26.04)	26.53 (29.40)	23.27 (28.39)	23.74 (27.94)	15.79 (22.37)	19.35 (24.96)	18.31 (25.14)	17.82 (24.15)
Comparing the means of		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A		0.50		1.87		0.45		1.67		0.41		1.52	
B		0.23		0.87		0.21		0.77		0.19		0.70	
A X B		0.87		3.24		0.78		2.89		0.71		2.64	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Table 53. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2009-10

Treatment	Corrected per cent mortality of mealybugs											
Insecticides (A))	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l	60.40 (51.00)	72.17 (58.15)	66.73 (54.77)	66.43 (54.64)	56.88 (48.93)	61.94 (51.89)	56.34 (48.62)	58.38 (49.82)	35.87 (36.77)	43.06 (40.99)	35.70 (36.67)	38.51 (38.15)
Thiamethoxam 25 WG @ 0.3 g/l	65.02 (53.74)	67.89 (55.50)	63.25 (52.67)	65.39 (53.97)	56.78 (48.88)	58.05 (49.61)	54.73 (47.70)	56.52 (48.73)	32.12 (34.51)	42.60 (40.73)	35.91 (36.80)	36.88 (37.34)
Acetamiprid 20 SP @ 0.3 g/l	20.28 (26.75)	31.16 (33.91)	31.21 (33.89)	27.55 (31.52)	12.01 (20.27)	16.91 (24.27)	26.12 (30.72)	18.35 (25.09)	13.20 (21.23)	19.47 (26.17)	16.10 (23.64)	16.26 (23.68)
Imidacloprid 70 WG @ 0.3 g/l	79.12 (62.81)	83.81 (66.31)	80.00 (63.41)	80.98 (64.18)	75.17 (60.11)	84.40 (66.81)	79.58 (63.14)	79.72 (63.35)	47.76 (43.70)	58.60 (49.93)	50.72 (45.40)	52.36 (46.34)
Imidacloprid 17.8 SL @ 0.3 ml/l	80.18 (63.57)	85.19 (67.42)	84.22 (66.63)	83.19 (65.87)	73.81 (59.21)	77.59 (61.74)	73.69 (59.12)	75.03 (60.02)	43.10 (41.01)	56.35 (48.68)	48.08 (43.88)	49.18 (44.53)
Chlorfenapyr 10 SC @ 1ml/l	15.11 (22.81)	23.91 (29.26)	29.80 (33.03)	22.94 (28.36)	15.59 (23.25)	18.89 (25.73)	22.52 (28.30)	19.00 (25.76)	8.21 (16.58)	15.83 (23.41)	13.72 (21.70)	12.59 (20.57)
Emamectin benzoate 5 SG @ 0.3 g/l	16.67 (24.09)	16.73 (24.12)	23.26 (28.77)	18.88 (25.66)	19.25 (26.01)	22.65 (28.41)	24.03 (29.34)	21.98 (27.92)	6.90 (15.22)	10.87 (19.23)	8.42 (16.79)	8.73 (17.08)
Buprofezin 25 EC @ 2.00 ml/l	60.41 (50.99)	73.22 (58.84)	67.43 (55.19)	67.02 (55.01)	58.35 (49.79)	66.51 (54.63)	57.39 (49.23)	60.75 (51.22)	31.56 (34.16)	43.79 (41.36)	38.85 (38.41)	38.06 (37.98)
Bifenthrin 10 EC @ 1 ml/l	72.58 (58.41)	80.74 (63.97)	76.09 (60.73)	76.47 (61.04)	65.87 (54.24)	79.26 (62.89)	68.25 (55.70)	71.13 (57.61)	46.77 (43.13)	59.07 (50.21)	46.97 (43.24)	50.93 (45.53)
Profenophos 50 EC @ 2ml/l	59.03 (50.19)	74.74 (59.83)	67.97 (55.52)	67.24 (55.18)	51.86 (46.05)	62.18 (52.03)	54.73 (47.70)	56.26 (48.59)	31.37 (34.04)	43.34 (41.15)	38.93 (38.59)	37.88 (37.93)
Diafenthiuron 50 WP @ 1.2 g/l	39.13 (38.70)	52.96 (46.68)	49.60 (44.76)	47.23 (43.38)	46.67 (43.07)	52.84 (46.61)	52.06 (46.74)	50.85 (45.47)	20.18 (26.68)	29.37 (32.80)	24.57 (29.60)	24.71 (29.69)
Dimethoate 30 EC @ 1.7 ml/l	59.71 (50.59)	68.32 (55.73)	60.47 (51.02)	62.83 (52.45)	51.75 (45.99)	62.91 (52.47)	54.50 (47.56)	56.39 (48.67)	29.92 (33.15)	38.97 (38.61)	32.05 (34.46)	33.65 (35.41)
Dichlorvos 76 EC @ 0.5 ml/l	63.25 (52.67)	73.98 (59.34)	72.14 (58.14)	69.79 (56.71)	57.11 (49.07)	71.89 (57.98)	63.89 (53.05)	64.29 (53.36)	41.43 (40.04)	50.96 (45.53)	41.83 (40.28)	44.74 (41.95)
Adjuvant alone	1.11 (3.51)	0.00 (0.52)	30.99 (33.80)	10.70 (12.44)	0.00 (0.52)	0.00 (0.52)	24.60 (29.71)	8.20 (9.90)	0.00 (0.52)	0.00 (0.52)	15.65 (23.27)	5.22 (7.76)
Mean	49.43 (43.56)	57.49 (48.50)	57.37 (49.45)	54.76 (47.17)	45.79 (41.06)	52.57 (45.36)	50.96 (45.47)	49.77 (43.97)	27.74 (30.02)	36.59 (35.63)	31.96 (33.77)	32.10 (33.14)
Comparing the means of	S.Em.±			C.D. (0.01)			S.Em.±			C.D. (0.01)		
A	0.75			2.81			0.40			1.50		
B	0.35			1.30			0.19			0.69		
A X B	1.31			4.87			0.70			2.60		

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Third instar mealybugs

The insecticides imidacloprid 70 WG @ 0.3 g/l, bifenthrin 10 EC @ 1 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l recorded significantly higher mortality of 28.66, 27.02, 24.60 and 24.50 per cent, respectively as compared to rest of the insecticides. The adjuvant Dhanuvit @ 1 ml/l and FORS @ 5 ml/l recorded non-significant differences with 19.35 and 18.31 per cent mortality, respectively (Table 52).

Among the interactions, the imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l caused mortality of 33.14 per cent, which was on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (31.81%). However, all the combinations of insecticides with adjuvants caused significant mortality of mealybugs (Table 52).

4.3.3.3 Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment (2 DAT)

4.3.3.3a During 2009-10

First instar mealybug

Imidacloprid 17.8 SL @ 0.3 ml/l and imidacloprid 70 WG recorded significantly higher mortality of 83.19 and 80.98 per cent, respectively as compared to other insecticides, which were on par with bifenthrin 10 EC @ 1 ml/l with mortality of 76.47 per cent. However, all the insecticides proved effective against first instar mealybug. The adjuvant Dhanuvit @ 1 ml/l and FORS @ 5 ml/l were most effective with mortality of 57.49 and 57.37 per cent, respectively as compared to APSA-80 @ 1 ml/l (49.43%) (Table 53).

Among the combination of insecticides and adjuvants, imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l + FORS @ 5 ml/l recorded significantly higher mortality of 85.19, 84.22 and 83.81 per cent, respectively, which were on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l + APSA-80 @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l and imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l with mortality of 80.74, 80.18, 80.00 and 79.12 per cent, respectively (Table 53).

Second instar mealybug

Significantly higher mortality was noticed in imidacloprid 70 WG @ 0.3 g/l (79.72%), followed by imidacloprid 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l with mortality of 75.03 and 71.13 per cent, respectively. However, lower mortality was recorded acetamiprid 20 SP @ 0.3 g/l (18.35%), chlorfenapyr 10 SC @ 1 ml/l (19.00%) and emamectin benzoate 5 SG @ 0.3 g/l (21.98%). The adjuvants, FORS @ 5 ml/l and Dhanuvit @ 1 ml/l recorded significantly higher mortality of 52.57 and 50.96 per cent, respectively. However, the adjuvant APSA-80 @ 1 ml/l recorded lower mortality of second instar mealybug (45.79%) (Table 53).

Significantly higher mortality was noticed in the combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l with 84.40 per cent, which was superior over other interactions. The next better combinations were imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l, bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l with mortality of 79.58, 79.26 and 77.59 per cent, respectively (Table 53).

Third instar mealybug

The insecticides imidacloprid 70 WG @ 0.3 g/l, bifenthrin 10 EC, imidacloprid 17.8 SL @ 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l registered significantly higher mortality of third instar mealybugs with 52.36, 50.93, 49.18 and 44.74 per cent, respectively as compared to other insecticides. Among the adjuvants, Dhanuvit @ 1 ml/l was most effective with mortality of 36.59 per cent. However, the adjuvants FORS @ 5 ml/l and APSA-80 @ 1 ml/l registered the mortality of 31.96 and 27.74 per cent, respectively on third instar mealybugs (Table 53).

The insecticides bifenthrin 10 EC @ 1 ml/l and imidacloprid 70 WG @ 0.3g/l with Dhanuvit @ 1 ml/l resulted higher mortality of 59.07 and 58.60 per cent, respectively. These were found on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l, dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l with mortality of 56.35, 50.96 and 50.72 per cent, respectively as compared to other interactions (Table 53).

4.3.3.3b During 2010-11

First instar mealybugs

All the insecticides caused significant mortality except acetamiprid 20 SP @ 0.3 g/l (21.00%), chlorfenapyr 10 SC @ 1 ml/l (15.33%) and emamectin benzoate 5 SG @ 0.3 g/l (14.93%). However, the insecticides bifenthrin 10 EC @ 1 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l and imidacloprid 70 WG @ 0.3 g/l were significantly superior over other insecticides with mortality of 78.64, 75.24 and 71.99 per cent, respectively. There was no significant difference between Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with 50.21 and 46.93 per cent mortality as compared to APSA-80 @ 1 ml/l (41.76%) (Table 54).

Among the combinations of insecticide and adjuvant, the imidacloprid 70 WG @ 0.3 g/l, bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l with Dhanuvit @ 1 ml/l registered significantly superior mortality of 84.13, 84.04 and 82.21 per cent, respectively, which were on par with the combination of bifenthrin 10 EC @ 1 ml/l + FORS @ 5 ml/l with mortality of 77.98 per cent, as compared to other combinations (Table 54).

Second instar mealybugs

The lowest mortality was observed in chlorfenapyr 10 SC @ 1 ml/l, emamectin benzoate 5 SG @ 0.3 g/l and acetamiprid 20 SP @ 0.3 g/l with 10.35, 9.63 and 9.07 per cent, respectively. However, significantly highest mortality was noticed in imidacloprid 70 WG @ 0.3 g/l, imidacloprid 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l with mortality of 52.81, 49.42 and 48.31 per cent, respectively, which were on par with dichlorvos 76 EC @ 0.5 ml/l (46.16%) as compared to rest of the insecticides. The adjuvant FORS @ 5 ml/l resulted highest mortality of second instar mealybugs (32.44%) followed by Dhanuvit @ 1 ml/l and APSA-80 @ 1 ml/l with mortality of 30.83 and 25.59 per cent, respectively (Table 54).

All the insecticide combinations with adjuvant showed significantly higher mortality of second instar mealybugs as compared to water spray. However, significantly superior mortality was obtained in imidacloprid 70 WG @ 0.3g/l and Dhanuvit @ 1 ml/l with mortality of 56.70 per cent. This was on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + FORS @ 5 ml/l, dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l and dichlorvos 76 EC @ 0.5 ml/l + FORS @ 5 ml/l having mortality of 55.57, 54.63, 52.37, 49.83, 49.37 and 48.48 per cent, respectively (Table 54).

Third instar mealybugs

Significantly higher mortality was recorded in bifenthrin 10 EC @ 1 ml/l causing mortality of 42.60 per cent, which was on par with imidacloprid 70 WG @ 0.3g/l, imidacloprid 17.8 SL @ 0.3 ml/l and thiocloprid 240 SC @ 0.2 ml/l (40.50, 38.84 and 36.64, per cent, respectively) as compared to rest of the treatments. There was non-significant difference between Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with mortality of 27.50 and 24.13 per cent (Table 54).

Among the combinations of insecticide with adjuvant, the combinations of Dhanuvit @ 1 ml/l with bifenthrin 10 EC @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l were significantly superior over rest of the combinations with mortality of 46.24 and 45.99 per cent, respectively. However, these were on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + APSA-80 @ 1 ml/l, thiocloprid 240 SC @ 0.2 ml/l + Dhanuvit @ 1 ml/l, imidacloprid 70 WG @ 0.3 g/l + APSA-80 @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + FORS @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l + APSA-80 @ 1 ml/l with mortality of 43.86, 41.71, 41.32, 39.98, 39.83 and 37.60 per cent, respectively (Table 54).

4.3.3.3c Mean of two years (During 2009-10 and 2010-11)

First instar mealybugs

The insecticides imidacloprid 17.8 SL @ 0.3 ml/l, bifenthrin 10 EC @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l registered significantly superior mortality of 79.22, 77.55, and 76.48 per cent, respectively as compared to rest of the insecticides. However, lowest mortality was recorded in acetamiprid 20 SP @ 0.3 g/l (29.43%), chlorfenapyr 10 SC @ 1 ml/l (19.14%) and emamectin benzoate 5 SG @ 0.3 g/l (16.91%). Non-significant difference was observed between Dhanuvit @ 1 ml/l (53.85%) and FORS @ 5 ml/l (52.15%), which were highest in influencing per cent mortality of first instar mealybugs as compared to APSA-80 @ 1 ml/l (45.59%) (Table 55).

Table 54. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2010-11

Treatment	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
Insecticides (A)	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l	39.18 (38.73)	50.07 (45.02)	48.64 (44.20)	45.96 (42.65)	32.98 (35.03)	41.56 (40.11)	43.45 (41.22)	39.33 (38.79)	35.38 (36.48)	41.32 (39.99)	33.22 (35.13)	36.64 (37.20)
Thiamethoxam 25 WG @ 0.3 g/l	34.22 (35.77)	39.38 (38.85)	32.41 (34.68)	35.33 (36.43)	24.03 (29.33)	28.78 (32.39)	34.17 (35.75)	28.99 (32.49)	32.54 (34.75)	36.59 (37.21)	29.26 (32.70)	32.80 (34.89)
Acetamiprid 20 SP @ 0.3 g/l	18.30 (25.31)	19.73 (26.35)	24.98 (29.94)	21.00 (27.20)	8.17 (16.52)	8.34 (16.37)	10.68 (18.91)	9.07 (17.27)	14.53 (22.28)	11.74 (20.00)	13.03 (21.08)	13.10 (21.12)
Imidacloprid 70 WG @ 0.3 g/l	65.20 (53.90)	84.13 (66.51)	66.60 (54.68)	71.97 (58.36)	49.37 (44.62)	56.70 (48.83)	52.37 (46.35)	52.81 (46.60)	39.98 (39.18)	45.99 (42.68)	35.53 (36.58)	40.50 (39.48)
Imidacloprid 17.8 SL @ 0.3 ml/l	71.62 (57.81)	82.21 (65.10)	71.88 (57.98)	75.24 (60.30)	47.55 (43.56)	55.57 (48.18)	45.15 (42.20)	49.42 (44.65)	37.60 (37.80)	43.86 (41.45)	35.07 (36.29)	38.84 (38.52)
Chlorfenapyr 10 SC @ 1ml/l	9.49 (17.88)	13.59 (21.58)	22.92 (28.58)	15.33 (22.68)	8.22 (16.59)	7.05 (15.39)	15.77 (23.38)	10.35 (18.45)	8.42 (16.79)	12.17 (20.20)	13.20 (21.29)	11.26 (19.43)
Emamectin benzoate 5 SG @ 0.3 g/l	9.46 (17.87)	12.81 (20.93)	22.53 (28.27)	14.93 (22.36)	9.24 (17.60)	9.28 (17.50)	10.36 (18.65)	9.63 (17.92)	6.99 (15.32)	6.99 (15.32)	8.34 (16.37)	7.44 (15.67)
Buprofezin 25 EC @ 2.00 ml/l	58.70 (50.00)	65.40 (53.97)	57.95 (49.56)	60.69 (51.17)	29.26 (32.70)	30.76 (33.66)	34.38 (35.88)	31.46 (34.08)	22.05 (27.77)	29.17 (32.67)	23.53 (29.01)	24.92 (29.82)
Bifenthrin 10 EC @ 1 ml/l	73.89 (59.37)	84.04 (66.86)	77.98 (62.02)	78.64 (62.75)	42.39 (40.61)	54.63 (47.64)	47.90 (43.78)	48.31 (44.01)	41.71 (40.21)	46.24 (42.83)	39.83 (39.12)	42.60 (40.72)
Profenophos 50 EC @ 2ml/l	51.52 (45.85)	64.39 (53.34)	53.91 (47.22)	56.60 (48.80)	26.23 (30.78)	36.88 (37.36)	36.69 (37.26)	33.27 (35.14)	27.57 (31.66)	31.10 (33.88)	26.59 (31.00)	28.42 (32.18)
Diafenthiuron 50 WP @ 1.2 g/l	46.14 (42.77)	52.91 (46.65)	44.37 (41.75)	47.81 (43.72)	11.54 (19.85)	15.59 (23.25)	24.05 (29.34)	17.06 (24.15)	17.75 (24.75)	21.01 (27.25)	21.51 (27.60)	20.09 (26.53)
Dimethoate 30 EC @ 1.7 ml/l	47.10 (43.32)	61.98 (51.91)	50.85 (45.47)	53.31 (46.90)	29.16 (32.66)	36.71 (37.27)	33.23 (35.19)	33.04 (35.04)	21.05 (27.28)	26.93 (31.23)	21.91 (27.89)	23.30 (28.80)
Dichlorvos 76 EC @ 0.5 ml/l	59.83 (50.70)	72.29 (58.24)	59.63 (50.54)	63.92 (53.16)	40.17 (39.31)	49.83 (44.89)	48.48 (44.11)	46.16 (42.77)	26.03 (30.65)	31.90 (34.37)	26.75 (31.03)	28.23 (32.02)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	22.35 (28.19)	7.45 (9.40)	0.00 (0.52)	0.00 (0.52)	17.52 (24.70)	5.84 (8.23)	0.00 (0.52)	0.00 (0.52)	10.00 (18.26)	3.33 (6.09)
Mean	41.76 (38.52)	50.21 (43.95)	46.93 (43.08)	46.30 (41.85)	25.59 (28.51)	30.83 (31.63)	32.44 (34.05)	29.62 (31.40)	23.69 (27.50)	27.50 (29.93)	24.13 (28.81)	25.11 (28.75)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.70		2.62		0.67		2.49		0.73		2.70	
B	0.33		1.21		0.31		1.15		0.34		1.25	
A X B	1.22		4.54		1.16		4.32		1.26		4.68	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformation

Table 55. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at two days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatment	Corrected per cent mortality of mealybugs											
Insecticides (A)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l	49.79 (44.86)	61.12 (51.40)	57.69 (49.41)	56.20 (48.56)	44.93 (42.07)	51.75 (45.99)	49.89 (44.92)	48.86 (44.33)	35.62 (36.63)	42.19 (40.49)	34.46 (35.92)	37.43 (37.68)
Thiamethoxam 25 WG @ 0.3 g/l	49.62 (44.76)	53.64 (47.07)	47.83 (43.74)	50.36 (45.19)	40.40 (39.45)	43.41 (41.19)	44.45 (41.80)	42.76 (40.81)	32.33 (34.63)	39.60 (38.98)	32.58 (34.79)	34.84 (36.13)
Acetamiprid 20 SP @ 0.3 g/l	19.29 (26.04)	25.44 (30.27)	28.09 (31.97)	24.28 (29.43)	10.09 (18.51)	12.63 (20.77)	18.40 (25.37)	13.71 (21.55)	13.86 (21.84)	15.60 (23.25)	14.57 (22.40)	14.68 (22.50)
Imidacloprid 70 WG @ 0.3 g/l	72.16 (58.18)	83.97 (66.40)	73.30 (58.87)	76.48 (61.15)	62.27 (52.08)	70.55 (57.12)	65.98 (54.30)	66.27 (54.50)	43.87 (41.46)	52.30 (46.30)	43.13 (41.03)	46.43 (42.93)
Imidacloprid 17.8 SL @ 0.3 ml/l	75.90 (60.58)	83.70 (66.23)	78.05 (62.07)	79.22 (62.96)	60.68 (51.16)	66.58 (54.67)	59.42 (50.41)	62.23 (52.08)	40.35 (39.42)	50.11 (45.04)	41.57 (40.12)	44.01 (41.53)
Chlorfenapyr 10 SC @ 1ml/l	12.30 (20.47)	18.75 (25.64)	26.36 (30.87)	19.14 (25.66)	11.90 (20.17)	12.97 (21.09)	19.15 (25.93)	14.67 (22.40)	8.32 (16.69)	14.00 (21.90)	13.46 (21.51)	11.93 (20.03)
Emamectin benzoate 5 SG @ 0.3 g/l	13.06 (21.17)	14.77 (22.57)	22.89 (28.53)	16.91 (24.09)	14.25 (22.16)	15.97 (23.50)	17.19 (24.48)	15.80 (23.38)	6.95 (15.27)	8.93 (17.38)	8.38 (16.67)	8.09 (16.44)
Buprofezin 25 EC @ 2.00 ml/l	59.56 (50.49)	69.31 (56.35)	62.69 (52.33)	63.85 (53.06)	43.80 (41.42)	48.63 (44.20)	45.88 (42.62)	46.11 (42.75)	26.80 (31.13)	36.48 (37.11)	31.19 (33.87)	31.49 (34.04)
Bifenthrin 10 EC @ 1 ml/l	73.23 (58.86)	82.39 (65.30)	77.03 (61.35)	77.55 (61.84)	54.13 (47.35)	66.95 (54.89)	58.08 (49.63)	59.72 (50.62)	44.24 (41.68)	52.55 (46.50)	43.40 (41.19)	46.77 (43.12)
Profenophos 50 EC @ 2ml/l	55.27 (48.01)	69.56 (56.50)	60.94 (51.30)	61.92 (51.93)	39.05 (38.66)	49.53 (44.71)	45.71 (42.52)	44.76 (41.96)	29.47 (32.86)	37.22 (37.58)	32.76 (34.90)	33.15 (35.11)
Diafenthiuron 50 WP @ 1.2 g/l	42.64 (40.75)	52.93 (46.66)	46.98 (43.25)	47.52 (43.55)	29.10 (32.63)	34.21 (35.78)	38.55 (38.37)	33.96 (35.59)	18.96 (25.76)	25.19 (30.11)	23.04 (28.65)	22.40 (28.17)
Dimethoate 30 EC @ 1.7 ml/l	53.40 (46.93)	65.15 (53.80)	55.66 (48.23)	58.07 (49.66)	40.46 (39.48)	49.81 (44.87)	43.87 (41.46)	44.71 (41.94)	25.49 (30.30)	32.95 (35.02)	26.98 (31.27)	28.47 (32.20)
Dichlorvos 76 EC @ 0.5 ml/l	61.54 (51.66)	73.13 (58.78)	65.89 (54.24)	66.85 (54.90)	48.64 (44.20)	60.86 (51.25)	56.19 (48.54)	55.23 (48.00)	33.73 (35.48)	41.43 (40.05)	34.29 (35.80)	36.48 (37.11)
Adjuvant alone	0.56 (2.47)	0.00 (0.52)	26.67 (31.08)	9.08 (11.18)	0.00 (0.52)	0.00 (0.52)	21.06 (27.29)	7.02 (9.10)	0.00 (0.52)	0.00 (0.52)	12.83 (20.92)	4.28 (6.97)
Mean	45.59 (41.09)	53.85 (46.21)	52.15 (46.23)	50.13 (44.51)	35.69 (34.95)	41.70 (38.57)	41.70 (39.83)	39.70 (37.79)	25.71 (28.80)	32.05 (32.84)	28.05 (31.36)	28.60 (31.00)
Comparing the means of	S.Em.±			C.D. (0.01)	S.Em.±			C.D. (0.01)	S.Em.±			C.D. (0.01)
A	0.57			2.13	0.37			1.37	0.53			1.97
B	0.26			0.99	0.17			0.63	0.24			0.91
A X B	0.99			3.69	0.64			2.37	0.91			3.41

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Among the combinations, the combination of imidacloprid 70 WG @ 0.3 g/l and 17.8 SL @ 0.3 ml/l with Dhanuvit @ 1 ml/l resulted significantly higher mortality of 83.97 and 83.70 per cent, respectively. These were on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (82.39%) (Table 55).

Second instar mealybugs

The insecticide imidacloprid 70 WG @ 0.3g/l registered significantly higher mortality of 66.27 per cent, which was on par with imidacloprid 17.8 SL @ 0.3 ml/l with mortality of 62.23 per cent as compared to rest of the insecticides. The adjuvant Dhanuvit @ 1 ml/l and FORS @ 5 ml/l recorded significantly higher mortality (41.70 % each) as compared to APSA-80 @ 1 ml/l (35.69%). The combinations of different insecticide with adjuvant were significantly effective on second instar mealybugs. However, the combination of imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l registered higher mortality (70.55 %) which was on par with bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l with Dhanuvit @ 1 ml/l causing mortality of 66.95 and 66.58 per cent, respectively (Table 55).

Third instar mealybugs

Bifenthrin 10 EC @ 1 ml/l, imidacloprid 70 WG @ 0.3g/l and imidacloprid 17.8 SL @ 0.3 ml/l proved significantly superior over all other treatments by causing mortality of 46.77, 46.43 and 44.01 per cent, respectively on third instar mealybugs. Among the adjuvants, the Dhanuvit @ 1 ml/l recorded significantly higher mortality of third instar mealybugs (32.05 %) followed by FORS @ 5 ml/l (28.05%). The combination of bifenthrin 10 EC @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l along with Dhanuvit @ 1 ml/l showed significantly highest mortality of 52.55 and 52.30 per cent, respectively. These were on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l with mortality of 50.11 per cent (Table 55).

4.3.3.4 Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment (3 DAT)

4.3.3.4a During 2009-10

First instar mealybug

Cent percent mortality was recorded in imidacloprid 70 WG @ 0.3 g/l and bifenthrin 10 EC @ 1 ml/l, which were significantly superior over other treatments. The next better treatments were imidacloprid 17.8 SL @ 0.3 ml/l and profenophos 50 EC @ 2 ml/l with mortality of 92.59 and 90.64 per cent, respectively. However, other insecticides proved to be effective on first instar mealybugs except acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 SC @ 1 ml/l and emamectin benzoate 5 SG (31.41, 17.51 and 12.12 per cent mortality, respectively) (Table 56). Dhanuvit @ 1 ml/l caused significantly highest mortality (72.36 %) followed by FORS @ 5 ml/l (63.12%) and APSA-80 @ 1 ml/l (63.11%) (Table 56).

The combinations of imidacloprid 70 WG @ 0.3 g/l and bifenthrin 10 EC @ 1 ml/l with all the adjuvants, thiacloprid 240 SC @0.2 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l, profenophos 50 EC @ 2 ml/l and dichlorvos 76 EC @ 0.7 ml/ with Dhanuvit @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l with FORS @ 5 ml/l registered 100 per cent mortality of mealybug and were significantly superior over rest of the treatment combinations. (Table 56).

Second instar mealybug

Cent percent mortality was recorded in the treatment of imidacloprid 70 WG @ 0.3 g/l and was significantly superior over rest of the insecticides. The next better treatments were dichlorvos 76 EC @ 0.5 ml/l and bifenthrin 10 EC@ 2 ml/l with mortality of 89.31 and 85.00 per cent, respectively. Among the adjuvants, the Dhanuvit @ 1 ml/l registered significantly higher (62.92 %) mortality of second instar mealybugs. The next best adjuvant was FORS @ 5 ml/l (59.72%) and APSA-80 @ 1 ml/l (55.69%).

A cent per cent mortality was recorded in combinations of imidacloprid 70 WG @ 0.3 g/l, imidacloprid 17.8 SL @ 0.3 ml/l, bifenthrin 10 EC@ 1 ml/l and dichlorvos 76 EC @ 0.5 ml/l with Dhanuvit @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l with APSA-80 @ 1 ml/l and FORS @ 5 ml/l. next best combination were dichlorvos76 EC with APSA-80 @ 1 ml/l (85.71%) and FORS @ 5 ml/l (82.22%).

Table 56. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2009-10

Treatment	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
Insecticides (A)	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l	85.52 (67.64)	100.00 (89.48)	72.22 (58.22)	85.91 (71.94)	58.93 (50.13)	62.22 (52.07)	66.67(54.80)	62.61 (52.33)	49.36 (44.61)	64.16 (53.21)	45.42 (42.36)	52.98 (46.73)
Thiamethoxam 25 WG @ 0.3 g/l	78.33 (62.26)	93.33 (75.21)	62.22 (52.07)	77.96 (63.18)	69.37 (56.38)	71.03 (57.45)	62.10 (52.01)	67.50 (55.28)	43.83 (41.44)	65.00 (53.71)	51.96 (46.11)	53.60 (47.09)
Acetamiprid 20 SP @ 0.3 g/l	32.05 (34.47)	36.43 (37.10)	25.76 (30.48)	31.41 (34.02)	19.79 (26.35)	23.77 (29.13)	23.58 (29.04)	22.38 (28.17)	14.94 (22.56)	16.13 (23.66)	15.00 (22.70)	15.36 (22.97)
Imidacloprid 70 WG @ 0.3 g/l	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	74.24 (59.48)	83.66 (66.29)	75.15 (60.13)	77.69 (61.97)
Imidacloprid 17.8 SL @ 0.3 ml/l	77.78 (61.87)	100.00 (89.48)	100.00 (89.48)	92.59 (80.60)	69.44 (56.47)	100.00 (89.48)	69.44 (56.47)	79.63 (67.63)	65.81 (54.22)	71.39 (57.64)	69.11 (56.22)	68.77 (56.03)
Chlorfenapyr 10 SC @ 1ml/l	9.70 (18.13)	15.91 (23.48)	26.92 (31.24)	17.51 (24.28)	16.96 (24.25)	23.33 (28.84)	21.83 (27.84)	20.71 (26.98)	10.26 (18.60)	11.48 (19.70)	13.04 (21.16)	11.59 (19.82)
Emamectin benzoate 5 SG @ 0.3 g/l	14.55 (22.41)	10.21 (18.62)	11.60 (19.89)	12.12 (20.31)	14.31 (22.21)	20.77 (27.09)	15.82 (23.42)	16.67 (24.24)	12.36 (20.53)	13.53 (21.53)	13.18 (21.23)	13.02 (21.09)
Buprofezin 25 EC @ 2.00 ml/l	84.13 (66.51)	93.33 (75.21)	75.48 (60.29)	84.31 (67.34)	59.88 (50.68)	75.00 (59.98)	69.84 (56.68)	68.24 (55.78)	55.03 (47.87)	64.67 (53.51)	60.63 (51.13)	60.11 (50.84)
Bifenthrin 10 EC @ 1 ml/l	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	76.67 (61.12)	100.00 (89.48)	78.33 (62.26)	85.00 (71.12)	73.33 (58.91)	93.33 (75.21)	77.21 (61.46)	81.29 (65.19)
Profenophos 50 EC @ 2ml/l	83.02 (65.68)	100.00 (89.48)	88.89 (70.54)	90.64 (75.40)	61.57 (51.70)	64.44 (53.39)	62.10 (52.01)	62.71 (52.37)	48.14 (43.92)	69.11 (56.22)	63.79 (53.00)	60.35 (51.05)
Diafenthiuron 50 WP @ 1.2 g/l	61.87 (51.85)	72.14 (58.14)	63.43 (52.78)	65.82 (54.26)	71.82 (57.92)	75.93 (60.60)	73.50 (59.04)	73.75 (59.19)	39.67 (39.02)	43.70 (41.36)	42.51 (40.67)	41.96 (40.35)
Dimethoate 30 EC @ 1.7 ml/l	78.25 (62.20)	92.67 (73.76)	69.44 (56.47)	79.79 (64.14)	75.19 (60.16)	64.44 (53.39)	75.93 (60.60)	71.85 (58.05)	44.64 (41.90)	63.89 (53.05)	52.83 (46.61)	53.79 (47.19)
Dichlorvos 76 EC @ 0.5 ml/l	78.33 (62.26)	100.00 (89.48)	61.11 (51.47)	79.81 (67.90)	85.71 (67.77)	100.00 (89.48)	82.22 (65.06)	89.31 (74.26)	73.26 (58.87)	77.59 (61.74)	76.83 (61.21)	75.89 (60.61)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	26.63 (31.05)	8.88 (10.35)	0.00 (0.52)	0.00 (0.52)	34.68 (36.05)	11.56 (12.02)	0.00 (0.52)	1.11 (3.51)	24.28 (29.49)	8.46 (11.00)
Mean	63.11 (53.94)	72.36 (64.38)	63.12 (56.03)	66.20 (58.12)	55.69 (48.22)	62.92 (55.84)	59.72 (51.80)	59.44 (51.96)	43.21 (39.42)	52.77 (45.74)	48.64 (43.82)	48.20 (42.99)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.63		2.36		0.64		2.38		0.73		2.71	
B	0.29		1.09		0.30		1.10		0.34		1.25	
A X B	1.10		4.09		1.11		4.13		1.26		4.69	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Table 57. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2010-11

Treatment		Corrected per cent mortality of mealybugs											
Insecticides (A)	Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
		APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l		71.33 (57.61)	81.11 (64.23)	75.93 (60.60)	76.12 (60.82)	59.74 (50.60)	63.65 (52.91)	59.39 (50.41)	60.93 (51.31)	44.96 (42.09)	55.57 (48.18)	44.33 (41.73)	48.29 (44.00)
Thiamethoxam 25 WG @ 0.3 g/l		63.06 (52.56)	69.96 (56.75)	66.71 (54.74)	66.58 (54.68)	57.66 (49.39)	66.67 (54.71)	58.50 (49.88)	60.94 (51.33)	31.67 (34.23)	36.57 (37.19)	37.30 (37.63)	35.18 (36.35)
Acetamiprid 20 SP @ 0.3 g/l		16.47 (23.92)	21.57 (27.63)	22.24 (28.13)	20.09 (26.56)	18.27 (25.29)	21.33 (27.48)	18.76 (25.65)	19.46 (26.14)	5.19 (12.95)	6.74 (15.02)	8.23 (16.62)	6.72 (14.86)
Imidacloprid 70 WG @ 0.3 g/l		83.90 (66.34)	100.00 (89.48)	84.20 (66.58)	89.37 (74.29)	69.41 (56.40)	73.30 (58.87)	67.63 (55.31)	70.11 (56.86)	59.31 (50.35)	61.43 (51.59)	57.57 (49.34)	59.44 (50.42)
Imidacloprid 17.8 SL @ 0.3 ml/l		80.54 (63.81)	85.17 (67.33)	81.53 (64.52)	82.41 (65.22)	68.00 (55.53)	74.54 (59.69)	60.44 (51.01)	67.66 (55.41)	57.17 (49.10)	58.52 (49.89)	59.44 (50.42)	58.38 (49.81)
Chlorfenapyr 10 SC @ 1ml/l		11.85 (20.12)	17.17 (24.47)	18.81 (25.69)	15.94 (23.43)	21.08 (27.29)	12.51 (20.71)	19.25 (26.00)	17.61 (24.67)	6.47 (14.54)	8.97 (17.35)	15.70 (23.27)	10.38 (18.38)
Emamectin benzoate 5 SG @ 0.3 g/l		15.81 (23.42)	17.70 (24.86)	19.43 (26.13)	17.65 (24.80)	17.46 (24.68)	15.03 (22.80)	15.62 (23.27)	16.04 (23.58)	14.03 (21.92)	15.44 (23.12)	16.93 (24.29)	15.47 (23.11)
Buprofezin 25 EC @ 2.00 ml/l		62.10 (52.01)	66.03 (54.38)	74.73 (59.80)	67.62 (55.40)	48.48 (44.11)	58.65 (49.97)	54.15 (47.36)	53.76 (47.15)	41.46 (40.06)	46.20 (42.80)	31.07 (33.83)	39.58 (38.90)
Bifenthrin 10 EC @ 1 ml/l		100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	66.73 (54.76)	77.31 (61.55)	63.90 (53.05)	69.31 (56.45)	47.05 (43.29)	65.68 (54.12)	50.90 (45.50)	54.54 (47.64)
Profenophos 50 EC @ 2ml/l		75.13 (60.07)	71.43 (57.67)	73.51 (59.00)	73.36 (58.91)	46.48 (42.96)	50.88 (45.48)	43.14 (41.04)	46.83 (43.16)	41.65 (40.17)	41.10 (39.85)	42.72 (40.79)	41.82 (40.27)
Diafenthiuron 50 WP @ 1.2 g/l		51.11 (45.62)	63.43 (52.78)	60.07 (50.80)	58.21 (49.73)	33.38 (35.26)	37.58 (37.79)	39.29 (38.78)	36.75 (37.28)	27.54 (31.62)	30.81 (33.70)	31.64 (34.21)	29.99 (33.18)
Dimethoate 30 EC @ 1.7 ml/l		67.52 (55.24)	66.87 (54.87)	69.74 (56.61)	68.04 (55.57)	41.65 (40.18)	48.15 (43.92)	43.92 (41.49)	44.57 (41.86)	39.34 (38.82)	44.55 (41.85)	46.09 (42.74)	43.33 (41.14)
Dichlorvos 76 EC @ 0.5 ml/l		87.77 (69.50)	100.00 (89.48)	87.96 (69.68)	91.91 (76.38)	62.99 (52.51)	66.01 (54.32)	57.95 (49.56)	62.32 (52.13)	50.00 (44.98)	59.53 (50.48)	58.58 (49.92)	56.04 (48.46)
Adjuvant alone		0.00 (0.52)	0.00 (0.52)	34.73 (36.10)	11.58 (12.03)	0.00 (0.52)	0.00 (0.52)	20.96 (27.23)	6.99 (9.08)	0.00 (0.52)	0.00 (0.52)	34.33 (35.85)	11.44 (11.95)
Mean		56.19 (48.58)	61.46 (53.92)	62.11 (53.45)	59.92 (51.98)	43.67 (39.93)	47.54 (42.16)	44.49 (41.43)	45.23 (41.17)	33.27 (33.15)	37.94 (36.08)	38.20 (37.58)	36.47 (35.60)
Comparing the means of		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A		0.41		1.54		0.44		1.63		0.47		1.76	
B		0.19		0.71		0.20		0.75		0.22		0.82	
A X B		0.72		2.67		0.76		2.82		0.82		3.06	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Third instar mealybug

The mortality of third instar mealybug was significantly highest in bifenthrin 10 EC @ 1 ml/l and imidacloprid 70 WG @ 0.3g/l with 81.29 and 77.69 per cent, respectively, which were on par with dichlorvos 76 EC @ 0.5 ml/l (75.89%) as compared to rest of the treatments. Dhanuvit @ 1 ml/l recorded significantly highest and superior in influencing mortality (52.77%) of third instar mealybug as compared to adjuvants FORS @ 5 ml/l (48.64%) and APSA-80 @ 1 ml/l (43.21%) (Table 56).

The combinations of bifenthrin 10 EC @ 1 ml/l along with Dhanuvit @ 1 ml/l was significantly superior and recorded highest mortality (93.33 %) as compared to rest of the combinations of insecticides with adjuvants. However, lowest mortality was observed with acetamiprid 20 SP @ 0.3 g/l, emamectin benzoate 5 SG @ 0.3 g/l and chlorfenapyr 10 SC in combination with adjuvants (Table 56).

4.3.3.4b During 2010-11

First instar mealybugs

Cent percent mortality was recorded in insecticide bifenthrin 10 EC @ 1 ml/l followed by dichlorvos 76 EC @ 0.5 ml/l, imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l with mortality of 91.91, 89.37 and 82.41 per cent, respectively as compared to rest of the treatments. No significant difference was observed between Dhanuvit @ 1 ml/l and FORS @ 5 ml/l on mortality of first instar mealybugs with mortality of 62.11 and 61.46 per cent, respectively (Table 57).

Among the combinations of adjuvants with insecticides, cent percent mortality of first instar mealybugs was observed in combinations of Dhanuvit @ 1 ml/l with imidacloprid 70 WG @ 0.3 g/l, bifenthrin 10 EC @ 1 ml/l and dichlorvos 76 EC @ 0.5 ml/l and bifenthrin 10 EC @ 1 ml/l with APSA-80 @ 1 ml/l and FORS @ 5 ml/l (Table 57).

Second instar mealybugs

Significantly higher mortality was recorded in imidacloprid 70 WG @ 0.3g/l, bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l with 70.11, 69.31 and 67.66 per cent, respectively. However, rests of the treatments were also significantly effective, but lowest per cent mortality was resulted in acetamiprid 20 SP @ 0.3 g/l (6.72%) chlorfenapyr 10 SC @ 1 ml/l (10.38%) and emamectin benzoate 5 SG @ 0.3 g/l (15.47%). Significantly higher mortality was recorded in adjuvant Dhanuvit @ 1 ml/l (47.54%) and FORS @ 5 ml/l (44.49%) (Table 57).

Among the combination of insecticide and adjuvant, the combination of bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l along with Dhanuvit @ 1 ml/l registered significantly higher mortality (77.31 and 74.54 %, respectively). The next better treatment was imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l with mortality of 73.30 per cent and was on par with above treatment. However, the remaining combinations recorded higher mortality except the combination of adjuvants with acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 SC @ 1 ml/l and emamectin benzoate 5 SG @ 0.3 g/l (Table 57).

Third instar mealybugs

The insecticides imidacloprid 70 WG @ 0.3g/l and imidacloprid 17.8 SL @ 0.3 ml/l, bifenthrin 10 EC @ 1 ml/l and dichlorvos 76 EC @ 0.5 ml/l caused significantly higher mortality (59.44, 58.38, 56.04 and 54.54 %, respectively) and proved superior over rest of the insecticides (Table 57). Significantly higher mortality was observed in FORS @ 5 ml/l with mortality of 38.20 per cent followed by Dhanuvit @ 1 ml/l (36.94%). Among the combination of insecticide and adjuvant, the combination of bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l registered significantly superior mortality (65.68%), which was on par with imidacloprid 70SG @ 0.3 g/l + Dhanuvit @ 1 ml/l with mean mortality of 61.63 per cent. However, the combination of rest of the insecticides with adjuvants recorded higher mortality except the combination of adjuvants with acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 SC @ 1 ml/l and emamectin benzoate 5 SG @ 0.3 g/l (Table 57).

4.3.3.4c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

Significantly high mortality was obtained in the treatment of bifenthrin 10 EC @ 1 ml/l. The next better treatments were imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l with mortality of 94.68, 87.50 and 85.86 per cent, respectively. However, the lowest mortality of mealybugs was registered in acetamiprid 20 SP @ 0.3 g/l (25.75%) followed by

Table 58. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at three days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatment		Corrected per cent mortality of mealybugs											
Insecticides (A)	Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
		APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l		78.42 (62.30)	90.56 (72.09)	74.07 (59.37)	81.02 (64.59)	59.33 (50.36)	62.94 (52.49)	63.03 (52.54)	61.77 (51.80)	47.16 (43.35)	59.87 (50.67)	44.88 (42.04)	50.63 (45.35)
Thiamethoxam 25 WG @ 0.3 g/l		70.69 (57.22)	81.65 (64.61)	64.46 (53.40)	72.27 (58.41)	63.51 (52.82)	68.85 (56.06)	60.30 (50.93)	64.22 (53.27)	37.75 (37.89)	50.79 (45.43)	44.63 (41.90)	44.39 (41.74)
Acetamiprid 20 SP @ 0.3 g/l		24.26 (29.49)	29.00 (32.55)	24.00 (29.32)	25.75 (30.46)	19.03 (25.84)	22.55 (28.32)	21.17 (27.39)	20.92 (27.18)	10.07 (18.43)	11.43 (19.74)	11.62 (19.88)	11.04 (19.35)
Imidacloprid 70 WG @ 0.3 g/l		91.95 (73.50)	100.00 (89.48)	92.10 (73.66)	94.68 (79.04)	84.71 (66.95)	86.65 (68.54)	83.82 (66.26)	85.06 (67.25)	66.78 (54.78)	72.55 (58.39)	66.36 (54.53)	68.56 (55.90)
Imidacloprid 17.8 SL @ 0.3 ml/l		79.16 (62.82)	92.58 (74.17)	90.77 (72.28)	87.50 (69.76)	68.72 (55.99)	87.27 (69.09)	64.94 (53.69)	73.65 (59.59)	61.49 (51.63)	64.95 (53.68)	64.28 (53.27)	63.57 (52.86)
Chlorfenapyr 10 SC @ 1ml/l		10.77 (19.15)	16.54 (23.99)	22.87 (28.55)	16.73 (23.90)	19.02 (25.81)	17.92 (25.03)	20.54 (26.94)	19.16 (25.93)	8.36 (16.69)	10.23 (18.57)	14.37 (22.25)	10.99 (19.17)
Emamectin benzoate 5 SG @ 0.3 g/l		15.18 (22.92)	13.96 (21.93)	15.51 (23.18)	14.88 (22.67)	15.88 (23.47)	17.90 (25.02)	15.72 (23.34)	16.50 (23.94)	13.19 (21.29)	14.48 (22.35)	15.06 (22.82)	14.24 (22.15)
Buprofezin 25 EC @ 2.00 ml/l		73.12 (58.77)	79.68 (63.23)	75.11 (60.05)	75.97 (60.68)	54.18 (47.38)	66.83 (54.81)	61.99 (51.92)	61.00 (51.37)	48.24 (43.98)	55.43 (48.10)	45.85 (42.60)	49.84 (44.89)
Bifenthrin 10 EC @ 1 ml/l		100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	71.70 (57.84)	88.65 (70.31)	71.12 (57.47)	77.16 (61.87)	60.19 (50.86)	79.51 (63.07)	64.05 (53.14)	67.92 (55.69)
Profenophos 50 EC @ 2ml/l		79.07 (62.77)	85.71 (67.77)	81.20 (64.29)	82.00 (64.94)	54.03 (47.29)	57.66 (49.39)	52.62 (46.48)	54.77 (47.72)	44.90 (42.05)	55.10 (47.91)	53.25 (46.85)	51.09 (45.60)
Diafenthiuron 50 WP @ 1.2 g/l		56.49 (48.71)	67.79 (55.41)	61.75 (51.78)	62.01 (51.97)	52.60 (46.47)	56.75 (48.86)	56.39 (48.66)	55.25 (48.00)	33.60 (35.41)	37.25 (37.60)	37.07 (37.49)	35.98 (36.83)
Dimethoate 30 EC @ 1.7 ml/l		72.89 (58.60)	79.27 (62.98)	69.59 (56.53)	73.92 (59.37)	58.42 (49.83)	56.30 (48.60)	59.92 (50.70)	58.21 (49.71)	41.99 (40.37)	54.22 (47.40)	49.46 (44.67)	48.56 (44.15)
Dichlorvos 76 EC @ 0.5 ml/l		83.05 (65.67)	100.00 (89.48)	75.54 (59.74)	85.86 (71.79)	74.35 (59.55)	83.01 (65.63)	70.09 (56.82)	75.82 (60.67)	61.63 (51.71)	68.56 (55.88)	67.70 (55.35)	65.97 (54.31)
Adjuvant alone		0.00 (0.52)	0.00 (0.52)	30.68 (33.62)	10.23 (11.21)	0.00 (0.52)	0.00 (0.52)	27.82 (31.81)	9.27 (10.60)	0.00 (0.52)	0.56 (2.47)	29.30 (32.76)	9.95 (11.74)
Mean		59.65 (50.85)	66.91 (57.76)	62.62 (53.98)	63.06 (54.20)	49.68 (43.54)	55.23 (47.30)	52.11 (46.07)	52.34 (45.64)	38.24 (36.32)	45.35 (40.81)	43.42 (40.68)	42.34 (39.27)
Comparing the means of		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A		0.41		1.52		0.39		1.47		0.43		1.61	
B		0.19		0.70		0.18		0.68		0.20		0.75	
A X B		0.70		2.63		0.68		2.54		0.75		2.79	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Table 59. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2009-10

Treatment	Corrected per cent mortality of mealybugs											
Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Insecticides (A)												
Thiacloprid 240 SC @ 0.2 ml/l	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	66.67 (54.71)	100.00 (89.48)	61.11 (51.47)	75.93 (65.38)	55.75 (48.28)	60.00 (50.75)	59.02 (50.18)	58.25 (49.74)
Thiamethoxam 25 WG @ 0.3 g/l	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	57.96 (49.57)	66.67 (54.71)	71.04 (57.42)	65.22 (53.90)
Acetamiprid 20 SP @ 0.3 g/l	25.12 (30.05)	39.17 (38.73)	23.15 (28.74)	29.14 (32.51)	17.07 (24.38)	20.06 (26.59)	25.55 (30.33)	20.89 (27.10)	12.82 (20.93)	21.21 (27.39)	19.45 (26.16)	17.83 (24.83)
Imidacloprid 70 WG @ 0.3 g/l	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)
Imidacloprid 17.8 SL @ 0.3 ml/l	100.00 (89.48)	0.00 (0.52)	0.00 (0.52)	33.33 (29.99)	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	78.33 (62.26)	88.90 (70.55)	72.22 (58.22)	79.82 (63.68)
Chlorfenapyr 10 SC @ 1ml/l	10.74 (19.12)	12.63 (20.79)	15.95 (23.50)	13.11 (21.14)	16.70 (24.11)	19.58 (26.25)	20.95 (27.23)	19.08 (25.86)	8.63 (17.07)	16.09 (23.61)	15.00 (22.78)	13.24 (21.15)
Emamectin benzoate 5 SG @ 0.3 g/l	5.68 (13.77)	11.38 (19.69)	13.13 (21.22)	10.06 (18.23)	16.70 (24.11)	13.13 (21.22)	20.76 (27.07)	16.86 (24.13)	11.25 (19.52)	12.52 (20.64)	12.07 (20.26)	11.95 (20.14)
Buprofezin 25 EC @ 2.00 ml/l	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	61.11 (51.47)	100.00 (89.48)	100.00 (89.48)	87.04 (77.13)	63.06 (52.56)	64.44 (53.39)	52.38 (46.35)	59.96 (50.77)
Bifenthrin 10 EC @ 1 ml/l	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)
Profenophos 50 EC @ 2ml/l	100.00 (89.48)	0.00 (0.52)	0.00 (0.52)	33.33 (29.99)	69.44 (56.47)	100.00 (89.48)	100.00 (89.48)	89.81 (78.80)	54.23 (47.41)	66.67 (54.76)	61.13 (51.42)	60.68 (51.20)
Diafenthiuron 50 WP @ 1.2 g/l	53.33 (46.90)	55.56 (48.23)	66.67 (54.98)	58.52 (50.04)	88.90 (70.55)	100.00 (89.48)	100.00 (89.48)	96.30 (83.49)	36.75 (37.29)	47.22 (43.38)	38.72 (38.46)	40.90 (39.71)
Dimethoate 30 EC @ 1.7 ml/l	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	45.15 (42.19)	64.44 (53.39)	56.02 (48.46)	55.20 (48.01)
Dichlorvos 76 EC @ 0.5 ml/l	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	72.23 (58.19)	55.56 (48.23)	77.80 (61.88)	68.53 (56.10)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	37.58 (37.79)	12.53 (12.60)	0.00 (0.52)	0.00 (0.52)	24.51 (29.64)	8.17 (9.88)
Mean	49.63 (46.40)	8.48 (9.10)	37.06 (34.88)	31.73 (30.13)	59.76 (53.97)	46.63 (43.85)	69.00 (63.83)	58.46 (53.88)	49.73 (45.37)	54.55 (48.62)	54.24 (49.37)	52.84 (47.79)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.58		2.17		0.48		1.80		0.65		2.42	
B	0.27		1.01		0.22		0.83		0.30		1.12	
A X B	1.01		3.76		0.84		3.12		1.12		4.18	

FORS - Fish oil rosin soap

- Figures in parentheses are Arcsine transformations

chlorfenapyr 10 SC @ 1 ml/l (16.73%) and emamectin benzoate 5 SG @ 0.3 g/l (14.88%). The adjuvant Dhanuvit @ 1 ml/l recorded significantly superior mortality (66.91 %) over other adjuvants i.e., FORS @ 5 ml/l (62.62%) and APSA-80 @ 1 ml/l (59.65%) (Table 58).

Cent percent mortality was observed in the combination of bifenthrin 10 EC @ 1 ml/l with all the three adjuvants, imidacloprid 70 WG @ 0.3 g/l and dichlorvos 76 EC @ 0.5 ml/l with Dhanuvit @ 1 ml/l, which were significantly superior over rest of the combinations (Table 58).

Second instar mealybugs

Significantly higher mortality was recorded in the treatment of imidacloprid 70 WG @ 0.3 g/l (85.06%) which was superior over rest of the insecticidal treatments. However, the next better treatments were bifenthrin 10 EC @ 1 ml/l (77.16%), dichlorvos 76 EC @ 0.5 ml/l (75.82%) and imidacloprid 17.8 SL @ 0.3 ml/l (73.65%). Among the adjuvants, the Dhanuvit @ 1 ml/l registered higher mortality (55.23 %) which was significantly superior over rest of the adjuvants followed by FORS @ 5 ml/l (52.11%) and APSA-80 @ 1 ml/l (49.68%) (Table 58).

Significantly higher mortality was resulted in the treatment combination of bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l with 88.65 per cent. This was on par with the combinations of imidacloprid 17.8 SL @ 0.3 ml/l and imidacloprid 70 WG @ 0.3 g/l along with Dhanuvit @ 1 ml/l causing mortality of 87.27 and 86.65 per cent, respectively (Table 58).

Third instar mealybugs

The insecticides imidacloprid 70 WG @ 0.3 g/l, bifenthrin 10 EC, dichlorvos 76 EC @ 0.5 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l were significantly superior over rest of the treatments causing mortality of 68.56, 67.92, 65.97 and 63.57 per cent, respectively. Non-significant difference was observed between the adjuvants Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with mortality of 45.35 and 43.42 per cent, respectively (Table 58). The combination of bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l resulted higher mortality of 79.51 per cent, which was significantly superior over rest of the combinations. The next better combinations were imidacloprid 70 WG @ 0.3 g/l and dichlorvos 76 EC @ 0.5 ml/l along with Dhanuvit @ 1 ml/l with mean mortality of 72.55 and 68.56 per cent, respectively as compared to other combinations (Table 58).

4.3.3.5 Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment (5 DAT)

4.3.3.5a During 2009-10

First instar mealybug

The mortality of first instar mealybugs was observed cent percent in insecticidal treatments viz., thiamethoxam 25 WG @ 0.3 g/l, thiacloprid 240 SC, imidacloprid 17.8 SL @ 0.3 ml/l, buprofezin 25 SC @ 2.00 ml/l, profenophos 50 EC @ 2 ml/l and dichlorvos 76 EC @ 0.5 ml/l, as compared to rest of the treatments. However, the insecticides acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 SC @ 1 ml/l and emamectin benzoate 5 SG @ 0.3 g/l failed to cause significant mortality of mealybugs. The adjuvant APSA-80 @ 1 ml/l caused highest mortality (49.63%) of first instar mealybugs followed by FORS @ 5 ml/l (37.06%) and Dhanuvit @ 1 ml/l (8.48%) (Table 59).

All the combinations APSA-80 @ 1 ml/l and FORS @ 1 ml/l with insecticides resulted cent percent mortality of first instar mealybugs except the combinations of adjuvants with acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 SC, emamectin benzoate 5 SG @ 0.3 g/l and diafenthiuron 50 SP (Table 59).

Second instar mealybug

The insecticides thiamethoxam 25 WG @ 0.3 g/l and dichlorvos 76 EC @ 0.5 ml/l registered cent percent mortality of second instar mealybugs followed by dimethoate 30 EC @ 1.7 ml/l, profenophos 50 EC @ 2 ml/l and buprofezin 25 SC @ 2.00 ml/l causing mortality of 96.30, 89.81 and 87.04 per cent, respectively. The adjuvant FORS @ 5 ml/l showed significantly highest mortality of second instar mealybug (69.00 %) as compared to other adjuvants i.e., APSA-80 @ 1 ml/l (59.76%) and Dhanuvit @ 1 ml/l (46.63%) (Table 59).

The combinations of imidacloprid 17.8 SL @ 0.3 ml/l, bifenthrin 10 EC, dimethoate 30 EC and dichlorvos 76 EC @ 0.5 ml/l with APSA-80 adjuvant and thiacloprid 240 SC @ 0.2 ml/l, thiamethoxam 25 WG @ 0.3 g/l, buprofezin 25 SC @ 2.00 ml/l, profenophos 50 EC @ 2 ml/l, diafenthiuron 50 WP @ 1.2 g/l and dimethoate 30 EC @ 1.7 ml/l in combination with Dhanuvit @ 1 ml/l and thiamethoxam 25

WG @ 0.3 g/l, imidacloprid 17.8 SL @ 0.3 ml/l, buprofezin 25 SC @ 2.00 ml/l, bifenthrin 10 EC @ 1 ml/l, diafenthiuron 50 WP @ 1.2 g/l, profenophos 50 EC @ 2 ml/l, dimethoate 30 EC @ 1.7 ml/l and dichlorvos 76 EC @ 0.5 ml/l with FORS @ 5 ml/l resulted cent percent mortality as compared to rest of the combinations (Table 59).

Third instar mealybug

Significantly cent percent mortality was recorded in treatments imidacloprid 70 WG @ 0.3 g/l and bifenthrin 10 EC @ 1 ml/l. However, all the insecticidal treatments were significantly effective on the third instar mealybugs except acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 EC @ 1 ml/l and emamectin benzoate 5 SG @ 0.3 g/l with mortality of 17.83, 13.24 and 11.95 per cent, respectively. Among the adjuvants, the Dhanuvit @ 1 ml/l and FORS @ 5 ml/l registered significantly higher mortality of 54.55 and 54.24 per cent, respectively (Table 59).

Lowest mortality was observed in the treatment combinations of insecticides acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 EC @ 1 ml/l and emamectin benzoate 5 SG @ 0.3 g/l with different adjuvants. However, the insecticides imidacloprid 70 WG @ 0.3 g/l and bifenthrin 10 EC @ 1 ml/l registered significantly cent percent mortality with combination of all the three adjuvants (Table 59).

4.3.3.5b During 2010-11

First instar mealybugs

Cent per cent mortality was obtained in the insecticides profenophos 50 EC @ 2 ml/l, followed by thiacloprid 240 SC @ 0.2 ml/l with mortality of 91.67 per cent. The adjuvant FORS @ 5 ml/l registered significantly highest mortality (58.14 %) followed by APSA-80 @ 1 ml/l (54.43%). However, the lowest mortality of mealybug was recorded in Dhanuvit @ 1 ml/l (35.28%) (Table 60).

The combinations of imidacloprid 70SG @ 0.3 g/l and 17.8 SL @ 0.3 ml/l dichlorvos 76 EC @ 0.5 ml/l with APSA-80 @ 1 ml/l and FORS @ 5 ml/l, bifenthrin 10 EC @ 1 ml/l with all three adjuvants and thiacloprid 240 SC @ 0.2 ml/l with Dhanuvit @ 1 ml/l and FORS @ 5 ml/l exhibited cent per cent mortality of first instar mealybugs.

Second instar mealybugs

Cent per cent mortality of second instar mealybugs was recorded in imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l. There was non-significant difference between Dhanuvit @ 1 ml/l and FORS @ 5 ml/l with mortality of 62.41 and 62.27 per cent, respectively. The combinations of imidacloprid 70 WG @ 0.3 g/l and 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l registered cent per cent mortality (Table 60). However, rest of the combinations were also effective on mealybugs (Table 60).

Third instar mealybugs

The insecticide bifenthrin 10 EC @ 1 ml/l resulted significantly superior mortality over rest of the treatments with of 93.52 per cent followed by imidacloprid 70 WG @ 0.3g/l (86.75%). The adjuvant Dhanuvit @ 1 ml/l recorded significantly higher mortality (51.71 %) of third instar mealybugs followed by FORS @ 5 ml/l (48.65%) and APSA-80 (46.83%). Significant mortality of third instar mealybugs was obtained in the combinations of insecticides with adjuvants. However, it was observed that the combination of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 1 ml/l + APSA-80 and Dhanuvit @ 1 ml/l caused cent per cent mortality as compared to other combinations (Table 60).

4.3.3.5c Mean of two years (2009-10 and 2010-11)

First instar mealybugs

Significantly higher mortality (79.17 %) was registered in the treatment of thiacloprid 240 SC @ 0.2 ml/l, followed by profenophos 30 EC @ 2 ml/l and dichlorvos 76 EC @ 0.5 ml/l with mortality of 66.67 and 66.67 per cent, respectively. The adjuvant APSA-80 @ 1 ml/l recoded significantly higher mortality of first instar mealybugs (52.03 %) as compared to other adjuvants (Table 61).

Cent per cent mortality was observed in the combination of imidacloprid 17.8 SL @ 0.3 ml/l, profenophos 30 EC and dichlorvos 76 EC @ 0.5 ml/l along with APSA-80 @ 1 ml/l and thiacloprid 240 SC @ 0.2 ml/l and dichlorvos 76 EC @ 0.5 ml/l in combination with FORS @ 5 ml/l as compared to rest of the combinations (Table 61).

Table 60. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2010-11

Treatment	Corrected per cent mortality of mealybugs												
Insecticides (A)	Adjuvants (B)	1 st Instar				2 nd Instar				3 rd Instar			
		APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Thiacloprid 240 SC @ 0.2 ml/l		75.00 (59.98)	100.00 (89.48)	100.00 (89.48)	91.67 (79.97)	53.70 (47.11)	62.69 (52.34)	56.91 (48.96)	57.77 (49.47)	47.62 (43.61)	62.22 (52.07)	58.33 (49.81)	56.06 (48.50)
Thiamethoxam 25 WG @ 0.3 g/l		64.44 (53.39)	75.00 (59.98)	62.22 (52.07)	67.22 (55.15)	53.68 (47.09)	60.66 (51.14)	65.28 (53.88)	59.87 (50.70)	58.93 (50.13)	60.00 (50.75)	54.76 (47.72)	57.90 (49.53)
Acetamiprid 20 SP @ 0.3 g/l		17.96 (25.04)	19.78 (26.38)	16.21 (23.69)	17.96 (25.04)	18.38 (25.37)	20.28 (26.75)	17.17 (24.47)	18.61 (25.53)	25.97 (30.61)	23.68 (29.09)	25.04 (30.01)	24.90 (29.91)
Imidacloprid 70 WG @ 0.3 g/l		100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	78.33 (62.26)	100.00 (89.48)	81.90 (64.86)	86.75 (72.36)
Imidacloprid 17.8 SL @ 0.3 ml/l		100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	60.00 (50.75)	69.44 (56.47)	68.25 (55.70)	65.90 (54.30)
Chlorfenapyr 10 SC @ 1ml/l		19.37 (26.08)	24.07 (29.36)	23.19 (28.76)	22.21 (28.07)	12.36 (20.57)	16.91 (24.27)	16.76 (24.15)	15.34 (22.99)	13.27 (21.30)	19.08 (25.88)	18.29 (25.31)	16.88 (24.17)
Emamectin benzoate 5 SG @ 0.3 g/l		0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	13.31 (21.37)	16.80 (24.18)	14.09 (22.03)	14.73 (22.53)	18.21 (25.24)	16.11 (23.64)	16.86 (24.21)	17.06 (24.37)
Buprofezin 25 EC @ 2.00 ml/l		66.67 (54.71)	50.00 (44.98)	50.00 (44.98)	55.56 (48.23)	83.12 (65.74)	90.86 (72.38)	84.87 (67.22)	86.28 (68.45)	48.13 (43.91)	63.89 (53.05)	57.50 (49.30)	56.51 (48.75)
Bifenthrin 10 EC @ 1 ml/l		0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	80.56 (63.91)	93.52 (81.28)
Profenophos 50 EC @ 2ml/l		100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	100.00 (89.48)	77.59 (61.74)	75.93 (60.60)	73.05 (58.71)	75.52 (60.35)	45.15 (42.19)	46.30 (42.86)	42.37 (40.59)	44.61 (41.88)
Diafenthiuron 50 WP @ 1.2 g/l		60.32 (50.96)	75.00 (59.98)	56.67 (48.83)	63.99 (53.25)	54.04 (47.30)	62.26 (52.08)	60.99 (51.34)	59.11 (50.24)	43.35 (41.22)	40.09 (39.27)	40.39 (39.44)	41.31 (39.98)
Dimethoate 30 EC @ 1.7 ml/l		58.33 (49.81)	50.00 (44.98)	69.44 (56.47)	59.26 (50.42)	73.33 (58.91)	80.42 (63.82)	77.59 (61.74)	77.12 (61.49)	51.52 (45.85)	60.83 (51.24)	56.67 (48.83)	56.34 (48.64)
Dichlorvos 76 EC @ 0.5 ml/l		100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	81.35 (64.54)	86.90 (68.83)	79.44 (63.09)	82.57 (65.49)	65.06 (53.74)	62.23 (52.06)	50.40 (45.21)	59.23 (50.34)
Adjuvant alone		0.00 (0.52)	0.00 (0.52)	36.20 (36.97)	12.07 (12.32)	0.00 (0.52)	0.00 (0.52)	26.62 (30.39)	8.54 (10.13)	0.00 (0.52)	0.00 (0.52)	29.73 (33.01)	9.91 (11.00)
Mean		54.43 (48.56)	35.28 (31.83)	58.14 (52.97)	49.28 (44.45)	58.63 (52.12)	62.41 (54.74)	62.27 (55.42)	61.10 (54.09)	46.83 (42.91)	51.71 (46.88)	48.65 (44.14)	49.06 (44.64)
Comparing the means of		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A		0.45		1.69		0.51		1.90		0.58		2.15	
B		0.21		0.78		0.24		0.88		0.27		0.99	
A X B		0.78		2.92		0.88		3.29		1.00		3.72	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Table 61. Effect of insecticides in combination with adjuvants on different instars of *Maconellicoccus hirsutus* at five days after treatment during 2009-10 and 2010-11 (Mean of two years)

Treatment	Corrected per cent mortality of mealybugs											
	1 st Instar				2 nd Instar				3 rd Instar			
	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean	APSA-80 @ 1 ml/l	Dhanuvit @ 1 ml/l	FORS @ 5 ml/l	Mean
Insecticides (A)												
Thiacloprid 240 SC @ 0.2 ml/l	87.50 (69.27)	50.00 (44.98)	100.00 (89.48)	79.17 (68.07)	60.19 (50.86)	81.34 (64.40)	59.01 (50.18)	66.85 (55.15)	51.68 (45.95)	61.11 (51.40)	58.67 (49.99)	57.16 (49.11)
Thiamethoxam 25 WG @ 0.3 g/l	82.22 (65.06)	37.50 (37.75)	81.11 (64.23)	66.94 (55.68)	76.84 (61.21)	80.33 (63.65)	82.64 (65.36)	79.93 (63.41)	58.45 (49.85)	63.33 (52.71)	62.90 (52.46)	61.56 (51.67)
Acetamiprid 20 SP @ 0.3 g/l	21.54 (27.64)	29.47 (32.87)	19.68 (26.31)	23.56 (28.94)	17.72 (24.88)	20.17 (26.67)	21.36 (27.50)	19.75 (26.35)	19.39 (26.12)	22.45 (28.25)	22.25 (28.13)	21.36 (27.50)
Imidacloprid 70 WG @ 0.3 g/l	50.00 (44.98)	0.00 (0.52)	0.00 (44.98)	33.33 (29.99)	50.00 (44.98)	50.00 (44.98)	50.00 (44.98)	50.00 (44.98)	89.17 (70.78)	100.00 (89.48)	90.95 (72.51)	93.37 (77.75)
Imidacloprid 17.8 SL @ 0.3 ml/l	100.00 (89.48)	0.00 (0.52)	50.00 (44.98)	50.00 (44.98)	100.00 (89.48)	50.00 (44.98)	100.00 (89.48)	83.33 (74.97)	69.17 (56.25)	79.17 (62.86)	70.24 (56.94)	72.86 (58.68)
Chlorfenapyr 10 SC @ 1ml/l	15.05 (22.81)	18.35 (25.34)	19.57 (26.25)	17.66 (24.80)	14.53 (22.40)	18.25 (25.28)	18.86 (25.72)	17.21 (24.46)	10.95 (19.29)	17.58 (24.78)	16.65 (24.07)	15.06 (22.71)
Emamectin benzoate 5 SG @ 0.3 g/l	2.84 (9.69)	5.69 (13.79)	6.56 (14.83)	5.03 (12.77)	15.00 (22.78)	14.96 (22.75)	17.43 (24.65)	15.80 (23.39)	14.73 (22.55)	14.32 (22.21)	14.46 (22.33)	14.50 (22.36)
Buprofezin 25 SC @ 2.00 ml/l	83.33 (65.88)	25.00 (29.99)	75.00 (59.98)	61.11 (51.95)	72.11 (58.13)	95.43 (77.63)	92.43 (74.11)	86.66 (69.96)	55.59 (48.19)	64.17 (53.21)	54.94 (47.82)	58.23 (49.74)
Bifenthrin 10 EC @ 1 ml/l	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	0.00 (0.52)	100.00 (89.48)	50.00 (44.98)	100.00 (89.48)	83.33 (74.97)	100.00 (89.48)	100.00 (89.48)	90.28 (71.88)	96.76 (83.94)
Profenophos 50 EC @ 2ml/l	100.00 (89.48)	50.00 (44.98)	50.00 (44.98)	66.67 (59.98)	73.52 (59.01)	87.96 (69.68)	86.53 (68.44)	82.67 (65.71)	49.69 (44.81)	56.48 (48.71)	51.75 (45.99)	52.64 (46.50)
Diafenthiuron 50 WP @ 1.2 g/l	56.83 (48.92)	65.28 (53.91)	61.67 (51.76)	61.26 (51.53)	71.47 (57.69)	81.13 (64.23)	80.49 (63.78)	77.70 (61.90)	40.10 (39.27)	43.66 (41.34)	39.55 (38.95)	41.10 (39.85)
Dimethoate 30 EC @ 1.7 ml/l	29.17 (32.64)	25.00 (29.99)	34.72 (36.08)	29.63 (32.90)	86.67 (68.57)	90.21 (71.82)	88.80 (70.43)	88.56 (70.28)	48.33 (44.03)	62.64 (52.31)	56.34 (48.63)	55.77 (48.32)
Dichlorvos 76 EC @ 0.5 ml/l	100.00 (89.48)	0.00 (0.52)	100.00 (89.48)	66.67 (59.98)	90.67 (72.31)	43.45 (41.22)	89.72 (71.33)	74.62 (61.62)	68.64 (55.92)	58.89 (50.12)	64.10 (53.17)	63.88 (53.07)
Adjuvant alone	0.00 (0.52)	0.00 (0.52)	18.10 (25.16)	6.03 (8.39)	0.00 (0.52)	0.00 (0.52)	31.60 (34.18)	10.53 (11.39)	0.00 (0.52)	0.00 (0.52)	27.12 (31.35)	9.04 (10.45)
Mean	52.03 (46.91)	21.88 (22.40)	47.60 (44.25)	40.50 (37.85)	59.19 (51.62)	54.52 (47.31)	65.63 (57.19)	59.78 (52.04)	48.28 (43.78)	53.13 (47.70)	51.44 (46.02)	50.95 (45.83)
Comparing the means of	S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)		S.Em.±		C.D. (0.01)	
A	0.37		1.38		0.37		1.37		0.47		1.75	
B	0.17		0.64		0.17		0.64		0.22		0.81	
A X B	0.64		2.38		0.64		2.38		0.81		3.03	

FORS - Fish oil rosin soap

Figures in parentheses are Arcsine transformations

Second instar mealybugs

The insecticides dimethoate 30 EC @ 1.7 ml/l (88.56%), buprofezin 25 SC @ 2.00 ml/l (86.66%), imidacloprid 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l recorded 83.33 per cent mortality each (Table 61). The per cent mortality registered in the treatments of acetamiprid 20 SP @ 0.3 g/l (19.75%), chlorfenapyr 10 SC @ 1 ml/l (17.21%) and emamectin benzoate 5 SG @ 0.3 g/l (15.80%) was least. Among the adjuvants, the FORS @ 5 ml/l recorded significantly higher mortality (65.63 %) followed by APSA-80 @ 1 ml/l (59.19%). The lower mortality was recorded in the adjuvant Dhanuvit @ 1 ml/l (54.52%) (Table 61).

The combination of imidacloprid 17.8 SL @ 0.3 ml/l and bifenthrin 10 EC @ 1 ml/l with APSA-80 @ 1 ml/l and FORS @ 5 ml/l resulted significantly cent per cent mortality. The next better combinations were buprofezin 25 SC @ 2.00 ml/l with Dhanuvit @ 1 ml/l (95.43%) and FORS @ 5 ml/l (92.43%) and dichlorvos 76 EC @ 0.5 ml/l + APSA-80 (90.67%) and dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l (90.21%). However, all the combination of adjuvants with insecticides were significantly effective on mealybugs (Table 61).

Third instar mealybugs

Among the insecticidal treatments, bifenthrin 10 EC @ 1 ml/l showed significantly superior mortality of third instar mealybugs 96.76 per cent. However, the next best treatment was imidacloprid 70 WG @ 0.3 g/l with mortality of 93.37 per cent as compared to rest of the treatments (Table 61). The adjuvant Dhanuvit @ 1 ml/l recorded highest mortality of third instar mealybug with 53.13 per cent as compared to FORS @ 5 ml/l (51.44%) and APSA-80 @ 1 ml/l (48.28%) (Table 61).

Cent per cent mortality was observed in the treatment combinations of imidacloprid 70 WG @ 0.3 g/l and bifenthrin 10 EC @ 1 ml/l with Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 1 ml/l along with APSA-80 @ 1 ml/l. However, lower mortality was observed in the combinations of all the adjuvants with acetamiprid 20 SP @ 0.3 g/l, chlorfenapyr 10 SC 1 ml/l and emamectin benzoate 5 SG @ 0.3 g/l (Table 61).

4.4 Evaluation of promising treatments for the management of grapevine mealybug under field condition

4.4.1 Efficacy of various insecticidal treatments against grapevine mealybug, *Maconellicoccus hirsutus* on vines

The data on efficacy of various treatments against grapevine mealybug, *M. hirsutus* on vines recorded in terms of number of colonies per vine at one day before spray and two, five and ten days after first spray and two, five, ten and fifteen days after second spray are furnished in Table 62.

4.4.1.1 One day before spray

The pre-count recorded at one day before spray indicated non-significant differences among various treatments and population ranged from 32.67 to 36.33 colonies per vine.

4.4.1.2 Two days after first spray

There was significant reduction in mealybug population over a pre-count in all the treatments except water spray. Among the treatments, non-significant difference was recorded. However, lowest number of mealybug colonies were recorded in treatment imidacloprid 70 WG @ 0.3 g/l with Dhanuvit @ 1 ml/l (26.00 colonies/vine).

4.4.1.3 Five days after first spray

At five days after treatment bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l recorded significantly lower number of mealybugs colonies (17.00 colonies/vine) which was on par with imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l (18.00). Whereas remaining treatments were significantly effective in causing reduction of the mealybug colonies as compared to water spray (39.00 colonies/vine).

4.4.1.4 Ten days after first spray

Least number of colonies per vine (14.00) were observed in imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l, which was on par with bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (18.00). However, rest of treatments were effective in reducing number of colonies per vine except water spray (41.33).

Table 62. Effect of insecticidal treatments on grapevine mealybug, *Maconellicoccus hirsutus* under field condition on vine

Treatments	Pre-treatment count	Post treatment counts (Number of colonies / vine)						
		First Spray			Second Spray			
	1 DBS	2 DAS	5 DAS	10 DAS	2 DAS	5 DAS	10 DAS	15 DAS
T ₁ -Thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @1 ml/l	33.67 (5.84)	30.00 (5.51)	26.67 (5.21)	22.00 (4.73)	18.00 (4.28)	13.00 (3.67)	10.33 (3.28)	8.33 (2.97)
T ₂ - Thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @1 ml/l	34.67 (5.93)	31.67 (5.66)	27.33 (5.27)	22.33 (4.73)	18.00 (4.29)	13.00 (3.66)	9.67 (3.17)	8.00 (2.90)
T ₃ - Imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @1 ml/l	33.67 (5.84)	26.00 (5.14)	18.00 (4.30)	14.00 (3.79)	10.00 (3.23)	5.67 (2.45)	3.00 (1.86)	2.00 (1.56)
T ₄ - Imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @1 ml/l	36.00 (6.04)	32.00 (5.69)	26.00 (5.15)	18.67 (4.38)	16.33 (4.08)	10.33 (3.29)	4.67 (2.24)	3.67 (2.00)
T ₅ - Buprofezin 25 EC @ 2.00 ml/l + Dhanuvit @1 ml/l	35.33 (5.98)	30.33 (5.55)	25.67 (5.11)	22.00 (4.78)	18.67 (4.37)	16.00 (4.06)	10.67 (3.34)	8.00 (2.91)
T ₆ - Bifenthrin 10 EC @ 1 ml/l + Dhanuvit @1 ml/l	35.33 (5.98)	29.67 (5.51)	17.00 (3.86)	18.00 (4.29)	15.33 (3.97)	11.33 (3.44)	5.33 (2.39)	3.33 (1.90)
T ₇ - Profenophos 50 EC @ 2 ml/l + Dhanuvit @1 ml/l	36.33 (6.06)	32.00 (5.69)	29.00 (5.43)	26.00 (5.14)	22.67 (4.80)	17.67 (4.25)	13.00 (3.67)	9.00 (3.08)
T ₈ - Dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @1 ml/l	32.67 (5.76)	29.67 (5.48)	24.67 (5.20)	21.33 (4.66)	17.67 (4.26)	13.00 (3.67)	8.67 (3.02)	6.00 (2.54)
T ₉ - Dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @1 ml/l	33.67 (5.84)	29.00 (5.42)	24.67 (5.20)	20.33 (4.55)	17.00 (4.18)	13.00 (3.67)	8.67 (3.02)	7.00 (2.73)
T ₁₀ - Water spray	33.00 (5.79)	35.00 (5.96)	39.00 (6.28)	41.33 (6.47)	43.33 (6.62)	44.00 (6.67)	46.00 (6.82)	48.00 (6.96)
S.Em.±	0.1	0.23	0.37	0.19	0.19	0.15	0.16	0.18
C.D. (0.05)	NS	0.68	1.09	0.57	0.57	0.44	0.47	0.52
C.V. (%)	2.87	7.10	12.56	7.01	7.49	6.66	8.43	10.33

NS- Non-significant; Figures in parenthesis are $\sqrt{X+0.5}$ transformed

Table 63. Effect of insecticide treatments on grapevine mealybug, *Maconellicoccus hirsutus* on bunches under field condition

Treatments	Pre-treatment count	Post treatment counts (Number of colonies / bunch)						
		First Spray			Second Spray			
	1 DBS	2 DAS	5 DAS	10 DAS	2 DAS	5 DAS	10 DAS	15 DAS
T ₁ -Thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @1 ml/l	11.33 (3.44)	10.33 (3.26)	8.33 (2.96)	8.67 (2.20)	5.67 (2.48)	4.50 (2.11)	2.00 (1.56)	2.33 (1.68)
T ₂ - Thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @1 ml/l	13.33 (3.72)	12.33 (3.58)	10.33 (3.29)	9.33 (3.13)	8.00 (2.91)	5.83 (2.54)	4.33 (2.20)	3.67 (2.04)
T ₃ - Imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @1 ml/l	13.67 (3.76)	12.00 (3.53)	9.67 (3.19)	7.50 (2.97)	7.00 (2.73)	4.00 (2.20)	2.67 (1.77)	1.33 (1.29)
T ₄ - Imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @1 ml/l	14.33 (3.84)	13.00 (3.67)	10.00 (3.23)	7.83 (3.02)	7.67 (2.86)	4.33 (2.41)	3.33 (1.95)	1.67 (1.46)
T ₅ - Buprofezin 25 EC @ 2.00 ml/l + Dhanuvit @1 ml/l	13.00 (3.66)	12.33 (3.57)	9.33 (3.12)	7.33 (2.79)	6.33 (2.61)	4.50 (2.11)	3.33 (1.95)	2.33 (1.68)
T ₆ - Bifenthrin 10 EC @ 1 ml/l + Dhanuvit @1 ml/l	15.33 (3.97)	14.33 (3.85)	10.50 (3.34)	8.33 (2.97)	7.33 (2.80)	4.17 (2.27)	2.67 (1.74)	2.00 (1.56)
T ₇ - Profenophos 50 EC @ 2 ml/l + Dhanuvit @1 ml/l	14.33 (3.85)	13.33 (3.72)	10.33 (3.29)	8.00 (2.91)	7.33 (2.80)	5.33 (2.40)	3.67 (2.03)	3.00 (1.86)
T ₈ - Dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @1 ml/l	12.67 (3.62)	11.67 (3.48)	9.00 (3.07)	8.33 (2.96)	7.67 (2.85)	5.67 (2.47)	4.33 (2.18)	3.33 (1.95)
T ₉ - Dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @1 ml/l	13.33 (3.72)	12.67 (3.62)	10.33 (3.29)	9.33 (3.13)	8.33 (2.97)	5.33 (2.41)	3.33 (1.95)	2.67 (1.77)
T ₁₀ - Water spray	12.33 (3.72)	12.33 (3.57)	13.67 (3.76)	14.33 (3.85)	15.00 (3.93)	15.67 (4.02)	16.67 (4.14)	17.67 (4.26)
S.Em.±	0.16	0.13	0.12	0.11	0.10	0.12	0.15	0.15
C.D. (0.05)	NS	0.37	0.36	0.33	0.30	0.36	0.44	0.44
C.V. (%)	7.28	6.04	6.44	6.37	6.03	8.43	11.85	13.09

NS- Non-significant; Figures in parenthesis are $\sqrt{X+0.5}$ transformed

4.4.1.5 Two days after second spray

The reduction in number of colonies per vine due to various treatments at two days after second spray was statistically significant. The treatment imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l proved superior over all the treatments at two days after second spray which recorded minimum number of colonies per vine (10.00) followed by bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (15.33). Whereas remaining treatments were on par with each other. However, maximum number of colonies per vine were observed in water spray (45.33).

4.4.1.6 Five days after second spray

The reduction in number of colonies per vine due to various treatments at five days after second spray showed statistical difference among them. Least number of colonies per vine were observed in imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l (5.67) followed by imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (10.33) and bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (11.33) which were on par with each other. Other four treatments viz., thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @ 1 ml/l, thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l, dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l and dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l were on par with each other (13.00 colonies per vine).

4.4.1.7 Ten days after second spray

The data regarding number of mealybug colonies per vine at ten days after second spray was statistically significant. The treatment of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l recorded significantly least number of colonies per vine (3.00) followed by imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l which were on par with each other. The next better treatments were thiamethoxam 25 WG @ 3.0 g/l + Dhanuvit @ 1 ml/l, dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l and dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l which recorded 9.67, 8.67, 8.67 colonies per vine, respectively and were on par with each other. The remaining treatment viz., thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @ 1 ml/l (10.35) and buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l (10.67) were on par with each other. Maximum number of colonies per vines were observed in water spray (46.00). (Table 62)

4.4.1.8 Fifteen days after second spray

There was a decrease in mealybug population and the treatment imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l recorded lowest number of colonies per vine (2.00, 3.33 and 3.67, respectively) at fifteen days after second spray (Table 62). The next better treatments were thiacloprid 240 SC @ 0.2 ml/l + Dhanuvit @ 1 ml/l (8.33), thiamethoxam 25 WG@ 0.3 g/l g/l + Dhanuvit @ 1 ml/l (8.00), buprofezin 25 SC 2.00 ml/l + Dhanuvit @ 1 ml/l and dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l (7.00) and were on par with each other.

4.4.2 Effect of various treatments on grape vine mealybug, *Maconellicoccus hirsutus* on bunches

The data on efficacy of various treatments against grape vine mealybug, *M. hirsutus* recorded in terms of number of colonies per bunch at one day before spray, two, five and ten days after first spray and two, five, ten and fifteen days after second spray are furnished in Table 63.

4.4.2.1 One day before spray

The pre-count indicated non-significant differences among the treatments and the population ranged from 11.33 to 14.33 colonies per bunch.

4.4.2.2 Two days after first spray

There was a significant reduction in mealybug population over pre count in all the treatments. Among all the treatments thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @ 1 ml/l recorded lowest number of colonies per bunch (10.33) and highest in treatment dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l (14.33). Remaining all the treatments were statistically on par with each other.

4.4.2.3 Five days after first spray

Thiacloprid 240 SC @ 0.2 ml/l + Dhanuvit @ 1 ml/l recorded lowest population of mealybug colonies per bunch (8.33) followed by dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l, buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l and imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l

recording 9.0, 9.33 and 9.67 colonies per bunch at five days after first spray which were on par with rest of the treatments except water spray (13.67).

4.4.2.4 Ten days after first spray

The reduction in number of colonies per bunch observed at ten days after first spray reflected significant differences among the various treatments, wherein imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l, buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l both recorded least number of colonies per bunch (7.50 and 7.33, respectively). The next better treatments were imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l, profenophos 50 EC @ 2 ml/l, bifenthrin 10 EC @ 1 ml/l and dimethoate @ 1.7 ml/l (7.83, 8.0, 8.33 and 8.33 colonies/bunch) followed by thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l (9.33), dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l (9.33).

4.4.2.5 Two days after second spray

The treatment thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @ 1 ml/l recorded least number of colonies per bunch (5.67) and highest in neem oil 2% + Dhanuvit @ 1 ml/l (10.00) and the next better treatment was buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l (6.33). The treatments of imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l (7.00), imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (7.67), bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (7.33), profenophos 50 EC @ 2 ml/l + Dhanuvit @ 1 ml/l (7.33) and dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l (7.67) were on par with each other.

4.4.2.6 Five days after second spray

The number of colonies per bunch were significantly less in various treatments as compared to water spray (15.67) at five days after second spray. The effective treatments which caused higher reduction in number of colonies per bunch were imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l (4.00) and bifenthrin 10 EC @ 2 ml/l + Dhanuvit @ 1 ml/l (4.17) which were on par with each other. These were followed by imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (4.33) and buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l (4.50), thiacloprid 240 SC @ 0.2 ml/l + Dhanuvit @ 1 ml/l (4.50) which were also on par with each other. Remaining treatments were significantly superior over water spray which recorded highest colonies per bunch (15.67).

4.4.2.7 Ten days after second spray

The data regarding number of mealybug colonies per bunch at ten days after second spray indicated that all the treatments were statistically superior to water spray (16.67). Least number of colonies per bunch were observed in the treatment of thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @ 1 ml/l (2.00). The next best treatments in which highest number of reduction in number of colonies per bunch included imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l, bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (2.67, each), followed by imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l and buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l, dichlorvos 76 EC @ 0.7 ml/l + Dhanuvit @ 1 ml/l.

4.4.2.8 Fifteen days after Second spray

The number of colonies per bunch were significantly less in various treatments as compared to water spray (17.67). The best treatment which caused higher reduction in number of colonies per bunch included imidacloprid 70 WG @ 0.3g/l + Dhanuvit @ 1 ml/l (1.33). The next best treatment was imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (1.67). The treatments bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (2.00), thiacloprid 240 SC @ 0.2 ml/l + Dhanuvit @ 1 ml/l (2.33) and buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l (2.33) were on par with each other. Remaining treatments were superior over water spray.

4.4.3 Efficacy of insecticidal treatments against grape mealybug, *Maconellicoccus hirsutus* on vines, bunches and fruit yield

The data on efficacy of insecticidal treatments against grapevine mealybug on vines and bunches as per cent protection over untreated check are presented in Table 64.

The treatments of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l recorded highest protection over untreated check on vines by recording 95.70, 92.20 and 92.90 per cent, respectively.

Table 64. Efficacy of insecticidal treatments against grapevine mealybug, *Maconellicoccus hirsutus* on vines and bunches and fruit yield

Treatments	% Protection over untreated check on		% Decrease (-) or increase (+) over pre-count on		Fruit Yield (t/ha)	Incremental B:C ratio
	Vines	Bunches	Vines	Bunches		
T ₁ -Thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @1 ml/l	82.68 (65.40)	86.77 (68.73)	-75.2	-79.41	30.46	1 : 45.56
T ₂ - Thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @1 ml/l	83.20 (65.90)	79.00 (62.80)	-76.9	-72.50	32.78	1 : 36.17
T ₃ - Imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @1 ml/l	95.74 (78.37)	92.13 (76.58)	-94.1	-90.24	37.92	1 : 44.73
T ₄ - Imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @1 ml/l	92.17 (74.20)	90.47 (72.21)	-89.8	-88.37	36.21	1 : 70.76
T ₅ - Buprofezin 25 EC @ 2.00 ml/l + Dhanuvit @ 1 ml/l	83.33 (65.90)	86.87 (68.78)	-77.4	-82.05	33.97	1 : 29.63
T ₆ - Bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l	92.91 (75.23)	88.29 (70.51)	-90.6	-86.96	37.21	1 : 105.51
T ₇ - Profenophos 50 EC @ 2 ml/l + Dhanuvit @ 1 ml/l	81.11 (64.27)	83.26 (65.94)	-75.2	-79.07	31.92	1 : 37.95
T ₈ - Dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l	87.38 (69.25)	81.08 (64.24)	-81.6	-73.68	31.17	1 : 21.02
T ₉ - Dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l	85.34 (67.51)	84.69 (67.08)	-79.2	-80.00	33.64	1 : 52.37
T ₁₀ - Water spray	-	-	+45.5	+43.24	24.78	-
S.Em.±	1.53	1.75	-	-	1.35	-
C.D. (0.05)	4.60	5.25	-	-	4.02	-
C.V. (%)	4.24	4.94	-	-	7.10	-

Figures in parentheses are Arcsine transformations

Table 65. Effect of insecticide treatments on grapevine mealybug, *Maconellicoccus hirsutus* under field condition on vine

Treatments	Pre-treatment count	Post treatment counts (Number of colonies / vine)						
		First Spray			Second Spray			
	1 DBS	2 DAS	5 DAS	10 DAS	2 DAS	5 DAS	10 DAS	15 DAS
T ₁ - Neem oil @ 2% + Dhanuvit @1 ml/l	36.33 (6.07)	33.67 (5.84)	30.67 (5.58)	26.67 (5.20)	23.33 (4.88)	20.00 (4.52)	16.33 (4.10)	13.67 (3.76)
T ₂ - Neem seed kernel extract @ 5% + Dhanuvit @ 1 ml/l	35.33 (5.98)	32.33 (5.69)	30.00 (5.52)	27.33 (5.26)	24.00 (4.94)	18.67 (4.38)	14.67 (3.89)	12.00 (3.53)
T ₃ - Neem oil @ 2% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/ l	34.00 (5.87)	32.33 (5.72)	28.33 (5.37)	24.33 (4.98)	22.00 (4.73)	17.67 (4.26)	14.00 (3.80)	12.00 (3.53)
T ₄ - Neem oil @ 2% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/ l	34.33 (5.90)	32.00 (5.70)	29.67 (5.49)	27.00 (5.23)	25.33 (5.08)	22.00 (4.74)	18.00 (4.28)	14.67 (3.89)
T ₅ - Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/ l	34.33 (5.90)	31.67 (5.66)	28.67 (5.40)	25.33 (5.07)	22.33 (4.76)	18.67 (4.36)	16.00 (4.06)	15.00 (3.92)
T ₆ - Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/ l	34.33 (5.90)	31.67 (5.66)	28.33 (5.37)	25.00 (5.04)	22.00 (4.73)	19.00 (4.41)	16.67 (4.14)	14.67 (3.89)
T ₇ - Water spray	33.00 (5.79)	35.00 (5.96)	39.00 (6.28)	41.33 (6.47)	43.33 (6.62)	44.00 (6.67)	46.00 (6.82)	48.00 (6.96)
S.Em.±	0.09	0.21	0.20	0.18	0.22	0.18	0.14	0.15
C.D. (0.05)	NS	0.64	0.60	0.56	0.67	0.55	0.44	0.47
C.V. (%)	2.55	6.28	6.14	5.93	7.37	6.45	5.59	6.30

NS- Non-significant; Figures in parenthesis are $\sqrt{X+0.5}$ transformed

These treatments showed similar degree of superiority with respect to protection on bunches, by recording 76.60, 72.20 and 70.50 per cent protection against mealybugs on bunches, respectively (Table 64). All other insecticidal treatments were found to be next better treatments with respect to protection on vines and bunches.

The data pertaining to fruit yield presented in Table 64 reveals that, the yield ranged between 24.78 to 37.92 t/ha. The highest fruit yield was obtained from the treatment of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l (37.92 t/ha), followed by bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (37.21 t/ha), imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (36.21 t/ha) and buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l (33.97) and were on par with each other. The next better treatments were dichlorvos 76 WC @ 0.5 ml/l + Dhanuvit @ 1 ml/l, thiamethoxam 25 WG @ 0.3g/l + Dhanuvit @ 1 ml/l, profenophos 50 EC @ 2 ml/l + Dhanuvit @ 1 ml/l, dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l, thiacloprid 240 WC @ 0.2 g/l + Dhanuvit @ 1 ml/l, which recorded the fruit yield of 33.64, 32.78, 31.72, 31.17 and 30.46 t/ha, respectively. The treatments in combination with botanicals, entomopathogens and adjuvant resulted lower fruit yield ranging from 27.78 to 29.82 t/ha.

Among the different insecticidal treatments, application of bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l (1:105.51), imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (1:70.76) and dichlorvos 76 WC @ 0.5 ml/l + Dhanuvit @ 1 ml/l (1:52.37) recorded highest incremental cost benefit ratio as compared to other insecticidal treatments.

4.4.4 Efficacy of various biorational treatments against grapevine mealybug on vines

4.4.4.1 One day before spray

The pre-count recorded at one day before spray indicated non-significant differences among the treatments and the population ranged from 33.00 to 36.33 colonies per vine (Table 65).

4.4.4.2 Two days after first spray

Reduction in mealybug population was observed over a pre count in all the treatments, except water spray. Whereas, among the biorational treatments non-significant difference was recorded over reduction in number of mealybug colonies at two days after first spray. However, maximum number of colonies of mealybugs were recorded in water spray (35.00).

4.4.4.3 Five days after first spray

Among the biorationals, non-significant reduction in number of mealybug colonies per vine was recorded at five days after first spray. However, lowest number of colonies were observed in treatments of neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l by recording 28.33 colonies per vine, each.

4.4.4.4 Ten days after first spray

Non-significant difference was observed in the reduction of mealybugs colonies per vine among the biorationals at ten days after first spray. However, lowest number of colonies were observed in treatments of neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l by recording 24.33 and 25.00 colonies/vine, respectively, whereas water spray recorded maximum number of colonies per vine (41.33).

4.4.4.5 Two days after second spray

Non-significant difference was observed in the reduction of mealybugs colonies per vine among the biorationals at two days after second spray. However, lowest number of colonies were observed in treatments of neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l by recording 22.00 colonies/vine, each, whereas water spray recorded maximum colonies per vine (43.33).

4.4.4.6 Five days after second spray

Among the biorationals, non-significant reduction was recorded in number of mealybug colonies on vines except neem oil @ 2% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l (22.00) and water spray (44.00) at five days after second spray. However, lowest number of colonies were observed in treatments of neem oil @ 2% + *L. lecanii* @ 2 g/l, NSKE @ 5% + Dhanuvit @ 1ml/l and NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l by recording 17.67, 18.67 and 18.67 colonies/vine, respectively.

Table 66. Effect of biorational treatments on grapevine mealybug, *Maconellicoccus hirsutus* on bunches under field condition

Treatments	Pre-treatment count	Post treatment counts (Number of colonies / bunch)						
		First Spray			Second Spray			
	1 DBS	2 DAS	5 DAS	10 DAS	2 DAS	5 DAS	10 DAS	15 DAS
T ₁ - Neem oil @ 2% + Dhanuvit @ 1 ml/l	13.33 (3.72)	12.67 (3.62)	11.33 (3.44)	11.00 (3.39)	10.00 (3.24)	8.67 (3.03)	7.33 (2.77)	6.33 (2.61)
T ₂ - Neem seed kernel extract @ 5% + Dhanuvit @ 1 ml/l	12.67 (3.62)	12.00 (3.53)	10.33 (3.29)	9.00 (3.07)	8.33 (2.96)	6.67 (2.66)	5.00 (2.34)	4.33 (2.20)
T ₃ - Neem oil @ 2% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/ l	13.67 (3.76)	13.33 (3.72)	10.67 (3.34)	9.67 (3.18)	9.00 (3.08)	7.33 (2.80)	5.33 (2.41)	4.67 (2.27)
T ₄ - Neem oil @ 2% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/ l	12.67 (3.62)	12.33 (3.57)	10.67 (3.34)	9.67 (3.18)	9.00 (3.08)	7.00 (2.73)	5.33 (2.41)	4.33 (2.19)
T ₅ - Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/ l	12.67 (3.62)	11.67 (3.48)	10.33 (3.28)	9.33 (3.13)	8.67 (3.02)	7.00 (2.73)	5.67 (2.48)	5.00 (2.34)
T ₆ - Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/ l	12.33 (3.57)	12.00 (3.53)	10.33 (3.28)	9.33 (3.13)	9.00 (3.08)	8.00 (2.91)	6.33 (2.60)	5.67 (2.48)
T ₇ - Water spray	12.33 (3.57)	12.33 (3.57)	13.67 (3.76)	14.33 (3.85)	15.00 (3.93)	15.67 (4.20)	16.67 (4.14)	17.67 (4.26)
S.Em.±	0.18	0.16	0.15	0.15	0.11	0.12	0.12	0.11
C.D. (0.05)	NS	NS	0.45	0.45	0.35	0.38	0.37	0.33
C.V. (%)	8.71	7.99	7.51	7.72	6.08	7.11	7.52	7.06

NS- Non-significant; Figures in parenthesis are $\sqrt{X+0.5}$ transformed

Table 67. Efficacy of biorational treatments against grapevine mealybug, *Maconellicoccus hirsutus* on vines and bunches and fruit yield

Treatments	% Protection over untreated check on		% Decrease (-) or increase (+) over pre-count on		Fruit Yield (t/ha)	Incremental B:C ratio
	Vines	Bunches	Vines	Bunches		
T ₁ - Neem oil @ 2% + Dhanuvit @1 ml/l	71.58 (57.77)	63.78 (53.02)	-62.4	-52.50	29.51	1 : 8.99
T ₂ - Neem seed kernel extract @ 5% + Dhanuvit @1 ml/l	74.81 (59.92)	75.39 (60.37)	-66.0	-65.79	29.82	1 : 43.44
T ₃ - Neem oil @ 2% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/ l	74.76 (59.91)	73.64 (59.09)	-64.7	-65.85	27.78	1 : 3.79
T ₄ - Neem oil @ 2% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/ l	69.50 (56.46)	75.26 (60.33)	-57.3	-65.79	29.69	1 : 6.83
T ₅ - Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>L. lecanii</i> @ 2.0 g/ l	68.84 (56.06)	71.32 (57.73)	-56.3	-60.53	28.58	1 : 13.24
T ₆ - Neem seed kernel extract @ 5% + FORS @ 5 ml/l + <i>M. anisopliae</i> @ 2.0 g/ l	69.46 (56.44)	67.62 (55.35)	-57.3	-54.05	28.60	1 : 13.34
T ₇ - Water spray	-	-	+45.5	+43.24	24.78	-
S.Em.±	1.34	1.79	-	-	0.89	-
C.D. (0.05)	4.23	5.93	-	-	2.75	-
C.V. (%)	4.70	6.27	-	-	5.45	-

Figures in parentheses are Arcsine transformations

4.4.4.7 Ten days after second spray

Non-significant difference was observed in the reduction of mealybug colonies per vine among the biorational treatments. However, lowest number of colonies were observed in treatments of neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + Dhanuvit @ 1 ml/l by recording 14.00 and 14.67 colonies/vine, respectively, whereas, water spray recorded maximum colonies per vine (46.00).

4.4.4.8 Fifteen days after second spray

Among the biorationals, non-significant difference was recorded in number of mealybug colonies on vines. However, lowest number of colonies were observed in treatments of neem oil @ 2% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l, NSKE @ 5% + Dhanuvit @ 1ml/l and neem oil @ 2% + Dhanuvit @ 1ml/l by recording 12.00, 12.00 and 13.67 colonies/vine, respectively.

4.4.5 Efficacy of various biorational treatments against grapevine mealybug on bunches

4.4.5.1 One day before spray

The pre-count recorded at one day before spray indicated non-significant differences among the treatments and the population ranged from 12.33 to 13.67 colonies per bunch (Table 66).

4.4.5.2 Two days after first spray

There was non-significant reduction in mealybug population in all the treatments. However, maximum number of colonies of mealybugs were recorded in water spray (35.00).

4.4.5.3 Five days after first spray

Among the biorationals, there was non-significant reduction in number of mealybug colonies on bunches at five days after first spray as compared to water spray (13.67). However, lowest number of colonies were observed in treatments neem seed kernel extract @ 5% + Dhanuvit @1 ml/l, NSKE @ 5% + *L. lecanii* @ 2 g/l + FORS @ 5 ml/l and NSKE @ 5% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l by recording 10.33 colonies per bunch, each.

4.4.5.4 Ten days after first spray

Non-significant difference was observed in the reduction of mealybug colonies per bunch among the biorationals. However, lowest number of colonies were observed in treatment of NSKE @ 5% + Dhanuvit @ 1 ml/l by recording 9.00 colonies per bunch, whereas water spray recorded maximum colonies per bunch (14.33).

4.4.5.5 Two days after second spray

Non-significant difference was observed in the reduction of mealybug colonies per bunch among the biorationals at two days after second spray. However, lowest number of colonies were observed in treatments of NSKE @ 5% + Dhanuvit @ 1 ml/l by recording 8.33 colonies per bunch, whereas water spray recorded maximum colonies per bunch (15.00).

4.4.5.6 Five days after second spray

Among the biorationals non-significant reduction was recorded in number of mealybug colonies on vines except water spray (15.67). However, lowest number of colonies were observed in treatments of NSKE @ 5% + Dhanuvit @ 1 ml/l by recording 6.67 colonies per bunch.

4.4.5.7 Ten days after second spray

Non-significant difference was observed in the reduction of mealybug colonies per vine among the biorational treatments except neem oil @ 2% + Dhanuvit @1 ml/l (7.33) and water spray (16.67). However, lowest number of colonies were observed in treatments of NSKE @ 5% + Dhanuvit @ 1 ml/l by recording 5.00.

4.4.5.8 Fifteen days after second spray

Among the biorationals non-significant reduction was recorded in number of mealybug colonies on vines except neem oil @ 2% + Dhanuvit @1 ml/l (6.33) and water spray (17.67). However, lowest number of colonies were observed in treatments of NSKE @ 5% + Dhanuvit @ 1 ml/l

and neem oil @ 2% + *M. anisopliae* @ 2 g/l + FORS @ 5 ml/l by recording 4.33 colonies per bunch, each.

4.4.6 Efficacy of biorational treatments against grape mealybug, *Maconellicoccus hirsutus* on vines, bunches and fruit yield

The data on efficacy of biorational treatments against grapevine mealybug on vines and bunches recorded as per cent protection over untreated check, fruit yield and B:C ratio are presented in Table 67. Non-significant differences were recorded among biorational treatments over untreated check. However, the treatments of neem seed kernel extract @ 5% + FORS @ 5 ml/l + *L. lecanii* @ 2.0 g/l, neem seed kernel extract @ 5% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/l and neem oil @ 2% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/l recorded 68.84, 69.46 and 69.50 per cent protection, respectively against mealybugs. The treatments of neem seed kernel extract @ 5% + Dhanuvit @ 1 ml/l, neem oil @ 2% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/l and neem oil @ 2% + FORS @ 5 ml/l + *L. lecanii* @ 2.0 g/l showed similar degree of superiority over per cent protection on bunches, by recording 75.39, 75.26 and 73.64 per cent protection on bunches, respectively against mealybugs (Table 67).

The data pertaining to fruit yield presented in Table 67 reveals that, the yield ranged between 24.78 to 29.82 t/ha. The highest fruit yield was obtained from the treatment neem seed kernel extract @ 5% + Dhanuvit @ 1 ml/l (29.82 t/ha) followed by neem oil @ 2% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/l (29.69 t/ha) and neem oil @ 2% + Dhanuvit @ 1 ml/l (29.51 t/ha) and were on par with each other. The next better treatments were neem seed kernel extract @ 5% + FORS @ 5 ml/l + *L. lecanii* @ 2.0 g/l and neem seed kernel extract @ 5% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/l which recorded the fruit yield of 28.58 and 28.60 t/ha, respectively. Among the biorational treatments, application of NSKE @ 5% + Dhanuvit @ 1 ml/l recorded highest incremental cost benefit ratio (1:43.44) as compared to other biorational treatments. The next better treatments having higher incremental cost benefit ratio were neem seed kernel extract @ 5% + FORS @ 5 ml/l + *L. lecanii* @ 2.0 g/l and neem seed kernel extract @ 5% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/l (1:13.24 and 1:13.34, respectively).

DISCUSSION

The results of the studies carried out on the seasonal incidence, feeding potential of *Cryptolaemus montrouzieri* and management of grapevine mealybug, *Maconellicoccus hirsutus* are discussed in the light of published literature and presented in this chapter

5.1 Biology and predatory potential of coccinellid, *Cryptolaemus montrouzieri* on grapevine mealybug, *Maconellicoccus hirsutus*

5.1.1 Pre-mating, pre-oviposition, oviposition, adult longevity and fecundity incubation period and hatching percentage of *C. montrouzieri* eggs

In present investigations, the pre-mating period ranged from 4 to 9 days with an average of six days. This finding is in agreement with the findings of Bhat *et al.* (1981) and Shekhar (2001) who reported it as 6.2 and 6 days, respectively. Whereas Rao and David (1958) reported the pre-mating period of 8 to 11 days, which is slightly higher than present study. The variation though not much, may be due to differences in the experimental conditions and climatic conditions.

The pre-oviposition period of *C. montrouzieri* was 6 to 11 days with an average of 8.70 days. The present study is comparable with the findings of Gokudaskumar and Vijalaxmi (1986) and Shekhar (2001) who reported the pre-oviposition period of 6 to 7.80 and 4 to 10 days, respectively. However, it was shorter than that reported by Rao and David (1958) as 9 to 13 days at temperature of 24 to 29.5°C. In contrast, it was greater than what observed by Mineo (1967) *i.e.* 3 to 4 days at 25°C and Anon. (2006a) observed around 5 days for beginning for egg laying. The perusal of the study of Babu and Azam (1987a) revealed that the ambient temperature have influence on pre-oviposition period. They reported that pre-oviposition period extended (9.6 days) when the predator, *C. montrouzieri* was maintained at constant temperature of 20°C. Whereas, pre-oviposition period of *C. montrouzieri* was 3.6 days at 30°C as compared with the maintenance at ambient temperature (2.4 days). Thus, the slight variations in the findings of present investigations regarding pre-oviposition period as compared to earlier reports may be due to variations in temperature while conducting the experiment.

Oviposition period ranged between 58 to 89 days with an average of 73.80 days. The present study is in agreement with the findings of Rao and David (1958) and Shekhar (2001) who reported 75 and 69.5 days, respectively. It was also observed that the female predator preferred wax filaments of mealybugs for egg laying. The same was stated by Merlin *et al.* (1996) that female delay oviposition and withheld mature eggs in absence of wax filament produced by the prey.

The longevity of adult male and female was 65 to 91 and 72 to 91 days with an average of 78 and 88.50 days, respectively. The results of present study showed more or less similarity with the observations made by Rao and David (1958), Bhat *et al.* (1981) and Shekhar (2001) who recorded it as 52.2, 76.7 and 70.3 days for male and 80.2, 77.8 and 77.2 days for females of *C. montrouzieri*, respectively.

The egg laying capacity of female beetle was recorded in the range of 472 to 652 with an average of 550.30 eggs when fed with all the stages of mealybugs. The results of present investigation is quite deviating from the earlier report of Rao and David (1958) and Mani (1986) who reported it as 207 and 210.5 eggs, respectively. However, Fisher (1963), Shekhar (2001) and Anon. (2006a) recorded fecundity of female, *C. montrouzieri* in the range of 194 to 729, 370 to 682 and 400-500 eggs, respectively. Whereas Anil and Jeevan (2008) reported that, the female of *C. montrouzieri* laid on an average 476.2 eggs in her life time.

The incubation period ranged between 3.6 to 7.9 days with an average of 5.75 days. The present finding is in close agreement with the study conducted by Shekhar (2001) who reported the incubation period between 4.6 to 7.55 days. Bishop (1931) and Anil and Jeevan (2008) reported the incubation period of *C. montrouzieri* as 8-10 and 3-7 days, respectively. Babu and Azam (1987b) concluded that higher temperature shortened and lower temperature increased the incubation period of eggs. However, the present study is slightly deviating from the findings of Hall (1926); Rao and David (1958); Mani (1986) and Anon. (2006a) who reported incubation period in the range of 3 to 4, 2 to 4, 4 to 5 and 5 to 6 days, respectively.

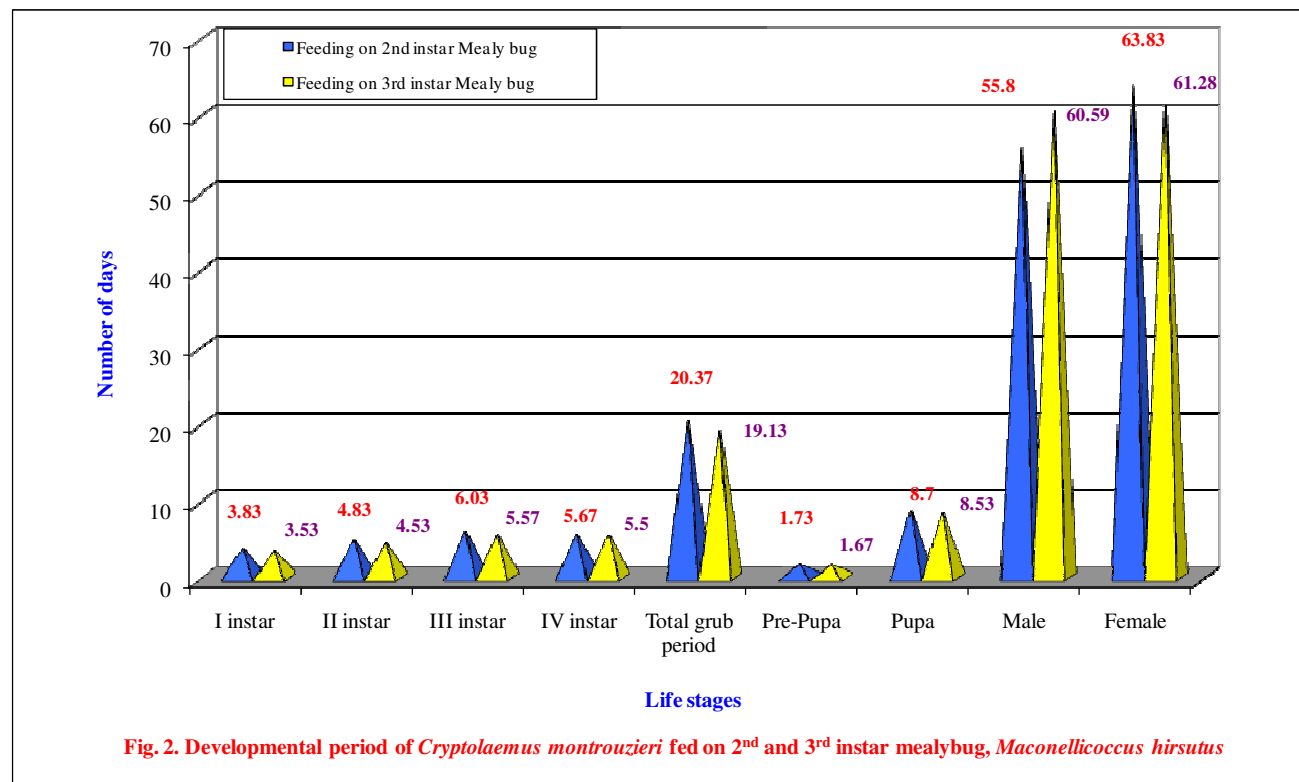


Fig 2. Developmental period of *Cryptolaemus montrouzieri* fed on second and third instar mealy bug, *Maconellicoccus hirsutus*

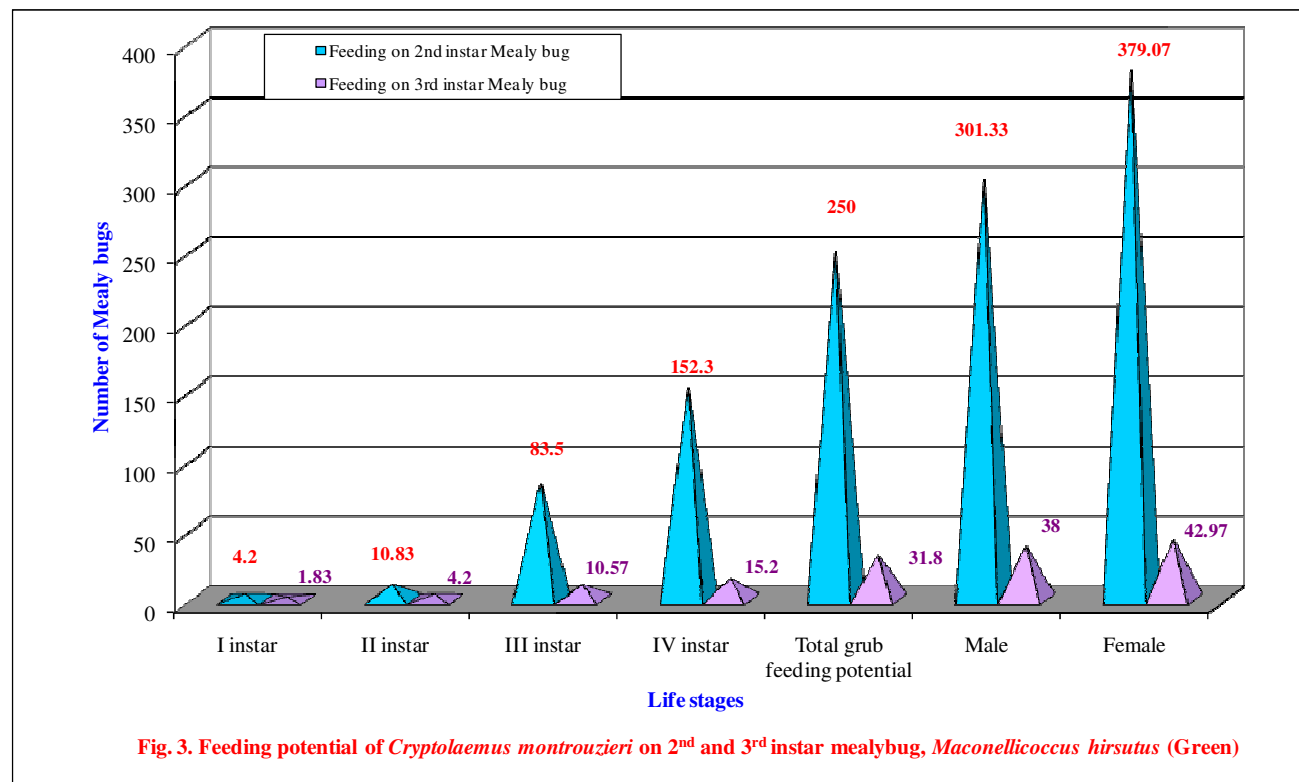


Fig 3. Feeding potential of *Cryptolaemus montrouzieri* on second and third instar mealy bug, *Maconellicoccus hirsutus*

Hatching percentage of eggs (95%) was noted in the present study is in close agreement with the findings of Mineo (1967), Bhat *et al.* (1981) and Shekhar (2001) who documented it as 93, 97 and 100 per cent, respectively.

5.1.2 Developmental period of *Cryptolaemus montrouzieri*

Results on the developmental period of grubs and adults on different stages of *M. hirsutus* indicated that the grub period extended when reared on second instar mealybugs when compared to third instar mealybugs. This difference in the developmental period of grubs and adults reared on different stages of the mealybugs may be due to the quality and quantity of the prey offered to the predator. The predatory grub took 3.83 and 3.53, 4.83 and 4.53, 6.03 and 5.57 and 5.67 and 5.50 days with an average of 3.68, 4.68, 5.80 and 5.58 days to complete its first, second, third and fourth instar, respectively, when supplemented with second and third instar mealybugs (Fig. 2). This is in agreement with Mani (1986) who reported 3.50, 2.20, 4.10 and 4.95 days on nymphs and 3.05, 2.25, 3.86 and 4.30 days on adult mealybug to complete its first, second, third and fourth instar by *C. montrouzieri*, respectively.

The total developmental period of grubs was 20.37 and 19.13 days with an average of 19.75 days when supplemented by second and third instar mealybug preys, respectively. The present study is supported by the findings of Shekhar (2001), Van Der Goot (1920) and Bhat *et al.* (1981) who reported the duration of grub development was 21.5, 20 and 19.5 days, respectively. However, the present investigation differs from the observations of Liotta and Mineo (1965), Mani (1986) and Murthy and Narayana (1986) who recorded it as 14 to 17, 13 to 16 and 31.6 days, respectively. The difference in the grub developmental period reported by several workers may be due to difference in quantity and quality of prey and different ecological factors prevalent during the study period.

The predator grubs feeding on second and third instar mealybug recorded pre-pupal duration of 1.73 and 1.67 days with a mean of 1.70 days. This finding is in close agreement with the study conducted by Murthy and Narayana (1986) and Shekhar (2001) who reported it as 1 to 2 days. Whereas, the pre-pupal period recorded in the present study is slightly deviating from the findings of Mani (1986), Anil and Jeevan (2008) and Hanchinal (2010) who recorded it as 2 to 3 days.

The fully matured grubs undergo pupation preferring mostly the dark and shady places. Pupa was dark brown in colour covered with white waxy filament. The pupal period was recorded for 8.70 and 8.53 days with an average of 8.62 days when fed on second and third instar mealybugs, respectively. The results of present study corroborate with the findings of Rao and David (1958), Liotta and Mineo (1965), Mani (1986), Shekhar (2001), Anon (2006b), Anil and Jeevan (2008) and Hanchinal (2010) who reported that the pupal period lasted for 7 to 8, 6 to 13, 7 to 9, 7 to 11, 6 to 10 and 8 to 9 days, respectively.

The duration of male beetle when reared on second and third instar mealybugs was 55.80 and 60.59 days with an average of 58.18 days, respectively. Similarly, the longevity of female beetle was 63.83 and 61.28 days with mean of 62.48 days. The results of present investigations showed more or less similarity with the observations recorded by Rao and David (1958), Mani (1986) and Hanchinal (2010) who reported average duration of male and female beetle as 52.2, 55.90 and 56.45 and 80.2, 61.40 and 62.56 days, respectively. But, the findings of Shekhar (2001) and Anil and Jeevan (2008) reported contradictory results of 70.3, 69.7 and 77.2, 74.7 days for male and female beetle, respectively. In present investigation, the variations recorded in the duration of male and female beetle when fed with second and third instar mealybugs, may be due to quantity and quality and stage of the prey.

5.1.3 Feeding potential of *Cryptolaemus montrouzieri*

The studies were made on the feeding potential of different larval instars as well as male and female beetles of *C. montrouzieri* under laboratory conditions. For these investigations, second and third instar mealybug were supplied separately as prey to the both the predatory stages.

In the present investigation, the increasing trend of consumption of second and third instar mealybugs with successive instars of grubs was noticed. The consumption of mealybug 4.20 and 1.83, 10.83 and 4.20, 83.50 and 10.57 and 152.30 and 15.20 were recorded by first, second, third and fourth instar predatory grubs when reared on second and third instar mealybug with an average of 3.02, 7.52, 47.03 and 83.75, respectively (Fig. 3). The predatory grub consumed an average of 250 and 31.80 second and third instars mealybugs, respectively. Similar study was made on *M. hirsutus* by Bhat *et al.* (1981) who reported that the average number of mealybugs consumed by first, second,

third and fourth instar grubs was one mealybug in three days, one in two days, one per day and three mealybugs in two days, respectively. Present findings are also in line with Mani (1986), Hanchinal (2010) who observed that average number of adult grape mealybugs consumed by 1st, 2nd, 3rd and 4th instar grubs of *C. montrouzieri* were 1.65, 3.35, 7.90 and 14.65 and 1.25, 4.35, 8.20 and 16.45 mealybugs, respectively.

The consumption rate of second and third instar mealybugs by male beetle, *C. montrouzieri* was 301 and 38.00 mealybugs, respectively. Whereas the female consumed 379.07 and 42.97 mealybugs of second and third instars, respectively.

The present investigation is having more or less in agreements with the findings of Shekhar (2001) who reported that the male consumed 317.16 and 28.70 mealybugs and female consumed 453.00 and 29.96 nymphs and adults of mealybug, respectively. Further, Jayaraman *et al.* (1988) reported that female and male beetle consumed 618 and 482.20 nymphs of *M. hirsutus*, respectively. Whereas, Murthy and Narayana (1986a) noticed higher consumption rate of female beetles than the males. However, the variation to certain extent may be due to rearing conditions, quality and quantity of the prey and stages of the mealybug provided.

5.2 Seasonal incidence of grapevine mealybug and its natural enemies and development of prediction model

5.2.1 Seasonal incidence of grapevine mealybugs and its natural enemies

In the present investigations, the seasonal incidence of mealybug over two seasons indicated that the mealybugs were noticed throughout the year. The population of mealybug (egg masses and colonies) was observed with two peaks during 36th and 26th MSW at Bijapur and Bagalkot area, respectively. It may be due to good vegetative and fruiting stage of the crop. However, the drastic reduction of the population of both egg masses and colonies was observed during 44th and 14th MSW due to the effect of September and April pruning at both the locations. The population of predators were observed from 28th to 48th and 28th to 50th MSW and again from 14th to 26th and 10th to 26th MSW with peak of 3.8 and 3.1 colonies/vine during 24th and 34th MSW in Bijapur and Bagalkot area, respectively. The population of parasitoids was observed throughout the season on mealybugs. The population of parasitoids was observed increasing from 28th standard week and reached peak at 34th and 36th MSW in Bijapur and Bagalkot areas, respectively. From there onwards, the population of parasitoids started decreasing upto 16th MSW and again it started increasing in both the locations.

Azam (1983) also found that the active period of *M. hirsutus* was during June-August and October-March on grapes around Hyderabad. According to Manjunath (1985) the mealybugs were present throughout the year with peak during February-March and to a lesser extent during October-November. As per the reports of Babu and Azam (1987a), the pest was found infesting vegetative parts of the crop from early June to the end of December in Hyderabad. During first fortnight of September to second fortnight of October, the female adult population decreased largely due to pruning operation. The mealybug again become active during January and increased as the grape cluster developed and was abundant by March when the fruits were at ripening stage. Similarly, Mani (1989) also reported that, the population of the mealybug, *M. hirsutus* was found to be heavy from January to May and low from June to December in the vineyards in South India and in general, the activity of the natural enemies coincided with that of the mealybugs. In grapevine gardens situated at Arvi Pimpalgaon of Pune district (Maharashtra) the mealybug population was maximum from middle of February to May and middle of September to middle of November (Anon., 1992). According to Murthy and Babu (1996), the highest population was found on grapes during the first half of July (Vegetative phase) and during the second half of March (reproductive phase) in Andhra Pradesh. Balikai (1999a) reported that, the mealybug was recorded throughout the year at Tikota village of Bijapur district in Karnataka. About two months after pruning in October, the mealybug population started to increase from January and reached peak during February-March before harvesting. After harvesting, the mealybug population remained low from May to December. Rawat and Modi (1969) also reported that, mealybug was observed to be most active and numerous in numbers during August-November, 1965 and March-April, 1966. Mainly adult females were found during December, 1965 as well as January, May and June, 1966 in Madhya Pradesh. Koli (2003) was of the opinion that, grape mealybug was active during September to March in Rahuri (Maharashtra). Katke *et al.* (2009) observed the occurrence of mealybugs throughout the year with two peaks during 10th and 36th MSW recording 32.4 and 14.5 colonies/vine, respectively. During the study period due to April and

September pruning effect the colonies of mealybugs were reduced to lower during 22nd and 44th MSW (7.4 and 5.0 colonies/vine, respectively).

According to Misra (1919), matured female of *M. hirsutus* moved down and established themselves in leaf scars, under the bark and notches on the stem. There they remained quiescent until the winter was over. Eggs hatched after the winter and the crawlers moved and established on mulberry and cotton plants producing characteristic malformation. The predatory population was high during July to October. Das *et al.* (1948) observed heavy build-up of the *F. virgata* during July-August on jute while on garden land fruit crops during winter and early spring in Dacca. Ghose (1972) was of the opinion that *M. hirsutus* was active during winter also, without hibernation but was most active during March-October on roselle around West Bengal. In India, Singh and Ghosh (1970) studied the seasonal activity of *M. hirsutus* on mesta and reported that, the peak infestation was usually noted from the first week of September to the last week of October. The results of the present investigations are more or less in agreement with the above reports.

5.2.2 Correlation of mealybug population with weather parameters and prediction model for Bijapur area during fruiting season

The mealybug population correlated positively and significantly with maximum temperature and bright sunshine hours during the week of observation, one, two and three weeks lead time. Whereas negative and significant correlation existed between morning and afternoon relative humidity during the week of observation, one, two and three weeks lead time. Rainfall correlated negatively during all the lead time but showed significant during two and three weeks lead time. However, no correlation existed between the incidence of mealybug and minimum temperature during all the lead weeks but negatively and non-significantly correlated at two and three weeks lead time of observation.

The relative humidity was the main controlling variable for mealybug incidence on grape vines. Even though the R^2 at three weeks lead time was small, afternoon relative humidity was the only variable that could be considered to estimate mealybug incidence three weeks later. At two and one week lead time morning relative humidity was important to predict mealybug incidence. The reliability of estimation of mealybug incidence in the current week and lead weeks was completely depended on relative humidities.

The forecasting model on grape vine mealybug was developed for the first time in Karnataka keeping weather parameters as independent factors. Hence, the published literature is scanty on forecasting model of mealybugs. The mealybug population prediction model for current lead week ($LW_0 = 43.69 - 0.53X_4$), lead week one ($LW_1 = 68.03 - 0.6X_3$) and lead week two ($LW_2 = 76.53 - 1.15X_2 - 0.46X_3$) were developed, where X_2 = Minimum temperature, X_3 = morning relative humidity, RH_1 , X_4 = afternoon relative humidity. Because of high influence of afternoon relative humidity on the population development, this parameter was used in the development of the forecasting model for LW_1 , which showed less error in the forecasting model than the LW_2 . Hence, it inferred that the above weather parameters existing during current week could be substituted in this model and how much population of mealybug would come after one or two week can be predicted. This forecasting model information would be very useful for the grape growing farmers, who could estimate the mealybug population one week early and can take preventive measures for the management of mealybug population. It was also noticed that the pest incidence increased considerably in the same period (MSW 52-12). Therefore, the models developed at LW_1 can give best results when there is peak incidence of mealybug. Further, as the model can provide forecast of incidence one week before actual incidence, it has practical utility for the management of the mealybugs on grapevine.

Mani (1986) observed positive and significant correlation of the grape mealybug population with maximum temperature and negative correlation with the relative humidity. Shreedharan *et al.* (1989) reported that the population of mealybug, *P. citri* in Mandarin orange correlated positively with the temperature and negatively with relative humidity, while it showed no clear correlation with total rainfall. Koli (2003) reported that, the egg sacs, nymphs and adults of mealybugs on grapes showed highly significant positive correlation with maximum and minimum temperature and highly significant negative correlation with morning and evening relative humidity and non-significant negative correlation with rainfall. Katke *et al.* (2009) observed that, the mealybug incidence correlated positively and significantly with maximum temperature at one week lead time and during the week of observation. Whereas, it correlated negatively and significantly with minimum temperature at one, two, three and four weeks lead time. Similarly it also correlated negatively and significantly with morning and afternoon relative humidities that existed during the week of observation, one, two, three and four weeks lead time. Mealybug incidence correlated positively and significantly with bright

sunshine hours during the week of observation, one, two, three and four weeks lead time. Mealybug incidence correlated negatively and significantly with the rainfall received during the week of observation, one, two, three and four weeks lead time. As per the entomological reports from Rahuri, significant and positive correlation with maximum temperature, minimum temperature and significant negative correlation with morning relative humidity was observed in pomegranate mealybugs (Anon., 1995). The results of the present study are almost in line with the above workers when correlations were worked out for mealybug during its peak incidence period (38th to 52nd MSW). The correlations of weather parameters that existed during fruiting season influenced much on the mealybug population, particularly maximum temperature, minimum temperature and morning relative humidity.

5.2.3 Parasitoids of mealybug, *Maconellicoccus hirsutus*

Totally twelve parasitoids were recorded belonging to the order hymenoptera, family-Aphelinidae, Encyrtidae, Eulophidae, Braconidae and Pteromalidae. Among these parasitoids, *A. bambawalei*, *Oomyzus* sp., *Centiste* sp. and *M. concinnus* were recorded for the first time on *M. hirsutus* in Karnataka.

The results of present investigations are in conformity with Ghose (1971) and Manjunath (1985) who reported that *Anagyrus* sp. causing 19 to 47 per cent parasitization on *M. hirsutus* in West Bengal and *A. dactylopii* was found parasitizing *M. hirsutus* on grapes to an extent of 70 per cent in Bangalore, respectively. Similarly another parasitoid, *P. unfasciiventris* (Chalcidoidea: Aphelinidae) on mealybug was reported from Andhra Pradesh, Bihar, Delhi, Karnataka and Maharashtra by Sinha *et al.* (1985), Hayat (1986), Sureshan and Narendran (2005) and Tanwar *et al.*, (2008). Mani (1986) reported six species of parasitoids on *M. hirsutus*, among them *A. dactylopii* recorded maximum parasitisation as compared to others. Similar studies were made by Mani and Krishnamoorthy (1997), who found that *Coccidoxenoides peregrinus* and *Leptomastix dactylopii* are potential parasitoids of *Planococcus citri* on sapota. However, they do not appear to regulate *P. citri* throughout the year and are active only during specified months. The difference in the parasitism may be attributed to the differences in the hosts observed and change of location. Hanchinal (2010) found that the parasitoids *A. bambawalei*, *P. unfasciiventris*, *H. eytelweinii*, *P. pulchellus* and *A. dactylopii* parasitizing on cotton mealybug, *P. solenopsis*. Among them the activity of *A. bambawalei* was dominant as compared to other parasitoids at all the places surveyed in cotton growing area (Pinjarkar *et al.*, 2009; Saini *et al.*, 2009).

5.2.4 Predators of mealybug, *Maconellicoccus hirsutus*

Seven predators were recorded on grape vine mealybug, *M. hirsutus* belonging to four families from Coleopteran (Coccinellidae), two families from Diptera (Chamaemyiidae and Drosophilidae) and one family from Lepidoptera (Lycaenidae). Among these predators, *Leucopis* sp. was recorded for the first time on *M. hirsutus*.

Similar observations were made in the past (Misra 1919; Hall 1921; Dutt *et al.*, 1951; Rao, 1967; Manjunath, 1985) and reported that several species of *Scymnus* were found as active predators of *M. hirsutus* on grape vines. Twenty-nine species of predators belonging to five insect orders have been reported on *M. hirsutus* in India by Ranga Reddy and Lakshminarayana (1986). Activity of *C. montrouzieri* on *M. hirsutus* in Karnataka was reported by Mani (1986). Among the predators, *S. coccivora*, *C. montrouzieri*, *Chrysopa* sp. and *S. epius* were recorded with maximum activity on citrus mealybug (Malleshaiah *et al.*, 2000; Dinesh and Venkatesha, 2011; Dinesh *et al.*, 2010; Thangamalar *et al.*, 2010). Hanchinal (2010) recorded activity of three predators *viz.*, coccinellids, *Chrysoperla* and spiders feeding on cotton mealybug, *P. solenopsis* during survey made for two seasons in north Karnataka.

5.3 Evaluation of biorationals and newer chemical insecticide along with different adjuvants against grapevine mealybug under laboratory condition

5.3.1 Effect of botanicals in combination with soap on different instars of *Maconellicoccus hirsutus*

The botanical NSKE @ 5% recorded significantly highest per cent mortality of first, second and third instar mealybugs with 57.59, 39.43 and 43.98 per cent, respectively followed by neem oil @ 2% at five days after treatment. The *Pongamia* based botanicals were found next best effective

treatments but CASKE @ 5% recorded least mortality on all the stages of mealybugs. Among the adjuvants, the Dhanuvit @ 1 ml/l and FORS @ 5 ml/l recorded significantly higher mortality of first, second and third instar mealybugs, respectively as compared to APSA-80 @ 1 ml/l. Similarly, the neem based botanicals recorded higher per cent mortality in combination with all the adjuvants. Among these NSKE @ 5% + Dhanuvit @ 1 ml/l resulted significantly higher per cent mortality followed by neem oil @ 2% with adjuvant solution Dhanuvit @ 1 ml/l as compared to all other combinations with different adjuvant solutions on first, second and third instar mealybugs at five days after treatment.

The literature on the use of adjuvant and their combination with botanicals on mortality of mealybug is totally lacking. In the present study, the mortality in treatment NSKE and neem oil alone or in combination with adjuvant solution was significant compared to remaining treatments, which may be due to presence of *Azadirachtin* content, which is having insecticidal property and is absent with other botanicals and the next best botanicals was *Pongamia* based, which contain the pongamin. Also addition of adjuvant with botanicals increased the mortality rate of mealybug, due to surfactant property of the adjuvant, which help in the dissolving of the waxy mealy matter of the test insect and increase the penetration of botanical faster to show their insecticidal property on mealybug. But among the adjuvant solution FORS, though having insecticidal property showed next better adjuvant after Dhanuvit causing mortality of mealybugs. This may be due to their faster waxy mealy matter dissolving capacity present on mealybugs. However, the difference in the mortality of mealybug's instars may be due to the thickness of waxy layer on the body of mealybugs. The thickness of waxy layer differs from instars to instar; early instars have lesser thickness as compared to older instars. Hence, mortality is higher in early instars compared to older instars. The mortality at twelve hours after treatment was less on the mealybugs; it could be due to because of slower action of the botanicals. However, the botanicals having multidisciplinary action on the insects viz., act as antifeedant, growth regulator etc., but their effect will be exhibited slowly rather than rapid insecticidal property of the botanicals.

The present investigation is in conformity with finding of Verghese (1997) who reported 5 and 2.5 per cent NSKE @ 5% were highly effective on mortality of early instar nymphs after 24 and 48 hours after treatment on *M. hirsutus* under laboratory condition and commercial product econeem (*Azadirachtin*) 9 ppm was effective on late first instar mealybugs after 24 and 48 hours of treatment. Similarly, Balikai (1999b) observed lowest population of mealybugs (2.78/vine at 30 days after treatment) on grapes when the pest colony was sprayed with NSKE @ 5%. Srinivas *et al.* (2007) found appreciable and comparable mortality of nymphs and adults of *M. hirsutus* with dichlorvos. But, Koli (2003) reported that, NSKE (4%) and nimbecidine (0.5%) were found comparatively less effective as compared to conventional and bioinsecticides. Whereas, both 1 and 4% neem kerosene emulsions were effective against *C. viridis* causing 80 to 90 per cent mortality in 13-19 days (Kumar *et al.*, 1989). In the field study, neem (*A. indica*) and karanja oil (*Pongamia pinnata* (L.)) both at 4 per cent were recommended for the control of *P. citri* on guava. They caused 93.2 and 89.39 per cent mortality of the insect, respectively at 10 days after second spray (Hussain *et al.*, 1996). While, Katke (2008) recorded more than 50 per cent protection with treatments of NSKE @ 5% + soap powder @ 1% and neem oil @ 2% + soap powder @ 1% against *M. hirsutus* over untreated check on grape vines and bunches. Whereas, Maduri (2012) recorded NSKE (78.67%) was most effective followed by *Pongamia* (56.00%) and Mahua (46.67%).

5.3.2 Evaluation of different botanicals in combination with entomopathogenic fungus and fish oil rosin soap (FORS) against grapevine mealybug, *Maconellicoccus hirsutus*

The literature on compatibility study of botanicals and entomopathogens along with or without adjuvant solution on mealybug's mortality is very scanty. In present study, the combination of botanicals and entomopathogens (*L. lecanii* and *M. anisopliae*) with or without adjuvant FORS did not show higher and significant mortality differences on all the stages of mealybugs. But combination of botanicals, entomopathogens and FORS registered for higher mortality of mealybugs as compared to combinations without adjuvant, it may be due to the action of botanical and adjuvant solution. Whereas in the absence of adjuvant the combinations of botanicals and entomopathogens recorded lower mortality, it could be due to the detrimental effect of botanicals on entomopathogens which instead of giving higher mortality might have lowered per cent mortality. The entomopathogen, *L. lecanii* showed higher per cent mortality on all the stages of mealybugs, it may be due to production of mycotoxins viz., Helvolic acid, bassianolide, Cytochalasin C, D, destruxins (Russell and Paterson,

2006) and faster mycelial growth help to penetrate into the body of host which cause septicemia to the mealybug and caused death of the mealybug as compared to other entomopathogen, *M. anisopliae*. Among the botanicals, the combination of neem based botanicals and entomopathogens along with adjuvant solution gave higher mortality of the mealybugs over other botanical combinations. But, all the combinations of treatments with FORS gave higher mortality as compared to absence of adjuvant solution FORS, it could be due to enhancement of botanical penetration into insect body by dissolving the waxy filament layer. The next best treatment was *Pongamia* based botanical along with FORS. The *L. lecanii* with FORS gave higher per cent mortality over remaining treatments. However, *M. anisopliae* + FORS was next best treatment over other combinations. Similarly, among the botanicals, the neem based botanicals resulted significantly higher per cent mortality followed by *Pongamia* based botanicals. Based on the index of per cent mortality, the order of the effectiveness on mealybug, *M. hirsutus* could be arranged as NSKE > neem oil > PSKE > *Pongamia* oil > CASKE.

The present study is more or less in agreement with the findings of Shelke (2001) who observed that, fish oil rosin soap (0.5%) with *L. lecanii* (0.4%) was the safest and most suitable treatment against grapevine mealybug, *M. hirsutus*. The fungus, *L. lecanii* caused 80.20 per cent mortality of some sucking pests at 2×10^5 cfu/ml dose in Maharashtra state within two weeks (Jayachakravarthy, 2002). According to Koli (2003) *L. lecanii* WP @ 0.3% was effective against nymphs and adults of grape mealybug. Similarly, Gonzalez *et al.* (1995) observed that, the *L. lecanii* conidia as well as filtrates gave very good mortality (84.8 and 100%) against *P. citri* on 10th day. Eswaramoorthy and Javaraj (1987) reported that the *L. lecanii* was highly effective for the control of *C. viridis* under field condition in Tamil Nadu, India with fortnightly application of 1.6×10^6 spores per ml. Gulsarbanu *et al.* (2009) reported that *L. lecanii* (Zimm.) Zare & Gams was highly pathogenic under laboratory condition at 1×10^4 conidia per ml. Whereas, Ujjan and Shahzad (2007) showed that three different strains of the pathogenic fungus *M. anisopliae* var. *acridum* infected adults of *M. hirsutus* within two days, but 90 and 100 per cent mortality of adults and nymphs was achieved within 8th and 4th days, respectively. The infectious development of entomopathogenic fungus limited by different levels of humidity and temperature (Glare & Milner, 2001; Ujjan & Shahzad, 2007). Among the entomopathogenic fungus tested the *L. lecanii* ranked first followed by *M. anisopliae* in management of mealybug, *M. hirsutus* under field condition (Katke, 2008).

The results of present investigation on the effect of botanicals on mealybugs in this study are in agreement with the findings of Verghese (1997) who reported 5 and 2.5 per cent neem seed kernel extracts as highly effective in causing mortality of early instar nymphs after 24 and 48 hours after treatment on *M. hirsutus* under laboratory condition but also observed that the commercial product econeem (*Azadirachtin*) 9 ppm was effective on late first instar mealybugs after 24 and 48 hours of treatment. Similarly, Balikai (1999b) observed lowest population of mealybugs (2.78 /vine at 30 DAT) on grapes when the pet colony was sprayed with NSKE @ 5%. Srinivas *et al.* (2007) found appreciable and comparable mortality of nymphs and adults of *M. hirsutus* with dichlorvos. But, Koli (2003) reported that, NSKE (4%) and nimbecidine (0.5%) were found comparatively less effective as compared to conventional and bioinsecticides. Whereas, both 1 and 4% neem kerosene emulsion were effective against *C. viridis* causing 80 to 90 per cent mortality in 13-19 days (Kumar *et al.*, 1989). In field study, neem (*A. indica*) and karanja oil (*Pongamia pinnata* (L.)) both at 4 per cent were recommended for the control of *P. citri* on guava. They caused 93.2 and 89.39 per cent mortality of the insect, respectively at 10 days after second spray (Hussain *et al.*, 1996). While, Katke (2008) recorded more than 50 per cent protection with treatments of NSKE @ 5% + soap powder @ 1% and neem oil @ 2% + soap powder @ 1% against *M. hirsutus* over untreated check on grape vines and bunches.

5.3.3 Evaluation of newer chemical insecticides against grapevine mealybug, *Maconellicoccus hirsutus* along with different adjuvants

The literature on the combination of adjuvant solution with insecticide is scanty and meager. In present study, the insecticides imidacloprid 70 WG, imidacloprid 17.8 SL and bifenthrin 10 EC recorded highest per cent mortality on all the stages of mealybugs as compared to other insecticide molecules and they can kill the early instars even within three days after treatment. However, all the newer molecules registered higher per cent mortality on all the stages of mealybugs as compared to other insecticides. It could be due to smaller molecular size, fast penetration, spreading and target specific characteristic of newer molecules. Whereas in case of dichlorvos 76 EC the mortality per cent was next best to former insecticides, which may be due to presence of fumigation action of the insecticide. However, these insecticides performed better in combination with adjuvant Dhanuvit@ 1 ml/l due to its character of fast dissolving of waxy filament layer and making easy penetration of

insecticides which will influence the toxicant to act on the mealybug faster and cause the death of mealybug as compared to other adjuvant solution. Based on index of per cent mortality of insecticides, they could be ranked as follows- imidacloprid 70 WG> bifenthrin 10 EC > imidacloprid 17.8 SL > dichlorvos 76 EC > buprofezin 25 SC> profenophos 50 EC > thiacloprid 240 SC > thiamethoxam 25 WG > dimethoate 30 EC > diafenthiuron 50 WP. Whereas the insecticides acetamiprid 20 SP, chlorfenapyr 10 SC and emamectin benzoate 5 SG recorded lowest mortality on all the stages of mealybugs which may be due to ineffectiveness of these molecules on the mealybugs.

The present study on effectiveness of insecticides on different instars of mealybugs is in line with Gonazalez and Volosky (2006). Patel *et al.* (2010) reported that more than 95 per cent reduction in mealybug population over control after three days of spray in buprofezin was noticed at all the three doses (250, 312.5 and 625 g a.i. /ha) tested. Shafqat *et al.* (2007) obtained effective control cotton mealybug *Phenacoccus gossypiphilous* (Stanley) with bifenthrin, profenophos and chlorpyrifos under laboratory. Narsimha Rao *et al.* (1977) and Mani (1990) inferred that dichlorvos with combination of fish oil rosin soap gave 80 per cent mortality of mealybugs. According to Ranga Reddy and Lakshmi Narayana (1986), the efficacy of the treatments was increased when fish oil rosin soap was added. According to earlier workers, dimethoate was effective against mealybugs on citrus (Atwal, 1976), against *P. pacificus* on custard apple (Shukla and Tandon, 1984), against *P. citri* on grapes (Su and Wang, 1988), against *M. hirsutus* on grape (Shreedhar Rao *et al.*, 1988), against *D. mangiferae* on mango (Singh *et al.*, 1991) and against *F. virgata* on guava (Baskaran *et al.*, 1999). According to Katke (2008) the Dimethoate 30 EC at 1.7 ml + fish oil rosin soap at 5g/l and dimethoate 30 EC at 1.7 ml/l were effective against grape mealybug. The effectiveness of profenophos 50 EC in the present study is in conformity with Agarwal *et al.* (2009) who reported that the profenophos 50 EC (check) recorded 93.73 per cent mortality over control and was at par with spirotetramat (12%) + imidacloprid (36%) 480 SC (85.09% mortality) and thiodicarb 75 WP @750 g a.i. /ha (84.48% mortality) after three days of second spray. Superiority of profenophos 50 EC is also in line with Suresh *et al.* (2010) who reported that profenophos and methyl parathion caused cent per cent mortality of *P. solenopsis* at one day after treatment while imidacloprid, fish oil rosin soap and dimethoate caused cent per cent mortality after two days of the treatment imposition. The results of present investigations are more or less in line with the above reports.

5.4 Evaluation of promising treatments for the management of grapevine mealybug under field condition

5.4.1 Efficacy of insecticides against mealybug management under field conditions

The results indicated that the treatments of synthetic insecticides along with Dhanuvit @ 1 ml /l recorded highest protection against mealybugs. The imidacloprid 70 WG @ 0.3 gm /l + Dhanuvit @ 1 ml/l afforded highest protection (95.75%) against mealybug on vine over water spray followed by bifenthrin 10 EC @ 2 ml /l and imidacloprid 17.8 SL @ 0.3 ml /l with Dhanuvit @ 1 ml/l provided protection of 92.9 and 92.2 per cent, respectively against mealybugs on vines and were significantly superior over rest of the treatments (Fig. 4). The next best treatment was dimethoate 30 EC @ 1.7 ml /l + Dhanuvit @ 1 ml/l (87.4%) which in turn was on par with dichlorvos 76 EC + Dhanuvit @ 1 ml/l, buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l and thiamethoxam 25 WG @ 0.3gm /l + Dhanuvit @ 1 ml/l. Imidacloprid 70 WG @ 0.3 gm /l + Dhanuvit @ 1 ml/l afforded highest protection (92.1%) against mealybugs on bunches over water sprays and it was on par with imidacloprid 17.8 SL @ 0.3 ml /l + Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 2 ml/l + Dhanuvit @ 1 ml/l with 90.5 and 88.3 per cent mortality, respectively (Fig. 5). The next best treatment given protection against mealybug were buprofezin 25 SC @ 2.00 ml/l, thiacloprid 240 SC @ 0.2 gm/l, dichlorvos 76 EC @ 0.7 ml/l and profenophos 50 EC @ 2 ml/l along with Dhanuvit @ 1 ml/l.

The highest fruit yield 37.92 t/ha was obtained from the treatment imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l followed by bifenthrin 10 EC @ 2 ml/l + Dhanuvit @ 1 ml/l which in turn was on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (36.21 t/ha). The next best treatments in this respect were buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l, dichlorvos 76 EC @ 0.5 ml/l and thiamethoxam 25 WG @ 0.3 g/l along with Dhanuvit @ 1 ml/l. The remaining treatments were better in providing protection against mealybugs and gave higher yield as compared to water pray (Fig. 6). Among the different insecticidal treatments, application of bifenthrin 10 EC @ 1 ml/l + Dhanuvit @1 ml/l (1:105.51), imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @1 ml/l (1:70.76) and dichlorvos 76 WC @ 0.5 ml/l + Dhanuvit @ 1 ml/l (1:52.37) recorded highest incremental cost benefit ratio as compared to other insecticidal treatments.

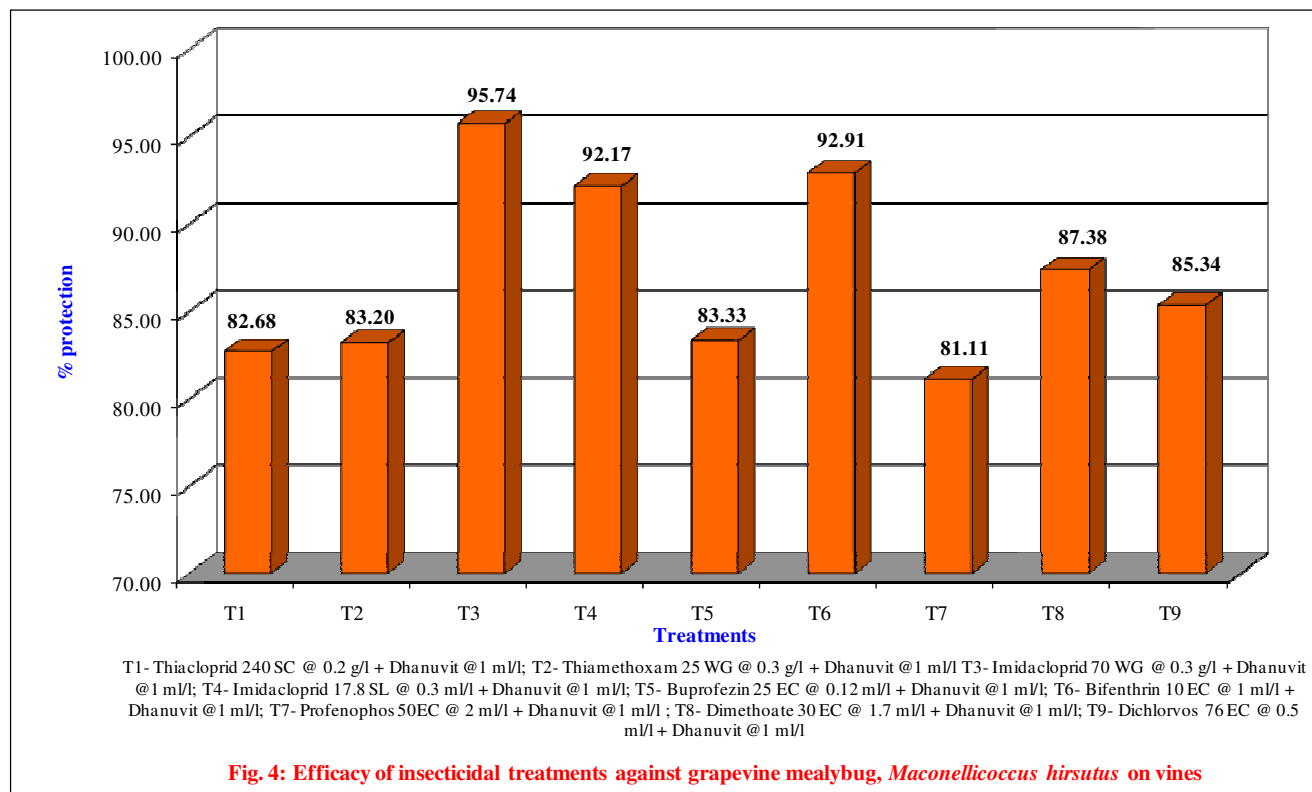


Fig 4. Efficacy of insecticide treatments against grapevine mealybug, *Maconellicoccus hirsutus* on vines

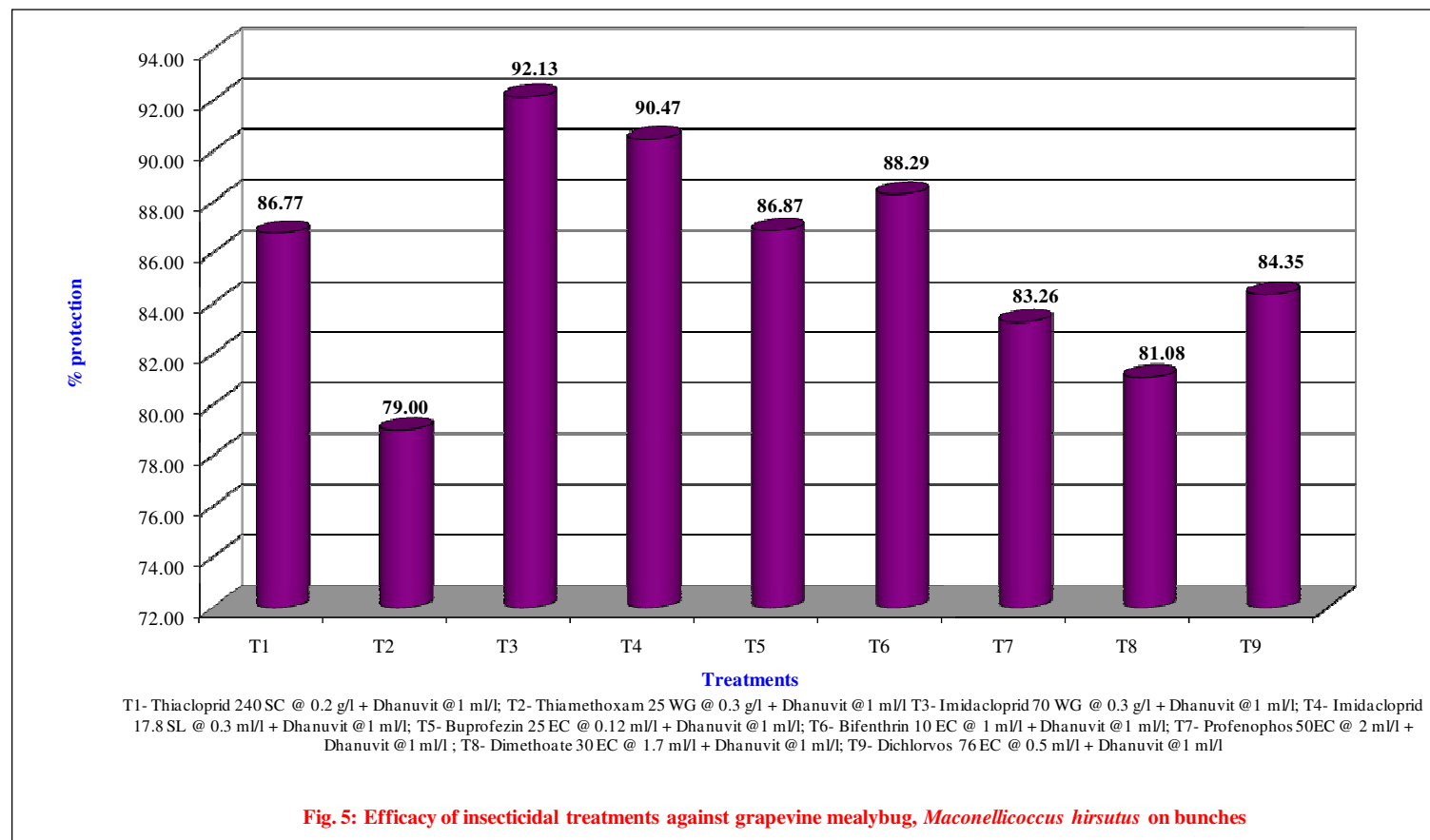


Fig 5. Efficacy of insecticide treatments against grapevine mealybug, *Maconellicoccus hirsutus* on bunches

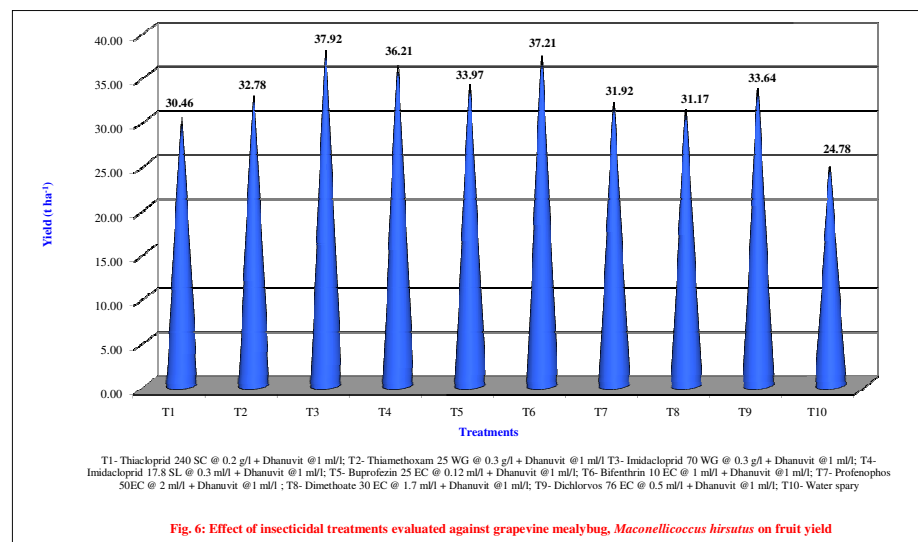


Fig 6. Effect of insecticidal treatments evaluated against grapevine mealybug, *Maconellicoccus hirsutus* on fruit yield

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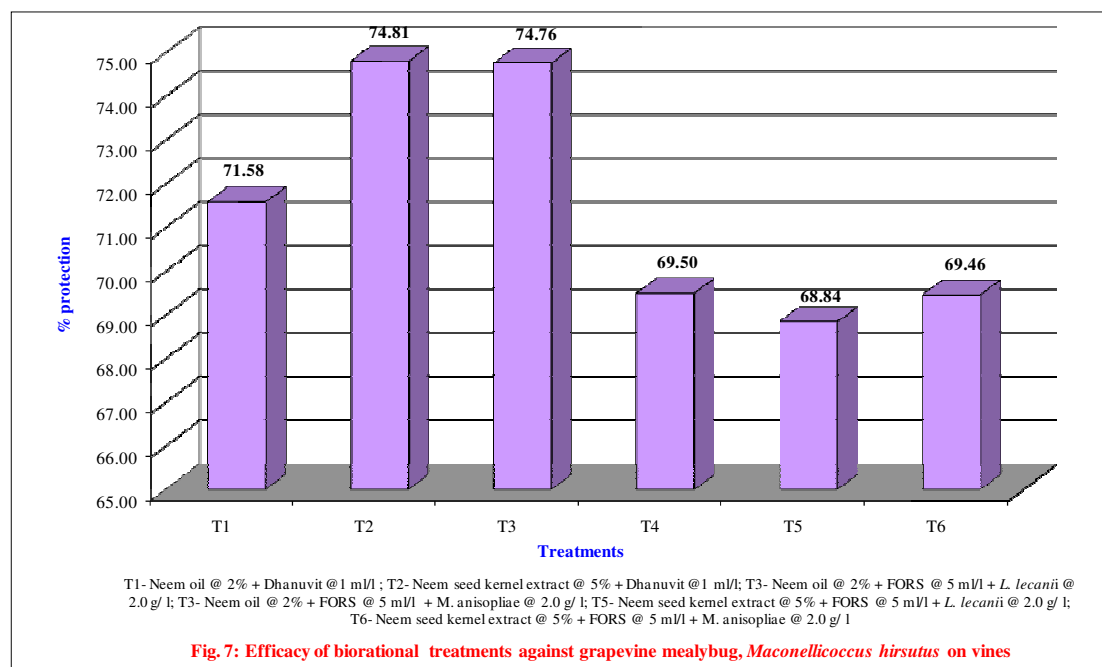


Fig 7. Efficacy of biorational treatments against grapevine mealybug, *Maconellicoccus hirsutus* on vines

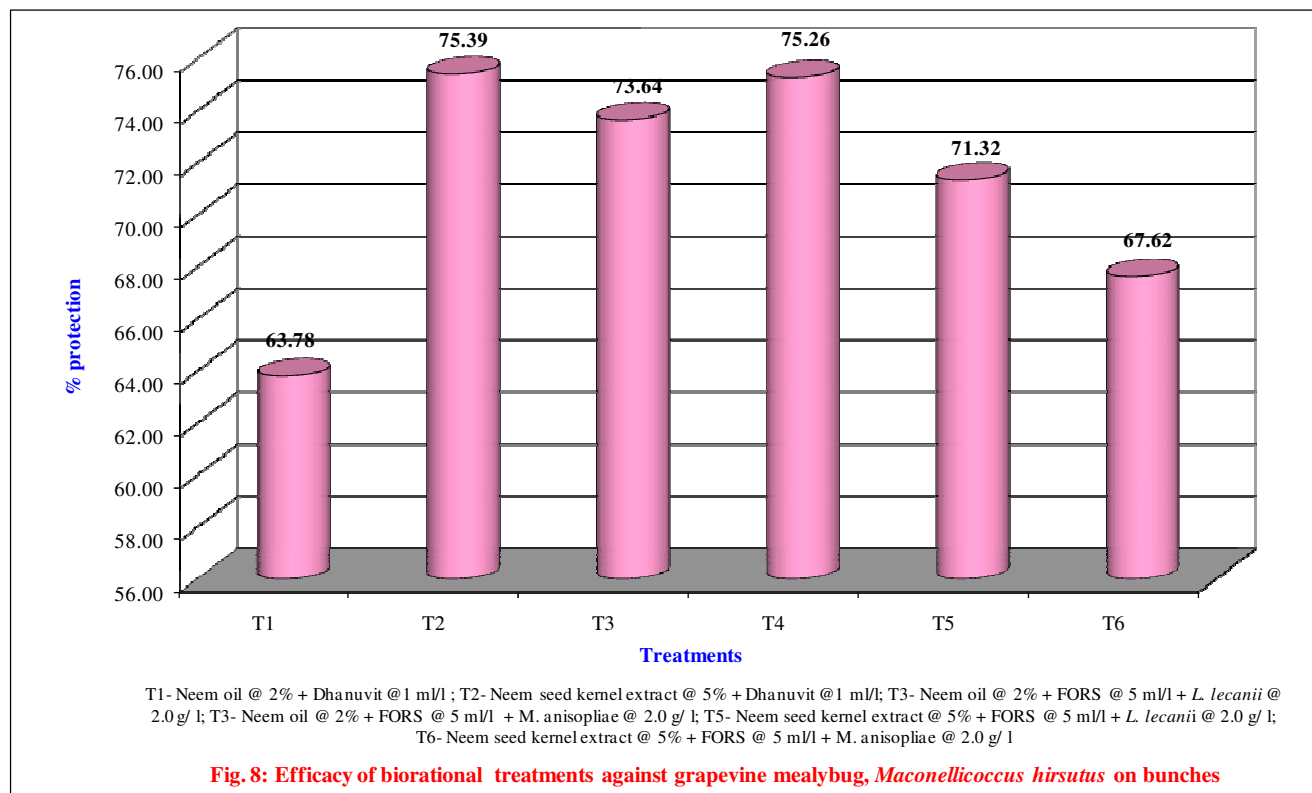


Fig 8. Efficacy of biorational treatments against grapevine mealybug, *Maconellicoccus hirsutus* on bunches

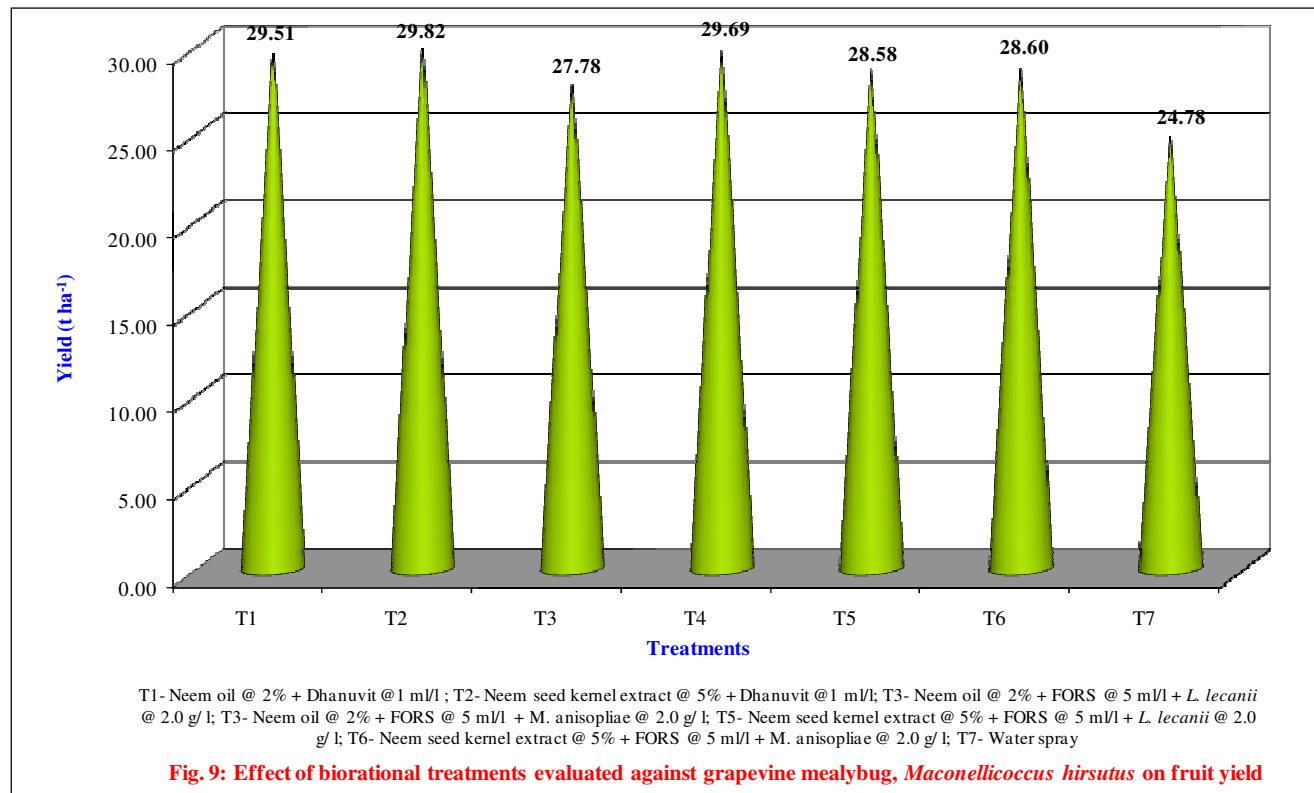


Fig 9. Effect of biorational treatments evaluated against grapevine mealybug, *Maconellicoccus hirsutus* on fruit yield

The effectiveness of insecticides on different instars of mealybugs revealed in the present study is in line with Gonzalez and Volosky (2006). The results of buprofezin 25 SC along with or without fish oil rosin soap is in line with reports of Balikai, 2002 and 2005, Muthukrishnan *et al.*, 2005, Daane *et al.*, 2008 and Patel *et al.*, 2010. Similar results were also obtained by Bedford *et al.* (1996). Dhawan *et al.* (2009) reported that profenophos and buprofezin were most effective on crawlers and adult mealybug, *P. solenopsis*. Shafqat *et al.* (2007) obtained effective control of cotton mealybug *P. gossypiphilous* with bifenthrin, profenophos and chlorpyrifos under field condition. The combination of dichlorvos with fish oil rosin soap gave 80 per cent mortality of mealybugs (Narsimha Rao *et al.*, 1977; Mani, 1990). Whereas, Ranga Reddy and Lakshmi Narayana (1986), reported that the efficacy of the treatments was increased when fish oil rosin soap was added. The appreciable and comparable mortality of nymphs and adults of *M. hirsutus* was achieved with dichlorvos (Srinivas *et al.*, 2007). According to Katke (2008) the addition of fish oil rosin soap at 5g/l with dimethoate 30 EC resulted significant reduction of mealybug under field condition as compared to dimethoate 30 EC without fish oil rosin soap against grape mealybug. Earlier workers reported that, the dimethoate was effective against mealybugs on citrus (Atwal, 1976), against *P. pacificus* on custard apple (Shukla and Tandon, 1984), against *P. citri* on grapes (Su and Wang, 1988), against *D. mangiferae* on mango (Singh *et al.*, 1991) and against *F. virgata* on guava (Baskaran *et al.*, 1999). Dimethoate at 0.05 per cent was effective against grape mealybug (Shreedhar Rao *et al.*, 1988). Agarwal *et al.*, (2009) reported that, after three days of second spray the profenophos 50 EC (check) recorded 93.73 per cent mortality over control and was at par with spirotetramat (12%) + imidacloprid (36%) - 480 SC (85.09% mortality) and thiodicarb 75 WP @750 g a.i. /ha (84.48% mortality) as compared to other treatments. Similarly, superiority of profenophos 50 EC was also confirmed by Suresh *et al.* (2010) who reported that profenophos was found to be quite effective and caused cent per cent mortality of *P. solenopsis* at one day after treatment while imidacloprid, fish oil rosin soap and dimethoate caused cent per cent mortality after two days of the treatment imposition. The results of present investigations are more or less in agreement with the above reports.

5.4.2 Efficacy of biorationals for mealybug management under field condition

The treatments of neem seed kernel extract @ 5% + FORS @ 5 ml/l + *L. lecanii* @ 2.0 g/ l, neem seed kernel extract @ 5% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/ l and neem oil @ 2% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/ l recorded higher per cent protection on vines (Fig. 7). The treatments of neem seed kernel extract @ 5% + Dhanuvit @ 1 ml/l, neem oil @ 2% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/ l and neem oil @ 2% + FORS @ 5 ml/l + *V. lecanii* @ 2.0 g/ l showed similar degree of superiority over per cent protection on bunches (Fig. 8).

The highest fruit yield was obtained from the treatment of neem seed kernel extract @ 5% + Dhanuvit @1 ml/l (29.82 t/ha), neem oil @ 2% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/ l (29.69 t/ha) and neem oil @ 2% + Dhanuvit @1 ml/l (29.51 t/ha) and were on par with each other. The next best treatments were neem seed kernel extract @ 5% + FORS @ 5 ml/l + *L. lecanii* @ 2.0 g/ l and neem seed kernel extract @ 5% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/ l. The application of NSKE @ 5% + Dhanuvit @1 ml/l recorded highest incremental cost benefit ratio (1:43.44) as compared to other biorational treatment. The next better treatments having higher incremental cost benefit ratio were neem seed kernel extract @ 5% + FORS @ 5 ml/l + *L. lecanii* @ 2.0 g/ l and neem seed kernel extract @ 5% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/ l (1:13.24 and 13.34, respectively) (Fig. 9).

The investigation on effect of botanicals on mealybugs in this study are in agreement with the findings Balikai (1999b) who reported that the pest colony sprayed with NSKE @ 5 % resulted lowest population of mealybugs on grapes. While, Katke (2008) recorded more than 50 per cent protection with treatments NSKE @ 5% + soap powder at 1% and neem oil at 2% + soap powder at 1% against *M. hirsutus* over untreated check on grape vines and bunches. Whereas, both 1 and 4% neem kerosene emulsion were effective against *C. viridis* causing 80 to 90 per cent mortality in 13-19 days (Kumar *et al.*, 1989). In field study, neem (*A. indica*) and karanja oil (*Pongamia pinnata* (L.)) both at 4 per cent were recommended for the control of *P. citri* on guava. They caused 93.2 and 89.39 per cent mortality of the insect, respectively at 10 days after second spray (Hussain *et al.*, 1996). According to Shelke (2001), the addition of adjuvant fish oil rosin soap (0.5%) with *L. lecanii* (0.4%) was the safest and most suitable treatment against grapevine mealybug, *M. hirsutus*. The *L. lecanii* conidia as well as filtrates gave very good mortality (84.8 and 100%) against *Planococcus citri* on 10th days (Gonzalez *et al.*, 1995). Findings of Eswaramoorthy and Jayaraj (1987) suggested fortnightly application of *L. lecanii* @ 1.6 x 10⁶ spores/ml would become highly effective in control of *C. viridis* under field condition. Among the entomopathogens tested the *L. lecanii* ranked first followed by *M.*

anisopliae in management of mealybug *M. hirsutus* under field condition (Katke, 2008). The results of present investigations corroborate with the above reports.

Future line of work

1. In depth studies on parasitoids need to be taken up to know the extent of parasitization by the individual parasitoid on mealybugs and their possible exploitation in IPM.
2. The prediction model developed for different lead weeks and its validation is preliminary and needs to be strengthened by developing models using more number of years of seasonal incidence data to predict the population of mealybug more precisely and accurately.
3. Large scale field studies need to be taken up for evaluation of best performing treatments from this study.
4. Safety periods of the best performing treatments on predator, *C. montrouzieri* needs to be determined for their better utilization in IPM.
5. Integrated pest management module should be developed to manage the mealybug incidence on grapevine.

SUMMARY AND CONCLUSION

During the present investigation, survey was conducted to know the seasonal incidence and fluctuation of mealybug, *Maconellicoccus hirsutus* and its natural enemies at Bijapur and Bagalkot area for two years during 2009-10 and 2010-11. Further, feeding potential and biology of *Cryptolaemus montrouzieri* on second and third instar mealybugs, efficacy of mixture of botanicals, entomopathogens and insecticides along with different adjuvants was studied on first, second and third instar mealybugs under laboratory conditions and best performing mixtures of botanicals, entomopathogens and insecticides with adjuvants were evaluated under field condition. The results of these investigations are summarized here under.

In the present investigations, the incubation period of *C. montrouzieri* eggs ranged between 3.6 to 7.9 days with an average of 5.75 days. The pre-mating, pre-oviposition and oviposition period of *C. montrouzieri* ranged from 4-9, 6-11 and 58 - 89 days with an average of 6, 8.70 and 73.80 days, respectively. The longevity of male and female was 65 to 91 and 72 to 91 days with an average of 78 and 88.50 days, respectively. The egg laying capacity of female beetle was in the range of 472 to 652 with an average of 700.30 eggs when fed with all the stages of mealybugs. The predatory grub took 3.83, 4.83, 6.03 5.67 and 3.53, 4.53, 5.57, 5.50 days with an average of 3.68, 4.68, 5.80 and 5.58 days to complete its first, second, third and fourth instar, respectively when fed with second and third instar mealybugs. The total developmental period of grubs was 20.37 and 19.13 days with an average of 19.75 days, when they were supplemented with second and third instar mealybugs, respectively. The pre-pupal and pupal duration of *C. montrouzieri* were 1.73, 8.70 and 1.67, 8.53 days with mean of 1.70 and 8.62 days when fed on second and third instar mealybugs, respectively. The longevity of male beetle reared on second and third instar mealybugs was 55.80 and 60.59 days with an average of 58.18 days, respectively. Similarly, the female beetle longevity was 63.83 and 61.28 with mean of 62.48 days.

The consumption of mealybugs was recorded as 4.20, 10.83, 83.50, 152.30 and 1.83, 4.20, 10.57, 15.20 with an average of 3.02, 7.52, 47.03 and 83.75 by first, second, third and fourth instar predatory grubs when reared on second and third instar mealybug, respectively. The consumption of second and third instar mealybugs by male beetle, *C. montrouzieri* was 301 and 38.00, respectively, whereas the female consumed 379.07 and 42.97 number of mealybugs, respectively.

The seasonal incidence of mealybug studied over two seasons indicated that the mealybugs were noticed throughout the year. The egg masses and colonies of mealybugs were observed on vine, during 28th MSW and it started increasing upto 36th MSW in Bijapur and Bagalkot area. From 38th MSW onwards (September-October) mealybug population started declining in Bijapur and Bagalkot area, due to September pruning but once again it started increasing upto 44th MSW. During 14th MSW once again declined due to April pruning, from thereafter it again started increasing upto 26th MSW.

The population predators was observed from 28th to 48th and 14th to 26th MSW with peak population during 24th MSW in Bijapur area and from 28th to 50th and 10th to 26th MSW. The predator population was observed with peak population during 34th MSW in Bagalkot area. The population of parasitoids of mealybugs was observed throughout the season. The population of parasitoids increased from 28th MSW and reached peak at 34th and 36th MSW in Bijapur and Bagalkot area, respectively. From then onwards, the population of parasitoids decreased upto 16th MSW and again increased at both the locations.

Three prediction models (current lead week (LW0), lead week one (LW1) and lead week two (LW2)) were developed considering weather factors. Among them the prediction model developed for lead week one (LW1) showed less error than LW2. Hence, by substituting current week's weather data, mealybug population can be predicted a week advance, which would help for initiating its management well in time.

Totally seven predators were recorded on grape vine mealybug, *M. hirsutus* viz., four from coleopteran coccinellids (*S. nubilus*, *N. regularis*, *S. coccivora* and *C. montrouzieri*), two from dipteran family Chamaemyiidae (*Leucopis* sp.) and Drosophilidae (*Cacoxenus* (= *Gitonides*) *perspicax*) and one from lepidopteran family Lycaenidae (*S. epieus*).

Totally twelve parasitoids were recorded belonging to the order hymenoptera viz., *C. pseudococci*, *Coccophagus* sp. near *sexvittatus*, *Coccophagus* sp. near *javensis*, *P. unfasciiventris* and *Euryischomyia* sp. from family Aphelinidae, *A. bambawalei*, *L. dactylopii*, *L. lyciae* and *H.*

eytelweirii belonging to family Encyrtidae and *Oomyzus sp.*, *Centiste sp.* and *M. concinnus* belonging to family Eulophidae, Braconidae and Pteromalidae, respectively.

The botanical NSKE @ 5% recorded significantly highest per cent mortality of first, second and third instar mealybugs, followed by neem oil @ 2% at five days after treatment. The *Pongamia* based botanicals were found effective as next best treatments but CASKE @ 5% recorded least mortality of all the stages of mealybugs. Among the adjuvant solutions, the Dhanuvit @ 1 ml/l and FORS @ 5 ml/l was significantly superior in recording higher mortality of first, second and third instar mealybugs as compared to APSA-80. Similarly, the neem based botanicals in combination with all the adjuvant solutions recorded higher mortality. Among these, NSKE @ 5% + Dhanuvit @ 1 ml/l resulted significantly higher mortality followed by neem oil @ 2% with adjuvant solution Dhanuvit @ 1 ml/l as compared to all other combinations with different adjuvant solutions on first, second and third instar mealybugs at five days after treatment.

The botanicals NSKE @ 5% and neem oil @ 2% recorded highest mortality of all the stages (first, second and third instar) of mealybugs. The next best were PSKE @ 5% and *Pongamia* oil @ 2%. However, the botanical CASKE @ 5% recorded least mortality of all the stages of mealybugs. Among the entomopathogens, *L. lecanii* @ 2 g/l was effective on all the stages of mealybugs followed by *M. anisopliae* @ 2 g/l. The addition of FORS @ 5 ml/l caused highest mortality of all the stages of mealybugs as compared to without FORS @ 5 ml/l. The combination of NSKE @ 5% with *L. lecanii* @ 2 g/l resulted higher mortality of first, second and third instar mealybugs followed by other combinations. The entomopathogen, *L. lecanii* @ 2 g/l with FORS @ 5 ml/l registered higher mortality of all the three stages of mealybugs as compared to remaining combinations. The combinations of neem based botanicals with *L. lecanii* @ 2 g/l + FORS @ 5 ml/l recorded higher mortality of all the three stages of mealybugs, followed by remaining interactions. However, the combinations of CASKE @ 5% with entomopathogens (*L. lecanii* and *M. anisopliae*) and with or without FORS @ 5 ml/l recorded least mortality of mealybugs.

The cent per cent mortality was obtained in bifenthrin 10 EC @ 1 ml/l on first instar mealybugs. The next best treatments were imidacloprid 70 WG @ 0.3 g/l, imidacloprid 17.8 SL @ 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l. Whereas, imidacloprid 70 WG, bifenthrin 10 EC @ 1 ml/l, imidacloprid 17.8 SL 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l were significantly superior over rest of the treatments in causing highest per cent mortality of second and third instar mealybugs at three days after treatment. Among the adjuvant solutions, the Dhanuvit @ 1 ml/l enhanced highest mortality on first, second and third instar mealybug followed by FORS @ 5 ml/l and APSA-80 @ 1 ml/l on all the stages of mealybugs. The combination of bifenthrin 10 EC @ 1 ml/l with all the three adjuvant solution and imidacloprid 70 WG @ 0.3 g/l and dichlorvos 76 EC @ 0.5 ml/l along with adjuvant solution Dhanuvit @ 1 ml/l resulted cent per cent mortality of first instar mealybug. Whereas, bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l recorded highest mortality of second and third instar mealybugs. However, the next best treatments were imidacloprid 70 WG @ 0.3 g/l and imidacloprid 17.8 SL @ 0.3 ml/l and dichlorvos 76 EC @ 0.5 ml/l with Dhanuvit @ 1 ml/l adjuvant solution at three days after treatment. But rest of the insecticides viz., buprofezin 25 SC, thiamethoxam 25 WG, thiacloprid 240 SC, diafenthiuron 50 WP, dimethoate 30 EC and profenophos 50 EC or combinations with adjuvant solutions showed most effective after five days of treatment except the insecticides acetamiprid 20 SP, emamectin benzoate 5 SG and chlorfenapyr 10 SC on different stages of *M. hirsutus*.

Imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l afforded highest protection (95.75%) against mealybug on vines followed by bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l along with Dhanuvit @ 1 ml/l which provided protection of 92.9 and 92.2 per cent, respectively and were significantly superior over rest of the treatments. The next best treatments were dimethoate 30 EC @ 1.7 ml/l + Dhanuvit @ 1 ml/l, dichlorvos 76 EC + Dhanuvit @ 1 ml/l, buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l and thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l.

Imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l afforded highest protection (92.1%) against mealybugs on bunches followed by imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l. The next best treatments were buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l, thiacloprid 240 SC @ 0.2 g/l + Dhanuvit @ 1 ml/l, dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l and profenophos 50 EC @ 2 ml/l + Dhanuvit @ 1 ml/l.

The highest fruit yield 37.92 t/ha was obtained from the treatment imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l followed by bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l which in turn was on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (36.21 t/ha). The next best treatments

were buprofezin 25 SC @ 2.00 ml/l + Dhanuvit @ 1 ml/l, dichlorvos 76 EC @ 0.5 ml/l + Dhanuvit @ 1 ml/l and thiamethoxam 25 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l with 33.97, 33.64 and 32.78 t/ha of fruit yield, respectively.

The following are some of the conclusions from the present investigation.

- The predator and parasitoid populations were more during non-spraying seasons (May-September) but reduced at fruiting seasons.
- The biology of *C. montrouzieri* grubs and adults extends when fed on second instar than third instar mealybugs.
- Consumption rate by grubs and adult predator of *C. montrouzieri* was more when supplied with second than third instar mealybugs.
- The peak incidence of the mealybugs was observed during fruiting season from October onwards until April pruning.
- The neem based botanicals viz., NSKE 5% and neem oil 2% alone or in combination with adjuvant solution showed highest per cent mortality of all the stages of mealybug, *M. hirsutus* compared to other botanicals. The next best were *Pongamia* based botanicals.
- The combination of botanicals with entomopathogens and adjuvant solution FORS recorded higher mortality as compared to combinations without FORS but did not show compatibility effect on the mortality of different instars of mealybugs.
- The efficacy of all the insecticides on mortality was more on all the stages of mealybugs under laboratory condition. Among them the imidacloprid 70 WG, imidacloprid 17.8 SL, bifenthrin 10 EC, dichlorvos 76 EC, buprofezin 25 SC, thiacloprid 240 SC and profenophos 50 EC were found most effective against mealybugs.
- The treatment imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l afforded highest protection (95.75%) against mealybug on vine followed by bifenthrin 10 EC @ 1 ml/l and imidacloprid 17.8 SL @ 0.3 ml/l along with Dhanuvit @ 1 ml/l providing protection of 92.9 and 92.2 per cent against mealybugs on vines and were significantly superior over rest of the treatments under field condition.
- The treatment imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l afforded highest protection (92.1%) against mealybugs on bunches and it was on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l and bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l with 90.5 and 88.3%, respectively under field condition.
- The highest fruit yield of 37.92 t/ha was obtained from the treatment of imidacloprid 70 WG @ 0.3 g/l + Dhanuvit @ 1 ml/l followed by bifenthrin 10 EC @ 1 ml/l + Dhanuvit @ 1 ml/l which in turn on par with imidacloprid 17.8 SL @ 0.3 ml/l + Dhanuvit @ 1 ml/l (36.21 t/ha).

REFERENCES

- Agarwal, N., Vikas Jindal and Vikram Singh, 2009, Evaluation of some new insecticides against mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Psuedococcidae) on cotton. *Pestology*, 33(6): 29-33.
- *Alexandri, A. A., 1973, Efficacy of some insecticides in the control of moth, *Polychrosis botrana* Schieff Rouman. *Ann. Inst. Cerc. Penttu. Pl. Protec.*, 9: 507-514.
- Aida, H. M., Saber F. M., Ahmed H. A. and Sayed A. A., 2010, Efficiency of certain insecticides on the population(s) of the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) and their natural enemies under the field condition in Ismailia governorate. *Egypt. Acad. J. Biol. Sci.*, 2(2): 11-17.
- Ali, M., 1978, A Report on the wax scales on *Ceroplastes pseudoceriferus* Green and *Chloropulvinaria polygonata* (Ckll.) (Homoptera : Coccidae) on mango and their natural enemies. *Bangladesh J. Zool.*, 6: 69-70.
- Alizadeh, M. S., Mossadegh, M. S. and Esfandiari, M., 2013, Natural enemies of *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) and their population fluctuations in Ahvaz, southwest of Iran. *J. Crop Protec.*, 2(1): 13-21.
- Anil, K. M. and Jeevan, K. S., 2008, Biological studies on coccinellid predator, *Cryptolaemus montrouzieri* Mulsant of grapevine mealybug, *Maconellicoccus hirsutus* Green. *Asian J. Biol. Sci.*, 3(1): 152-158.
- Anonymous, 1946, Short notes and exhibits. *Indian J. Entomol.*, 7: 237-242.
- Anonymous, 1982, *Report of the All India Co-ordinated Fruit Improvement Project on Grapes*, Andhra Pradesh Agricultural University, Hyderabad, India, pp. 1-41.
- Anonymous, 1988, Bioecology and Management of Grape Mealybug. *Technical Bulletin No. 5*, Indian Institute of Horticultural Research, Bangalore, India.
- Anonymous, 1992, A Report submitted to the *Research Review Committee Meeting in Agricultural Entomology and Nematology for 1991-92*, Mahatma Phule Krishi Vidhyapeeth, Rahuri, (Maharashtra), p. 19.
- Anonymous, 1994, All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds. *Annual Report-1993-94*, published by the Project Directorate of Biological Control, Bangalore. pp. 159.
- *Anonymous, 1995, A Report submitted to the *Research Review Sub-Committee Meeting in Agricultural Entomology and Nematology for 1994-95*, Mahatma Phule Krishi Vidhyapeeth, Rahuri (Maharashtra), p. 20.
- Anonymous, 2002, Package of practices for higher yields in horticultural crops. University of Agricultural Sciences, Dharwad and Bangalore, Karnataka State Department of Horticulture, Bangalore, IIHR, Bangalore, Central Plantation Crops Research Institute, Kasargodu and Spice Board, Sakaleshpur, p. 465.
- Anonymous, 2006a, *Indian Horticulture Database*. www.agriexchange.apeda.gov.in
- Anonymous, 2006b, *Cryptolaemus montrouzieri*- mealybug predator. www.rinconvitova.com
- Anonymous, 2009, Crop protection- management of pests. *CICR Annual Report- 2007-08*, p. 66, 74, 75.
- Anonymous, 2010, *Grape*. www.en.wikipedia.org.
- Anonymous, 2010, *Annual report 2009-10* submitted to Andhra Pradesh Horticultural University. p. 52.
- Anonymous, 2011, *Facts and Figures*. Indian Horticulture Board Database. www.nhb.gov.in
- Arve, S. S., Patel, K. G., Chavan, S. M. and Vidhate, P. K., 2011, Investigation on population dynamics of hibiscus mealybug, *Phenacoccus solenopsis* Tinsley in relation to biotic factors under South Gujarat condition. *J. Biopesticides*, 4(2): 211-213.
- Atwal, A. S., 1976, Pests of Citrus. In : *Agricultural Pests of India and South East Asia*, Kalyani Publishers, Ludhiana, pp. 195-213.

- Avidow, Z., Erlich, S. and Golthif, S., 1960, Experiments in the control of citrus mealybug, *Pseudococcus citri*. Risso in grape fruit orchard. *Bull. Nat. Univ. Inst. Agric.*, 65: 33-45.
- Azam, K. M., 1983, Losses due to pests in grapes. *Indian J. Entomol.*, (Special Issue), 2: 387-389.
- Babu, B. G. and David, P. M. M., 1999, A simple technique for mealybug multiplication on grooveless pumpkins. *J. Biol. Control*, 13(1-2): 59-63.
- Babu, T. R. and Azam, K. M. 1987a, Studies on management of grape mealybug. *Indian Grape J.*, 3(5): 54-60.
- Babu, T. R. and Azam, K. M., 1987b, Studies on biology, host spectrum and seasonal population fluctuation of the mealybug, *Maconellicoccus hirsutus* (Green) on grapevine. *Indian J. Hort.*, 44(3-4): 284-288.
- Babu, T. R. and Azam, K. M., 1988, Predation potential of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera) in relation to temperature. *J. Res. APAU*, 16(2) : 108-110.
- Babu, T. R. and Azam, K. M., 1989, Biological control of grape mealybug, *Maconellicoccus hirsutus* (Green). *J. Pl. Protec. Sci.*, 17(4): 123-126.
- Balikai, R. A. 1999a, Seasonal incidence of grapevine, mealybug in North Karnataka. *Insect Environ.*, 4(4) : 148-149.
- Balikai, R. A., 1999b, Management of grapevine mealybug, *Maconellicoccus hirsutus* (Green). *Insect Environ.*, 4(4) : 149.
- Balikai, R. A., 2002, Bio-efficacy of buprofezin 25 SC against grape mealybug, *Maconellicoccus hirsutus* (Green). *Pestology*, 26(10): 20-23.
- Balikai, R. A., 2005, Management of grape mealybug, *Maconellicoccus hirsutus* (Green) using insect growth regulators. *Res. on Crops*, 6(1): 68-71.
- Balikai, R. A. and Bagali, A. N., 2000, Population density of mealybug, *Maconellicoccus hirsutus* (Green) on ber (*Zizyphus mauritiana* Lamarck) and economic losses. *Agric. Sci. Digest*, 20(1): 62-63.
- Balikai, R. A. and Kotikal, Y. K, 2003, Pest status of grapevine in northern Karnataka. *Agric. Sci. Digest*, 23(4): 276-278.
- Baskaran, R. K. M., Lakshmi, L. G. and Uthamasamy, S., 1999, Coccids and their management in guava intercropped with coconut. *Pest Manage. Hort. Ecosystems*, 5(1): 28-31.
- Bedford, H. W., 1935, Report on work carried out by the staff of the entomological section, during the season 1934-35. *Report of the Agricultural Research Service*, Sudan.
- *Bedford, I. D., Kelly, A. and Markham, P. Q., 1996, The effects of buprofezin against the citrus mealybug, *Planococcus citri*. In: *Proc. Int. Conference: Pests and Diseases*, Brighton, UK, 3: 1065-1070.
- Beevi, N. D., Janarthanan, R. and Natarajan, K., 1992, Efficacy of some insecticides against *Maconellicoccus hirsutus* (Green) on mulberry. *J. Insect Sci.*, 5(1): 114.
- Bhat, P. K., Chacko, M. J. and Sreedharan, K., 1981, Biology of the lady bird beetle, *Cryptolaemus montrouzieri* Mulsant, a predator of mealybugs. In: *Proc. Second Annu. Symp. on Pl. Crops*, p. 221.
- Bhosle, B. B., Sharma, O. P., More, D. G., Bhede, B. V. and Bambawale, O. M., 2009, Management of mealybug (*Phenacoccus solenopsis*) in rainfed cotton (*Gossypium hirsutum*). *Indian J. Agric. Sci.*, 79(3): 199-202.
- Bingham, C. T., 1907, The fauna of British India including Ceylon and Burma. Butterflies. London, UK : Taylor and Francis.
- Biradar, A. P., Kabadagi, C. B. and Patil, D. R., 2006, Evaluation of Diafenthiuron 50 SC (Polo) against grape mealybug, *Maconellicoccus hirsutus* (Green). *Int. J. Agric. Sci.*, 2(2): 470-471.
- *Bishop, H. J., 1931, Biological control of the citrus mealybug. *Fmg. S. Africa. Reprint No. 64*, p. 7.
- Bournier, A., 1977, Grape insects. *Ann. Rev. Ent.*, 22: 355-376.

- Butani, D. K. 1978, Insect pests of fruit crops and their control- Custard apple. *Pesticides*, 10(5): 27-28.
- Butani, D. K., 1979, *Insects and Fruits*, Periodical Export Book Agency, New Delhi, p. 398.
- Chacko, M. J., Bhat, P. K., Ananda Rao, L. V., Deepak Singh, M. B., Ramanarayan, E. P. and Sreedharan, K., 1978, The use of the lady bird beetle, *Cryptolaemus montrouzieri* for the control of coffee mealybugs. *J. Coffee Res.*, 8: 14-19.
- Chacko, M. J., Bhat, P. K. and Ramanarayan, E. P., 1977, New records of coccoidea with notes on natural enemies of *Planococcus* spp. on coffee in India. *J. Coffee Res.*, 7: 69-71.
- Compere, H., 1938, Description of a new species of *Leptomastix* parasite of *Phenacoccus hirsutus* Green. *Bull. Soc. Fouad Ent.*, 22: 36-38.
- Daane, K. M., Bentley, W. J., Miller, J. G., Walton, V. M., Cooper, M. L, Biscay, P. and Yokota, G. Y., 2008, Integrated management of mealybugs in California vineyards. *Acta Hort.*, 785: 235-252.
- Das, G. M., Mukherjee, T. D. and Sen Gupta, N., 1948, Biology of common mealybug, *F. virgata* (Ckll.) (Coccidae) a pest of jute (*Corchorus olitorios*) in Bengal. *Proc. Zool. Soc.*, 1: 109-115.
- Dhawan, A. K., 2007, Status of mealybug in Punjab. www.ncipm.org. in
- Dhawan, A. K., Saini, S., Singh, K. and Aneja, A., 2009, Persistence and residual toxicity of some insecticides against *Phenacoccus solenopsis* on cotton (*Gossypium* spp). *Indian J. Agric. Sci.*, 79(3): 203-206.
- Dhawan, A. K., Saini, S., Singh, K. and Mohindru, B., 2008, Toxicity of some new insecticides against *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton. *J. Insect Sci.*, 21: 103-105.
- Dinesh, A. S. and Venkatesha, M. G., 2011, Prey consumption by the mealybug predator *Spalgis epius* on pink hibiscus mealybug (*Maconellicoccus hirsutus*). *Phytoparasitica*, 39: 11-17.
- Dinesh, A. S., Venkatesha, M. G. and Ramakrishna, S., 2010, Development, life history characteristics and behaviour of mealybug predator, *Spalgis epius* (Westwood) (Lepidoptera : Lycaenidae) on *Planococcus citri* (Risso) (Homoptera : Pseudococcidae). *J. Pesticide Sci.*, 83: 339-345.
- Dorge, S. K. and Murthy, T. K., 1974, Control of mealybug on custard apple with modern insecticides in Maharashtra State. *Pl. Protec. Bull. India*, 22(3): 40-47.
- Dutt, N., Mukerjee, P. K. and Sen Gupta, N., 1951, Preliminary observations on the incidence of *Phenacoccus hirsutus* Green and its effect on the growth of *Hibiscus sabdariffa* L. var *altissima*. *Indian J. Agric. Sci.*, 21: 231-237.
- Eswaramoorthy, S. and Jayaraj, S., 1987, Effectiveness of white halo fungus *Cephalosporium lecanii* (Zimm.) against field population of coffee green bug. *Coccus viridis*. *J. Invertebr. Path.*, 36(1): 88-196.
- Felt, E. P., 1920, New Indian gall midge (Diptera) Mem. Dept. Agric. India (Ent. Ser.), 7: 1-11.
- *Finney, D. J., 1971, Probit analysis. Third Edition. Cambridge Press, NY, NY. pp. 668.
- Fisher, T. W., 1963, Mass culture of *Cryptolaemus* and *Leptomastix* natural enemies of citrus mealybug. *Bull. Calif. Agric. Exp. Sta.*, 797: 39.
- Fletcher, T. B., 1919, *Report of the Imperial Entomologist*. Scientific Report of Agricultural Research Institute, Pusa for 1918-19, p. 86-103.
- Fletcher, T. B., 1920, *Report of the Imperial Entomologist*. Scientific Report of Agricultural Research Institute, Pusa for 1919-20, p. 68-90.
- Fletcher, T. B., 1923, *Report of the Imperial Entomologist*. Scientific Report of Agricultural Research Institute, Pusa for 1922-23, p. 61-75.
- Flores, A., 2005, Mealybugs may have their match: Insect predators and parasites home in on this growing menace. *Agric. Res. Magaz.*, 53(4): 83-87.

- Games, W., Skou, S. L. and Subramanian, C. V., 1973, Genetic aspects in Hypomycetes with slimy one celled phialiole conidia in taxonomy of fungi imperfecti. *Hypomycetes*, 1: 112.
- Gautam, R. D., Usha, S. Sudhida, G., Md. Khan, A. and Gautam, C. P. N., 2007, studies on Solanum mealybug, *Phenacoccus solani* Ferris (Hemiptera : pseudococcidae), its parasitoid and predator complex, reproductive potential and utilization as laboratory prey for rearing the ladybird and green lace wing predators. *J. Ent. Res.*, 31(3): 259-264.
- Geiger, C. A., Daane, K. M., Bently, W. J., Yokota, G. Y. and Martin, L. A., 2001, Sampling programme for grape mealybugs improves pest management. *California Agric.*, 55(3): 1927.
- Ghose, S. K., 1971, Predators, parasites and attending ants of the mealybug, *Maconellicoccus hirsutus* (Green) (Pseudococcidae, Hemiptera). *Pl. Protec. Bull.*, 22: 22-30.
- Ghose, S. K., 1972, Biology of the mealybug, *Maconellicoccus hirsutus* (Green) (Pseudococcidae : Hemiptera). *Indian Agric.*, 16: 323-332.
- Glare, T. R. and Milner, R. J., 1991, Ecology of entomopathogenic fungi. In: *Handbook of Applied Mycology*, Vol. 2, *Humans, Animals and Insects*. (Eds. Arora, K. K., Ajello, L. and Mukerji, K. G.), Marcel Dekker Inc., New York, pp. 547-621.
- *Godfrey, L. D. and Pickel, C., 1998, Seasonal dynamics and management scheme for subterranean mealybug, *Rhizoecus kondonis* Kuwana, pest of alfalfa. *Southwestern Entomol.*, 23(4): 343-350.
- Gokuldas Kumar, M. and Vijayalaxmi, C. K., 1986, A study on the adult biology of *Cryptolaemus montrouzieri* Mulsant on two common species of coffee mealybug. *J. Coffee Res.*, 16(3&4): 107-110.
- Gomez, K. A. and Gomez, A. A., 1984, In: *Statistical Procedures for Agricultural Research*. New York, USA, John Wiley, pp. 680.
- Gonzales, R. H. and Volosky, F. C., 2006, Seasonal and management strategies for mealybugs, *Pseudococcus* spp., in pome fruits, table and wine grapes (Hemiptera : Psuedococcidae). *Fruiticola*, 27: 37-47.
- Gonzalez, E., Martinez, M. A., Delos, L. and Martinez, B. 1995. Effectiveness *in vitro* culture of *Verticillium lecanii* against *Planococcus citri*. *Revista de Protec. Vegetal.*, 10(3): 265-268.
- Gosalwad, S. S., Bhosle, B. B., Wadnerkar, D. W., Ilyas, M. and Khan, F. S., 2009, Biology and feeding potential of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera) on *Maconellicoccus hirsutus* and *Phenacoccus solenopsis*. *J. Pl. Protec. Environ.*, 6(2): 73-77.
- Govindaiah, M.C., Gayathri, V. and Nagaveni, 2006, Effect of medicinal plant extracts on mealy bugs (*Maconellicoccus hirsutus* Green) affecting mulberry. *Int. J. Indust. Entomol.*, 13(2):103-108.
- Gowda, D. K. S., Manjunath, D., Datta, R. K. and Kumar, P., 1996, *Spalgis epius* Westwood (Lepidoptera: Lycaenidae) a potential predator of mulberry mealybug, *Maconellicoccus hirsutus*. *Insect Environ.*, 2: 87-88.
- Green, E. E., 1908, Remarks of Indian Scale Insects (Coccidae) Part-III with a catalogue of all species hitherto recorded from the Indian Continent. Memo of the Department of Agriculture, India (Entomological Service), 2: 15-46.
- Gulsar Banu, J., Surulivelu, T., Amutha, M. and Gopalakrishnan, N., 2010, Laboratory evaluation of insecticides and biopesticides against *Phenacoccus solenopsis* and *Paracoccus marginatus* infesting cotton. *J. Biopesticides*, 3(1) Special Issue: 343-346.
- Gulsar Banu, J., Surlivelu, T., Balamurugan, M., Amutha, M. and Gopalkrishnan, N., 2009. Natural occurrence of entomopathogenic fungi in mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Psuedococcidae) in India. *Proc. Nation. Symp. Bt Cotton : Opportunities and Prospects*, CICR, Nagpur. p. 121.
- *Hall, W. J., 1921, The *Hibiscus* mealybug, *Pseudococcus hibisci* (Hemip). *Bull. Sco. Ent. d Egypt, Cairo*, 14: 17-29.
- *Hall, W. J., 1921a, The *Hibiscus* mealybug, *Phenacoccus hirsutus* (Green). *Bull. Minst. Agric. Egypt*, 17: 1-28.

- *Hall, W. J., 1921b, The *Hibiscus* mealybug, *Phenacoccus hirsutus* Green. *Egypt Minist. Agric. Cairo. Tech. Sci. Ser. Bull.*, 17: 28.
- Hall, W. J., 1926, The *Hibiscus* Mealybug, *Phenacoccus hirsutus* green in Egypt in 1925 with notes on the introduction of *Cryptolaemus montrouzieri* M. *Minist. Agric. Egypt. Bull.*, 70: 1-15.
- Hall, W. J., 1927, The introduction of *Cryptolaemus montrouzieri* Muls. in Egypt. *Bull. Ent. Res.*, 17: 385-392.
- Hanchinal, S. G., 2010, Bioecology and management of mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera : Pseudococcidae) on *Bt* cotton. *Ph. D. Thesis*. Univ. Agric. Sci., Dharwad (India).
- Handique, P. K. and Baruah, R., 2000, Evaluation of Biomix-1 against mealybug *Maconellicoccus hirsutus* (Green) of mulberry. *Indian J. Seric.*, 39(1): 79-80.
- *Hayat, M., 1986, Family Aphelinidae *Oriental insects*. The Chalcidoidea (Insect: Hymenoptera) of India and the adjacent countries. (Eds : Subba Rao, B. R. and Hayat, M.), (part II), 20: 170.
- Hiremath, I. G., Lingappa, S., Balikai, R. A. and Yelshetty, S., 1990, Severe occurrence of grape mealybug in Bijapur area (Karnataka). *Proc. Nation. Symp. Behavioural Sci. and XIX Annu. Meet Ethol. Soc. India*, Madurai, 27-28, Dec 1990, pp. 42.
- *Humber, R. A. and Soper, R. S., 1981, Isolation, preservation and identification of entomopathogenic fungi. In : *Entomopathogenic Fungi* (Ed. Rogers, D. W.). Allenheld Osmum, Mont. Clair, New Jersey.
- Hussain, M. A., Puttaswamy, C. and Viraktamath, C. A., 1996, Management of citrus mealybug, *Planococcus citri* Risso on guava using botanical oils. *Insect Environ.*, 2(3): 73-74.
- Ibarra-Cortés, K. H., Guzmán-Franco, A. W., González-Hernández, H., Suarez-Espinosa, J. and Baverstock, J., 2012, Selection of a fungal isolate for the control of the pink hibiscus mealybug *Maconellicoccus hirsutus*. *Pest Manag. Sci.*, 37: 213-219.
- Irulandi, S., Vinod Kumar, P. K., Seetharama, H. G. and Sreedharan, K., 2001, Bio-efficacy of neem formulations alone and in combination with synthetic insecticide against mealybug, *Planococcus citri* (Risso) on coffee. *J. Coffee Res.*, 29(1&2): 56-60.
- *James, B. B. and Fofanah, M., 1992, Population growth pattern for *Phenacoccus manihoti* Mat-Ferr. on cassava in Sierra Leone. *Tropical Pest Manage.*, 38(1): 89-92.
- Jayachakravarthy, G., 2002, Bioefficacy of fungal bioagent *Verticillium lecanii* (Zimmermann) Vigas against some sucking pests. *M. Sc. (Agri.) Thesis*, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (India).
- Jayaraman, V., Chandramohan, N., Gopalan, M. and Balasubramanian, G., 1988, Predatory potential of Coccinellid beetles on mealybugs of citrus and grapevine. *Madras Agric. J.*, 75(1-2): 77-78.
- Katke, M. 2008, Seasonal incidence, biology and management of grape mealybug, *Maconellicoccus hirsutus* (Green) (Homoptera: Pseudococcidae). *M. Sc. Thesis*. Univ. Agric. Sci., Dharwad (India).
- Katke, M. and Balikai, R. A. 2008, Comparative biology of grape mealybug, *Maconellicoccus hirsutus* (Green) on sprouted potato during winter and summer. *Indian J. Entomol.*, 70(4): 395-397.
- Katke, M., Balikai, R. A. and Venkatesh, H., 2009, Seasonal incidence of grape mealybug, *Maconellicoccus hirsutus* (Green) and its relation with weather parameters. *Pest Manage. Hort. Ecosystems*, 15(1): 9-16.
- Khan, H. A. A., Sayyed, A.H., Akram, W., Raza, S., Ali, M., 2012a, Predatory potential of *Chrysoperla carnea* and *Cryptolaemus montrouzieri* larvae on different stages of the mealybug, *Phenacoccus solenopsis*: A threat to cotton in South Asia. *J. Insect Sci.*, 12: 1-12.
- Khan, G.Z., Iqbal, T., Ahmad, N., Ahmad, M.T., Khan, M.H., Khan, M.S. and Parveen, R., 2012b, Efficacy of different synthetic and natural products against mealybug, *Maconellicoccus hirsutus* in cotton. *Sarhad J. Agric.* 28(4): 593-598.

- Kharbade, S. B., Navale, P. A., Mehetre, S. S. and Chandele, A. G., 2009, Evaluation of bio-pesticides against mealybug, *Phenacoccus solenopsis* Tinsley on cotton. *Proc. Nation. Symp. Bt Cotton: Opportunities and Prospects*, CICR, Nagpur. p. 107.
- Koli, H. R., 2003, Seasonal incidence and management of grape mealybug, *Maconellicoccus hirsutus* (Green). *M. Sc. (Agri.) Thesis*, Mahatma Phule Krishi Vidhyapeeth, Rahuri, Maharashtra (India).
- Kour, H. and Virk, J. S., 2011, Feeding potential of *Cryptolaemus montrouzieri* against the mealybug, *Phenacoccus solenopsis*. *Phytoparasitica*, 39: 67-72.
- Kulkarni, N.S., Patil, A.B. and Sathe, T.V., 2012, Bio-efficacy of methomyl 40 SP against mealybug, *Maconellicoccus hirsutus* (Green) in grapes. *Karnataka J. Agric. Sci.*, 25(1): 148-149.
- Kumar, M. G., Bhat, P. K. and Vijayalakshmi, C. K., 1989, Screening of kerosene and neem extract against *Coccus viridis* Green. *J. Coffee Res.*, 19(1): 51-55.
- *Le Pelley, R. H., 1943, An oriental mealybug (*Pseudococcus lilacinus*) and its natural enemies. *Transactions of Royal Entomological Society London*, 93: 73-93.
- *Liotta, G. and Mineo, G., 1965, Test for artificial biological control of *Planococcus citri* (Citrus mealybug) *Boll. Inst. Ent. Agri. Oss. Fitopat. Palermo*, 25: 129-142.
- Lohman, D. J. and Samarita, V. U., 2009, The biology of carnivorous butterfly larvae (Lepidoptera : Miletinae : Miletini) and their ant-tended hemipteran prey in Thailand and the Philippines. *J. Natural History*, 43: 569-581.
- Lower, H. F., 1968, Hard to kill pests of fruit crops. *J. Agric. South Australia*, 72: 75-77.
- Maduri, T., 2012, Investigation on the management of pink mealybug on mulberry using the plant products. *M. Sc. Thesis. Univ. Agric. Sci., Bangalore (India)*.
- Mahima, A. S. and Prasanna Kumar, S., 2010, <http://silkwormmori.blogspot.in/2010/07/diversity-of-insects-in-mulberry.html>
- Makadia, R. R., Kabaria, B. B., Jethva, D. M. and Virani, V. R., 2009, Effectiveness of *Vorticillium lecanii* against *Maconellicoccus hirsutus* on custard apple. *Ann. Pl. Protec. Sci.*, 17(2): 494-496.
- Malleshaiah, 1995, Potential of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) as a bio-control agent of citrus mealybug, *P. citri*. *M. Sc. (Agri) Thesis*, Univ. Agric. Sci., Bangalore (India).
- Malleshaiah, Rajagopal, B. K. and Gowda, K. N. M., 2000, Biology of citrus mealybug, *Planococcus citri* (Risso) (Hemiptera : Pseudococcidae). *Crop Res.*, 20(1): 130-133.
- Mani, M., 1986, Distribution, bioecology and management of the grape mealybug *Maconellicoccus hirsutus* (Green) with special reference to its natural enemies. *Ph. D Thesis*. Univ. Agric. Sci., Bangalore, (India).
- Mani, M., 1989, A review of the pink mealybug – *Maconellicoccus hirsutus*. *Insect Sci. Applic.*, 10: 157-167.
- Mani, M., 1990, Rid of the grapevine mealybug. *Indian Hort.*, 35(3): 28-29.
- Mani, M. and Krishnamoorthy, A., 1989, Feeding potential and development of green lacewing *Mallada boninensis* (Okamoto) on the grape mealybug, *Maconellicoccus hirsutus* (Green). *Entomon*, 14(1 & 2): 19-20.
- Mani, M. and Krishnamoorthy, A., 1990, Natural suppression of mealybugs in guava orchards. *Entomon*, 15(3 & 4): 245-247.
- Mani, M. and Krishnamoorthy, A., 1996, Biological suppression of oriental mealybug, *Planococcus lilacinus* (Ckll.) on ber. *Pest Manage. Hort. Ecosystems*, 2: 49-50.
- Mani, M. and Krishnamoorhty, A., 1997, Supression of *Planococcus citri* (Risso) on sapota. *Pest Manage. Hort. Ecosystems*, 3(1): 45 -57.

- Mani, M., Krishnamoorthy, A. and Pattar, G.L., 1995, Biological control of mango mealybug, *Rastrococcus iceryoides* (Green) (Homoptera; Pseudococcidae). *Pest Manag. Hort. Ecosystems*, 1; 15-20.
- Mani, M. and Thontadarya, T. S., 1987a, Record of mealybug species on grapevine in Karnataka. *Curr. Sci.*, 56: 1192.
- Mani, M. and Thontadarya, T. S., 1987b, Development and feeding potential of coccinellid predator, *Cryptolaemus montrouzieri* Muls. on the grape mealybug, *Maconellicoccus hirsutus* (Green). *J. Biol. Control*, 1(1): 19-22.
- Mani, M. and Thontadarya, T. S., 1987c, Population dynamics of the mealybug, *Maconellicoccus hirsutus* (Green) and its natural enemies in the grapevine ecosystem. *J. Biol. Control*, 1(2): 93-97.
- Mani, M., Thontadarya, T. S. and Singh, S. P., 1987, Record of natural enemies on the grape mealybug, *Maconellicoccus hirsutus* (Green). *Curr. Sci.*, 56: 624-625.
- Manjunath, T. M., 1985, India- *Maconellicoccus hirsutus* on grapevine. *FAO Pl. Protec. Bull.*, 33(2):74.
- Manjunath, D., Kishore, R., Satyaprasad, K., Vinod Kumar, Pradip Kumar and Datta, R.K., 1992, Biology of mulberry mealy bug and predatory potential of its biocontrol agent. *Annual Report* (1992-93), Central Sericultural Research and Training Institute, Mysore, pp.50-51.
- Mayne, W. V., 1953, *Cryptolaemus montrouzieri* Muls. in South India. *Nature*, 172: 85.
- *McKenzie, H. L., 1967, Mealybugs of California, Berkeley and Los Angeles. University of California Press, p. 525.
- Merlin, J., Lemeitre, O. and Gregoire, J. C., 1996, Oviposition in *Cryptolaemus montrouzieri* stimulated by wax filament of its prey. *Entomologia Experimentalis et Applicata*, 79(2): 141-146.
- Michaud, J. P. and Evans, G. A., 2000, Current status of pink hibiscus mealybug in Puerto Rico including a key to parasitoid species. *Florida Entomologist*, 83(1): 97-101.
- Mineo, G., 1967, *Cryptolaemus montrouzieri* – observations on morphology and bionomics. *Boll. Inst. Entomol. Agr. Oss Fitopat. Palermo*, 6: 99-143.
- Mishra, B. K., Mishra, I. and Mandal, S. M. A., 2012, Predatory potentiality of *Cryptolaemus montrouzieri* Muls. On pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) and papaya mealybug, *Paracoccus marginatus* Williams and Granara De Willink. *J. Pl. Protec. Environ.*, 9(2): 39-41.
- Misra, C. S., 1919, "Turka" disease of mulberry. *Proc. Third Entomol. Meeting*, Pusa, pp. 610-618.
- Mourier, M., 1997, Effect of neem (*Azadirachta indica*) kernel water extract on Cassava mealybug, *Phenacoccus manihoti* (Hom: Pseudococcidae). *J. Appl. Ent.*, 121(4): 231-236.
- *Moursi, A. A., 1948, Contributions to the knowledge of natural enemies of mealybugs. *Anagyrus kamali* Moursi, (Hymenoptera: Encyrtidae) a parasite of the *Hibiscus* mealybug, *Phenacoccus hirsutus* Green. *Bull. Soc. Fouad. Entomol.*, 32: 9-16.
- Muhammad Mamoon-Ur-Rashid, Masood Khan Khattak, Khalid Abdullah and Sajjad Hussain, 2011, Toxic and residual activities of selected insecticides and neem oil against cotton mealybug, *phenacoccus solenopsis* tinsley (sternorrhyncha: pseudococcidae) under laboratory and field conditions. *Pak. Entomol.*, 33(2): 151-155.
- Mukhopadhyay, S. K., Santha Kumar, M. V., Saha, A. K. and Bajpai, A. K., 2012, Management of pink mealybug, *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae), a major pest of mulberry (*Morus alba* L.) with botanicals. *Uttar Pradesh J. Zool.*, 31(1):9-14.
- Murthy, G. R. and Babu, T. R., 1996, Seasonal fluctuations of mealybug population on custard apple and grape. *J. Res. APAU*, 24(1-2): 87-91.
- Murthy, M. S. and Narayana, K. L., 1986a. Biology of *Cryptolaemus montrouzieri* M. (Coccinellidae; Coleoptera) a predatory beetle of mealybugs. *Indian Grape J.*, 2: 40-52.
- Murthy, M. S. and Narayana, K. L., 1986b. Feeding potential of the predatory beetle, *Cryptolaemus montrouzieri* Muls. on grape and citrus mealybug. *Indian Grape J.*, 2(2-3): 53-59.

- Muthukrishnan, N., Manmohan, T., Thirumalai Thevan and Anbu, S., 2005, Evaluation of buprofezin for the management of grape mealybug, *Maconellicoccus hirsutus* (Green). *J. Ent. Res.*, 29(4): 339-344.
- Nalini, T. and Manickavasagam, S., 2011, Records of Encyrtidae (Hymenoptera: Chalcidoidea) parasitoids on mealybugs (Hemiptera: Pseudococcidae) from Tamil Nadu, India. *J. Species Lists and Distribution*. 7(4): 510-515.
- Narasimha Rao, B., Narayana, K. L. and Krishnamurthy Rao, B. H., 1977, Control of mealybug on grapevine. *Pesticides*, 17(3): 49-51.
- *Ogilvie, L., 1926, Report of the plant pathologists for the year 1925, *Bermuda. Rep. Dept. Agric.*, 1925, pp. 36-63.
- *Oncuer, O. and Baylan, N., 1982, An investigation into feeding capacity and diet of *Cryptolaemus montrouzieri*. *Turkeye Bitki koruma Dergesi*, 6: 85-90.
- Padmaja, C. H., Babu, T. R., Reddy, D. D. R. and Sriramulu, M., 1995, Biology and predation potential of *Scymnus coccivora* Ayyar (Coleoptera; Coccinellidae) on mealybug. *J. Ent. Res.*, 19(1): 79-81.
- Panse, V. G. and Sukhatme, P. V., 1978, *Statistical Methods for Agricultural Workers*. ICAR Publications, New Delhi, p. 359.
- Patel, M. G., Jhala, R. C., Vaghela, N. M. and Chauhan, N. R., 2010, Bio-efficacy of buprofezin against *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) an invasive pest of cotton. *Karnataka J. Agric. Sci.*, 23(1): 14-18.
- Pinjarakar, D. B., Vennila, S., Ramamurthy, V. V., Kranthi, K. R., Ghodki, B. S. and Deshmukh, A. J., 2009, Diversity and abundance of Hymenopteran parasitoids of mealybug in rainfed cotton. *Proc. Nation. Symp. Bt Cotton: Opportunities and Prospects*, CICR, Nagpur. p. 127.
- Pradhan, S., Jotwani, M. G. and Rai, B. K., 1962. The neem seed deterrent to locust. *Indian Fmg.*, 12(8) : 7-11.
- Pushpaveni, G., Rao, P. R. M. and Rao, P. A., 1973, A new record of *Spalgis epius* Westwood as a predator of *Maconellicoccus hirsutus* Gr. on mesta (*Hibiscus sabdariffa* L.). *Indian J. Entomol.*, 32: 71.
- Puttarudraiah, M. and Murthy, E., 1976, *Planococcoides* sp. nr. *robusta*, a mango root mealybug and its control. *Curr. Res.*, 5: 205-207.
- Rahiman, A. P. and Vijayalakshmi, C. K., 1998, *Spalgis epius* Westwood (Lepidoptera : Lycaenidae) - a potential predator of coffee mealybugs. *J. Ent. Res.*, 22: 191-192.
- Raman, K. R., 1958, A new pest of importance on grapevine in Madhurai district. *South Indian Hort.*, 6: 64-66.
- Ramchandra Rao, 1926, The pollu disease of pepper. *J. Madras Agric. Univ.*, 1: 6.
- Raman Suresh Babu, Davi Dorcus and Munisami Vivekanadan, 1994, Changes in morpho-physiology, water relations and nutrients in tukra diseased leaves of a few mulberry varieties. *J. Seric. Sci. Japan*, 63: 183-188.
- Ranga Reddy, A. and Lakshminarayana, K., 1987, A new record of mealybug, *Maconellicoccus hirsutus* (Green) as a pest of grapevine, *Vitis vinifera* in Andhra Pradesh. *Indian J. Entomol.*, 49(3): 449-450.
- Ranga Reddy, A. and Lakshminarayana, K., 1986, Studies on the biology and control of grape mealybug. *Indian Grape J.*, 2: 32-39.
- Rao, T. V. and David, L. A., 1958, The biological control of coccid pest in South India by use of beetle, *Cryptolaemus montrouzieri* Mulsant. *Indian J. Agric. Sci.*, 28: 545-552.
- Rao, V. P., 1967, Biological control projects of the Commonwealth Institute of Biological Control, Indian Station, Bangalore-6, India. *Internal Adv. Commonwealth Inst. Biol. Control Information Bull.*, 2: 16

- Rao, V. P., Ghani, M. A., Sankaran, T. and Mathur, K. C., 1971, A review of the biological control of insects and other pests in South East Asia and Pacific region. *Commonwealth Inst. Biol. Tech. Communi.*, 6: 142.
- Rao, P. R. M., Kanagaraju, A., Appa Rao, R. V. and Azam, K. M., 1984, New record of predators on mealybug of mesta. *Andhara Pradesh Agric. J.*, 31: 83.
- Rawat, R. R. and Modi, B. N., 1969, Record of some predaceous beetle of coccids, aphids and mite pests from Madhya Pradesh. *Indian J. Agric. Sci.*, 39(11): 1057-1060.
- Reddy, G. V. P., Muniappan, R., Cruz, Z. T., Naz, F., Bamba, J. P. and Tenorio, J., 2009, Present status of *M. hirsutus* (Homoptera; Psuedococcidae) in the Mariana Islands and its control by two fortuitously introduced natural enemies. *J. Econ. Entomol.*, 102(4): 1431-1439.
- Rosas Garcia, N. M. and Parra Bracamonte, G. M., 2011, Incidence of the pink hibiscus mealybug in mango cultivars from Nayarit, Mexico. *Acta Zool. Mexicana*, 27(2): 407-418.
- Russell, R. and Paterson, M., 2006, Fungi and fungal toxins as weapons. *Mycological Res.*, 110: 1003-1010.
- Saini, R. K., Pala Ram, Sharma, S. S. and Rohilla, H. R., 2009, Mealybug (*Phenacoccus solenopsis* Tinsley) and its survival in cotton ecosystem in Haryana. *Proc. National Symp. Bt Cotton: Opportunities and Prospects*, CICR, Nagpur, p. 102.
- Satyanarayanamurthy, M., 1982, Studies on the biology and habits of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera). *M. Sc. (Agri.) Thesis*, Acharya N. G. Ranga Agric. Univ., Hyderabad (India).
- Sathya Prasad, K. and Dandin, S.B., 2005, Screening of plant extracts for insecticidal properties against mealybug, *Annual Report*, Central Sericultural Research and Training Institute, Mysore, p. 40.
- Satyanarayana, C., Yadava Babu, R. K. and Manjunatha, M., 2003, Preliminary studies on botanicals against *Maconellicoccus hirsutus* (Green). *Insect Environ.*, 9(3): 114-115.
- Satyaseelan, V. and Bhaskaran, V., 2010, Efficacy of some native botanicals extracts on the repellency property against the pink mealybug, *Maconellicoccus hirsutus* (Green) in mulberry crop. *Rec. Res. Sci. Techn.*, 2(10): 35-38.
- Shafqat, S., Munir, A., Mushtaq, A. and Kwon, Y. J., 2007, Insecticidal control of the mealybug, *Phenacoccus gossypiphilous* (Hemiptera: Pseudococcidae) a new pest of cotton in Pakistan. *Entomol. Res.*, 37(2): 76-80.
- Shekhar, K., 2001, The study on life history, feeding potential and safety of insecticides to predatory beetle, *Cryptolaemus montrouzieri* Mulsant under laboratory condition. *M. Sc. Thesis*, Marathwada Agric. Univ., Parbhani, Maharashtra (India).
- Shelke, R. K., 2001, Biology and biointensive methods of management of grapevine mealybug, *Maconellicoccus hirsutus* (Green). *M. Sc. (Agri.) Thesis*, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (India).
- Shirke, M. S. and Salunkhe, G. N., 1996, Biology and effect of food on adult longevity and fecundity of *C. Montrouzieri* Muls. a predator on mealybug. *J. Maharashtra Agric. Univ.*, 21(2): 301-302.
- Shreedhar Rao, A., Sreeramalu, M. and Azam, K. M., 1988, Comparison of certain insecticides with other insecticides against grape mealybug, *Maconellicoccus hirsutus* (Green). *Pestology*, 12(11): 22-23.
- Shreedharan, S., Seemanthini, R. and Thunmburaj, S., 1989, Association of weather factors with the population dynamics of green bug and mealybug in Mandarin orange in Shevroy hills of Tamil Nadu. *South Indian Hort.*, 37(5): 267-269.
- Shekhar, M.A. and Sathya Prasad, K., 1998, Control of mealybug using neem based insecticides. *Annual Report*, CSR&TI, Mysore, p.42.
- Shukla, R. P. and Tandon, P. L., 1984, Use of insecticides for control of *Phanococcus pacificus* (Cox), a mealybug of custard apple. *Entomon*, 9(3): 181-183.

- Singh, M. P. and Ghosh, S. N., 1970, Studies on *Maconellicoccus hirsutus* causing bunchy top in mesta. *Indian J. Sci. Industry*, 4: 99-105.
- Singh, S. P., 1978, Propagation of a coccinellid beetle for the biological control of citrus and coffee mealybugs. *Scientific Conf. CPA*. Dec. 1978, pp. 2.
- Sinha, P. K. Sayeed, M. Z. and Dinesh, D. S., 1985, A report on the mealybug (Hemiptera : Pseudococcidae), their host plants and natural enemies at Bhagalpur. *Proc. National Acad. Sci. India*, 55(2): 13-17.
- Samuthiravelu, P., Ravikumar, J., Qadri, S. M. H., Hemanthkumar, L. and Jayaraj, S., 2010, Influence of abiotic factors on population dynamics of leaf webber, *Diaphania pulverulentalis* and its natural enemies in Mulberry. *J. Biopesticides*, 3(1) Special Issue: 37 – 42.
- Smith, H. S. and Armitage, H. M., 1920, Biological control of mealybugs attacking citrus. *California Agric. Expt. Sta. Bull.*, 9: 104-158.
- Solangi, G.S., Lohar, M.K., Abro, G.H. and Buriro, A.S., 2012, Biology and release of exotic predator, *Cryptolaemus montrouzieri* Mulsant on mealybug, *Phenacoccus solenopsis* Tinsley at Tandojam. *Sarhad J. Agric.*, 28(3):429-435.
- Srinivas, T., Prasad, K. S., Shekhar, M. A. and Manjunath, D., 2007, Evaluation on neem based formulations vis-a-vis dichlorvos against *Maconellicoccus hirsutus*. *Uttar Pradesh J. Zool.*, 27(1): 13-20.
- Srinivasan, T. R., 1994, Mass culture of *Cryptolaemu montrouzieri* Mulsant. *J. Coffee Res.*, 9: 80-81.
- Srinivasan, T. R. and Sundara Babu, P. C., 1989, Field evaluation of *Cryptolaemus montrouzieri* Mulsant, the coccinellid predator against grapevine mealybug, *Maconellicoccus hirsutus* (Green). *South Indian Hort.*, 37(1): 50-51.
- Su, T. H. and Wang, C. M., 1988, Control measure for the citrus mealybugs and latania scale insects of grapevine. *Pl. Prot. Bull.*, Taiwan, 30(3): 279-288.
- Subba Rao, B. R., Sangwar, H. S., Abbasi, O. A., Singh, Y. and Kesheer Sagar, A. M., 1965, New records of hymenopterous parasites of *Nipaecoccus vastator* Maskell (Homoptera : Coccidae), a serious pest of Citrus spp. in India. *Indian J. Entomol.*, 27: 119-110.
- Sunitha, N. D., Jagginavar, S. B. and Biradar, A. P., 2009, Bioefficacy of botanicals and new insecticides against grape vine mealybug, *Maconellicoccus hirsutus* (Green). *Karnataka J. Agric. Sci.*, 22 (3-Spl. issue): 710-711.
- Suresh, S., Jothimani, R., Sivasubramanian, P., Karuppuachamy, R., Samiyappan and Jonathan, I., 2010, Invasive mealybugs of Tamil Nadu and their management. *Karnataka J. Agric. Sci.*, 23(1): 6-9.
- Sureshan, P. M. and Narendran, T. C., 2005, Description of a new species of *Ophelosia* Riley with synonymic and taxonomic notes on Indian Eunotinae (Hymenoptera: Chalcidoidea: Pteromalidae), *Zoo. Print. J.*, 20(5): 1984-1985.
- Tanwar, R. K., Jeyakumar, P., Monga, D., Kuraar, R. and Singh, A., 2008, Mealybugs and their management in cotton. *Extension Folder*. NCIPM, New Delhi.
- Tawfik, M. F. S., Hafez, M. and Said, B., 1962, Studies of *Scymnus* (= *Pullus*) *syriacus* Mar. (Coleoptera : Coccinellidae). *Bull. Soc. Ent. Egypte*, 46: 485-504.
- Tejkumar, S., Aftab Ahmed, M. and Dharamaraju, E., 1977, Occurrence of the mealybug, *Pseudococcus* spp. a serious pest of grapevine around Hyderabad. *Indian J. Entomol.*, 39: 189-190.
- Thangamalar, A., Subramaian, S. and Mahalingam, C. A., 2010, Bionomics of papaya mealybug, *Paracoccus marginatus* and its predator *Spalgis epius* in mulberry ecosystem. *Karnataka J. Agric. Sci.*, 23: 39–41.
- *Ujjan, A. A. and Shahzad, S., 2007, Pathogenicity of *Metarhizium anisopliae* var *acridum* strains on pink hibiscus mealybug (*Maconellicoccus hirsutus*) affecting cotton crop. *Pakistan J. Botany*, 39(3): 967-973.

- *Van der Goot, P., 1920, The introduction into Java of new and beneficial coccinellid, *Cryptolaemus montrouzieri* M. Teysnman. *Batarria*, 31: 456-473, 493-510.
- Venugopal, A., Harihararaju, A. and Jayaraj, S., 2004, Efficacy of botanicals on tukra mealybug in mulberry –An eco-friendly approach under irrigated pest management. In: *Progress of Research on Disease and Pest management*, [Eds. R. Govindan, Ramakrishna Naika and B. Sannappa], Seri Scientific Publishers, Bangalore, pp.77-77.
- *Vaughn, M., Walter, J. B., Jocelyn, G. M., Monica L. C., Peter, J. B. and Glenn, Y. Y., 2006, Developing a pheromone based mating disruption program for the vine mealybug. www.uckac.edu.
- Veeranna, G., Nirmala, M. R. and Ramegowda, T., 2000, Neem seed kernel extract (NSKE) for the management of mealybug, *Maconellicoccus hirsutus* (Green) causing Tukra to mulberry. *Bioorganics in Sericulture and Related Technologies of KSSRDI*. Pp. 81-82.
- Verghese, A., 1997, Effect of neem on first instar crawlers of the grape mealybug, *Maconellicoccus hirsutus* (Green). *Insect Environ.*, 2(4): 121-122.
- Verghese, A. and Tandon, P.L., 1987, Pest management in grapevine and guava. *Annual Report*, Indian Institute of Horticultural Research, Bangalore, pp. 61.
- Wadhi, S. R. and Batra, H. N., 1964, Pests of tropical and subtropical fruit trees. In: *Entomology in India*. Entomological Society of India, New Delhi, 227-260.
- *Whitcomb, W. D., 1940, Biological control of mealybugs in green houses. *Bull. Mass. Agric. Expt. Sta. Bull.*, 37: 22.
- *Wiltshire, E. P., 1948, The Lepidoptera of the Kingdom of Egypt part-I. *Bull. Soc. Fouad Ier. Ent.*, 32: 203-298.

* - Originals not seen

Appendix I. Weekly Meteorological data of Regional Agricultural Research Station, Bijapur for the year 2009

Std. Week No.	Temperature (°C)		Relative humidity (%)		Wind speed	Sunshine (h)	Rainfall (mm)	Pan Evaporation (mm/day)
	Maximum	Minimum	Morning	Afternoon	(kmph)			
1	30.3	12.5	77.9	41.1	2.6	10.0	0.0	5.1
2	30.2	15.4	88.0	38.6	5.5	10.1	0.0	4.8
3	29.8	12.0	84.7	35.4	5.1	10.2	0.0	5.1
4	33.2	12.2	64.3	26.9	3.5	10.6	0.0	6.0
5	34.7	15.0	60.0	28.6	2.8	10.4	0.0	6.5
6	34.0	17.1	59.3	34.7	3.2	10.2	0.0	6.8
7	33.7	15.9	55.3	33.0	5.0	10.1	0.0	7.3
8	35.1	18.4	53.1	28.4	5.2	10.2	0.0	8.8
9	37.7	16.7	43.7	28.3	4.2	10.6	0.0	9.7
10	37.3	20.7	49.7	25.1	7.0	10.1	0.0	10.2
11	35.3	19.5	65.6	25.4	5.7	8.7	0.4	8.3
12	36.2	20.6	54.9	30.3	7.0	8.6	0.2	8.8
13	37.4	23.1	53.1	28.3	6.3	8.5	0.0	8.7
14	39.0	23.3	63.9	28.1	5.4	7.5	0.6	9.3
15	38.1	23.6	57.4	26.4	7.7	8.4	0.0	9.7
16	40.5	24.6	59.3	25.3	11.3	8.4	0.0	11.6
17	40.1	24.6	57.3	18.9	10.2	8.1	2.8	12.5
18	40.8	23.7	65.9	25.4	12.3	4.1	5.2	12.0
19	40.5	23.8	55.4	26.0	9.9	2.0	0.0	12.8
20	38.8	22.5	81.6	37.4	12.6	7.0	63.8	8.5
21	34.9	22.2	83.1	42.0	13.9	6.9	67.6	7.3
22	37.7	23.2	80.1	34.1	13.0	9.9	0.6	9.8
23	34.5	22.7	81.9	49.4	13.0	7.1	13.4	8.1
24	35.1	21.6	87.7	48.3	11.6	7.4	83.2	8.7
25	33.1	21.8	86.7	53.3	11.0	6.7	72.0	7.8
26	32.4	21.7	85.0	51.1	14.2	6.4	0.0	6.9
27	30.8	21.8	87.7	63.9	15.4	3.8	11.4	6.1
28	29.2	21.6	90.1	71.6	15.8	2.7	14.8	3.8
29	29.9	22.4	87.0	66.4	17.1	4.1	1.8	4.3
30	30.6	21.6	86.6	66.4	16.9	5.7	5.8	6.2
31	31.6	21.0	89.0	52.4	14.0	5.5	1.0	5.7
32	32.5	21.4	87.6	57.6	14.8	5.4	0.8	6.4
33	32.7	21.7	89.9	54.6	9.6	6.0	30.4	5.9
34	29.4	20.4	93.7	76.3	6.3	2.6	164.9	3.5
35	30.9	21.1	89.4	63.7	12.0	6.5	9.6	4.9
36	29.6	20.8	89.9	60.3	12.9	4.6	77.6	4.8
37	31.1	21.3	92.0	68.4	5.8	6.5	26.2	4.3
38	32.1	21.6	87.9	61.1	5.5	6.6	50.8	4.6
39	31.5	21.1	93.3	67.1	8.3	5.5	175.4	5.4
40	28.1	20.8	93.7	74.7	13.6	2.3	216.0	3.5
41	30.0	21.3	90.6	66.1	3.9	5.7	37.0	4.1
42	32.0	20.0	80.7	53.4	2.2	7.2	0.0	4.1
43	31.8	16.0	74.4	42.3	3.0	10.2	0.0	5.5
44	32.0	16.1	72.9	46.4	4.4	8.8	0.0	5.1
45	29.8	19.2	87.4	66.9	7.4	5.4	9.6	4.9
46	30.0	20.9	91.6	66.0	5.1	5.0	19.6	3.5
47	29.2	16.9	85.1	52.9	2.8	8.1	14.8	3.2
48	29.6	13.4	83.3	47.1	2.4	0.0	0.0	3.8
49	30.4	13.7	80.6	42.6	2.5	9.5	0.0	3.8
50	29.5	13.4	89.3	50.4	3.6	9.2	0.0	4.0
51	29.1	15.8	89.3	51.4	4.4	4.9	0.0	3.9
52	28.1	14.6	86.0	56.5	4.4	6.1	19.0	4.0

Appendix II. Weekly Meteorological data of Regional Agricultural Research Station, Bijapur for the year 2010

Std. Week No.	Temperature (°C)		Relative humidity (%)		Wind speed	Sunshine (h)	Rainfall (mm)	Pan Evaporation (mm/day)
	Maximum	Minimum	Morning	Afternoon	(kmph)			
1	29.5	14.7	86.0	50.4	2.4	8.2	0.0	3.8
2	28.2	17.1	88.3	60.7	2.5	4.1	1.0	2.8
3	28.9	15.0	89.3	48.0	3.9	7.1	13.0	3.5
4	28.5	11.1	80.1	38.6	3.2	9.6	0.0	4.2
5	30.5	14.9	76.0	37.0	3.3	8.7	0.0	4.3
6	31.5	15.2	74.0	33.1	4.6	9.5	0.0	6.2
7	34.5	18.6	72.1	41.7	2.9	9.2	1.2	5.5
8	36.0	17.6	63.1	27.9	3.5	8.5	0.0	6.6
9	35.9	18.1	61.9	26.3	4.3	9.4	0.0	8.2
10	36.8	19.7	48.3	25.3	5.4	8.1	0.0	8.0
11	36.8	20.0	53.6	21.1	5.6	3.5	0.0	8.8
12	38.4	18.9	60.6	16.3	4.5	8.3	0.0	9.9
13	38.7	21.6	61.0	19.4	6.9	7.8	0.0	9.3
14	39.5	21.9	41.7	18.7	6.4	9.2	0.0	10.8
15	40.3	24.2	62.7	21.0	8.5	7.5	0.0	11.5
16	40.1	22.9	65.7	20.6	8.9	8.9	17.8	10.8
17	40.6	26.0	57.6	17.0	8.9	8.2	0.0	11.2
18	36.8	22.3	72.6	26.9	7.8	7.4	14.8	7.9
19	41.3	26.1	57.3	17.6	9.1	8.7	0.0	11.8
20	41.7	24.6	76.6	20.0	12.4	8.6	27.2	11.2
21	39.3	24.2	74.9	27.3	16.5	7.6	8.2	11.1
22	38.7	23.5	71.6	34.5	12.9	9.1	14.2	10.9
23	37.7	23.8	75.9	37.4	13.8	8.9	51.4	10.9
24	31.3	22.6	90.9	63.7	10.7	2.4	45.1	4.9
25	33.2	22.6	88.4	52.0	13.6	5.0	33.8	6.6
26	32.4	22.7	85.7	74.0	13.1	5.8	0.0	6.1
27	30.9	22.0	90.4	56.0	12.2	3.9	54.5	5.8
28	33.0	22.3	90.3	53.7	11.5	4.1	7.0	5.7
29	30.4	22.0	91.1	71.9	12.8	3.1	51.8	4.9
30	28.0	21.9	92.9	75.3	13.4	1.1	24.9	2.5
31	29.6	21.9	88.1	65.3	14.7	3.4	3.4	4.4
32	31.8	21.8	85.6	54.4	13.2	5.8	0.8	5.7
33	29.7	22.2	93.3	68.1	8.1	3.5	93.2	4.1
34	30.1	22.0	93.6	68.6	8.8	4.1	89.6	3.8
35	27.9	21.5	92.4	75.7	11.2	2.7	24.0	3.1
36	30.1	21.6	90.4	61.0	13.2	3.2	3.9	4.2
37	30.4	21.3	88.3	59.0	9.0	3.9	5.8	4.4
38	30.7	21.6	89.7	60.1	6.5	3.8	63.9	4.0
39	31.5	21.9	89.6	54.6	4.8	7.4	8.6	4.3
40	31.7	21.3	85.9	53.7	5.3	7.3	44.0	5.0
41	32.2	20.5	87.1	37.0	5.5	6.3	9.4	4.6
42	30.0	21.3	93.1	63.4	8.1	4.0	51.4	4.3
43	30.5	19.7	91.1	51.3	5.1	7.4	1.0	4.0
44	28.8	18.8	86.7	56.3	7.7	5.3	4.2	3.9
45	28.3	20.0	93.4	63.3	6.1	3.7	27.2	3.2
46	30.2	21.0	95.1	59.7	4.6	6.8	17.0	3.7
47	30.4	18.3	88.7	52.0	4.1	7.3	10.4	3.8
48	29.4	16.6	90.9	45.4	3.9	0.0	0.0	4.0
49	28.1	16.5	89.0	51.4	4.5	5.0	0.0	3.6
50	27.9	14.9	87.1	46.3	4.3	6.2	1.4	3.3
51	28.2	8.0	81.3	27.0	3.0	10.2	0.0	4.3
52	29.1	11.6	82.9	41.3	3.2	8.8	0.0	3.8

Appendix III. Weekly Meteorological data of Regional Agricultural Research Station, Bijapur for the year 2011

Std. Week No.	Temperature (°C)		Relative humidity (%)		Wind speed (kmph)	Sunshine (h)	Rainfall (mm)	Pan Evaporation (mm/day)
	Maximum	Minimum	Morning	Afternoon				
1	28.9	13.5	84.4	38.7	3.7	5.5	0.0	3.1
2	29.7	8.6	70.6	25.7	2.6	9.9	0.0	4.1
3	31.5	10.6	76.7	24.1	2.6	10.2	0.0	5.1
4	31.4	11.2	79.0	23.4	3.6	10.3	0.0	4.7
5	31.9	13.7	72.3	24.7	4.4	10.2	0.0	5.3
6	32.4	12.6	58.6	21.4	3.8	10.2	0.0	5.6
7	32.2	14.8	64.0	26.1	5.2	10.1	0.0	6.1
8	32.7	17.6	0.0	33.7	5.9	8.8	0.2	5.5
9	33.4	20.0	59.3	28.9	5.6	8.4	0.0	5.9
10	36.7	19.2	40.6	16.6	6.0	9.8	0.0	9.2
11	36.3	19.3	49.1	17.1	5.5	9.9	0.0	9.2
12	37.0	20.5	54.0	19.6	6.3	9.7	0.0	9.3
13	37.2	21.5	49.6	21.0	6.2	9.2	0.0	9.2
14	37.2	20.1	50.9	21.4	7.5	9.4	5.2	9.7
15	36.3	22.7	62.1	28.9	6.7	6.9	6.2	7.1
16	37.5	22.8	65.4	28.4	9.4	6.3	2.8	8.1
17	37.7	23.5	70.9	25.7	8.4	5.9	3.0	7.4
18	38.5	23.2	70.9	25.1	10.9	8.3	32.0	9.4
19	37.8	23.1	73.4	24.4	11.6	8.4	0.2	9.7
20	39.3	24.3	71.1	42.6	10.9	12.5	0.6	9.9
21	37.8	23.5	85.4	63.0	12.6	9.3	1.2	9.3
22	35.9	22.9	90.6	72.2	11.8	7.0	67.8	6.7
23	31.3	22.2	89.9	75.6	11.7	5.5	35.9	4.4
24	32.4	22.0	90.6	73.4	17.7	4.8	1.6	6.3
25	32.5	22.0	90.0	65.7	19.1	5.8	0.0	7.9
26	32.9	22.3	85.0	74.0	18.9	4.6	0.0	7.2
27	32.1	21.7	90.9	59.9	13.1	4.1	31.7	5.8
28	31.8	21.3	87.0	56.5	16.3	5.6	41.0	5.9
29	30.1	22.2	89.2	65.2	17.9	3.1	0.6	4.9
30	30.7	21.4	89.4	65.0	13.7	4.2	69.0	6.1
31	29.7	21.4	90.4	65.6	14.7	2.9	22.0	4.4
32	31.1	22.1	88.1	62.3	15.0	5.4	7.6	5.1
33	31.7	21.7	88.3	57.9	13.1	4.9	15.6	6.6
34	29.7	21.6	90.7	73.4	8.7	2.2	63.2	3.0
35	28.2	21.7	89.0	71.4	14.2	2.4	22.6	3.1
36	30.5	21.5	87.3	52.9	15.7	4.3	0.0	5.3
37	32.1	21.1	86.0	52.7	10.2	6.5	11.8	5.1
38	30.9	20.0	85.3	51.0	11.7	5.6	0.0	4.6
39	31.7	20.0	89.4	56.3	6.5	5.2	44.1	3.6
40	31.9	21.5	85.3	50.4	6.4	5.9	2.6	4.5
41	33.2	21.4	81.6	51.3	5.8	6.4	1.2	4.1
42	32.7	21.3	81.6	50.4	4.1	7.3	60.4	5.0
43	31.8	19.8	77.3	42.1	6.5	8.3	0.0	5.2
44	30.9	19.5	85.7	49.3	5.1	7.2	0.3	4.4
45	31.8	15.4	64.9	30.4	4.4	9.3	0.0	4.8
46	31.5	15.5	69.9	31.1	4.3	9.6	0.0	4.9
47	30.6	13.4	71.1	36.3	4.5	9.9	0.0	4.8
48	29.7	18.2	78.6	49.7	6.7	3.0	0.0	3.7
49	31.3	14.0	76.6	34.6	3.1	8.7	0.0	4.1
50	30.8	15.5	83.7	39.6	3.2	6.9	0.0	4.2
51	29.3	11.5	83.9	32.4	3.6	8.7	0.0	3.4
52	30.4	12.3	68.1	27.8	3.2	8.8	0.0	3.8

Appendix IV. Weekly Meteorological data of Main Agricultural Research Station, Dharwad for the year 2009

Std. Week No.	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Afternoon	
1	28.0	12.9	69.1	37.1	0.0
2	29.0	13.8	77.3	40.9	0.0
3	28.7	11.9	74.0	40.6	0.0
4	31.8	13.4	53.7	24.1	0.0
5	33.1	16.3	56.4	25.9	0.0
6	32.2	16.1	59.1	28.4	0.0
7	32.3	15.8	55.9	23.1	0.0
8	34.1	17.5	54.4	18.8	0.0
9	36.2	18.9	54.6	17.0	0.0
10	35.5	20.1	75.4	22.9	0.0
11	34.2	20.2	82.1	26.9	0.0
12	34.9	19.5	70.3	27.9	28.8
13	35.1	20.5	79.0	25.7	0.0
14	36.7	21.4	84.6	25.9	0.8
15	36.0	20.7	71.3	30.1	4.6
16	36.7	21.3	85.3	29.3	0.6
17	36.8	21.2	82.0	28.6	26.2
18	36.7	21.5	78.9	30.0	0.0
19	38.1	21.5	77.6	25.0	2.4
20	35.3	21.4	89.0	39.6	27.6
21	32.8	21.5	87.9	48.1	27.6
22	33.6	21.2	87.9	51.6	34.0
23	30.2	21.1	92.0	61.4	44.6
24	31.7	21.1	91.3	58.6	60.2
25	30.0	20.6	89.6	63.7	38.8
26	28.2	20.6	90.1	74.6	12.6
27	26.1	20.7	93.6	87.3	53.0
28	25.1	20.8	94.4	86.4	87.0
29	25.6	21.1	93.4	84.6	91.0
30	26.6	21.0	92.0	77.3	15.2
31	27.3	20.8	90.9	73.0	15.2
32	27.9	20.8	89.1	68.3	3.4
33	29.0	20.5	89.9	63.0	29.4
34	28.0	20.6	90.6	80.1	25.6
35	28.1	20.5	89.6	69.7	4.4
36	26.6	20.3	93.0	77.1	18.0
37	29.0	20.6	94.4	64.9	31.4
38	29.2	20.7	93.4	74.7	78.0
39	29.2	20.6	92.1	72.7	101.0
40	25.7	20.4	92.9	77.7	126.6
41	29.0	19.9	87.6	63.1	14.4
42	31.2	19.2	78.1	43.4	0.0
43	31.0	15.9	60.4	33.3	0.0
44	31.0	16.3	84.3	38.6	0.0
45	27.8	19.7	90.9	66.7	25.2
46	29.2	20.3	92.1	60.4	20.2
47	28.6	18.2	85.1	59.1	0.6
48	28.7	14.7	74.4	49.0	0.0
49	29.4	14.9	75.7	37.0	0.0
50	29.0	13.9	77.3	40.7	0.0
51	28.0	16.9	88.6	62.9	67.2
52	26.8	16.4	90.5	57.3	9.0

Appendix V. Weekly Meteorological data of Main Agricultural Research Station, Dharwad for the year 2010

Std. Week No.	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Afternoon	
1	28.2	15.5	84.6	49.7	0.0
2	27.9	17.7	87.4	58.4	0.8
3	28.5	15.9	86.9	48.0	0.0
4	27.8	12.8	66.1	31.7	0.0
5	29.5	14.7	75.3	34.9	0.0
6	30.6	15.1	67.9	28.6	0.0
7	33.2	18.7	72.4	33.3	0.0
8	34.5	19.0	78.6	28.0	0.4
9	34.4	19.2	73.4	27.6	0.0
10	35.5	20.1	63.6	23.6	0.0
11	35.6	20.3	64.9	20.9	0.0
12	36.6	20.5	79.9	18.1	0.0
13	36.4	20.3	80.7	26.0	0.0
14	37.8	21.6	76.7	20.4	0.0
15	38.4	22.6	81.0	25.3	0.0
16	37.1	21.9	78.9	36.7	17.6
17	37.6	22.6	82.7	29.0	25.4
18	34.4	21.0	66.6	52.3	19.2
19	37.4	23.0	76.4	60.0	36.0
20	36.9	22.8	70.3	52.4	1.6
21	34.9	22.7	76.4	58.9	7.1
22	35.4	22.7	66.4	57.1	0.6
23	35.1	22.1	64.9	59.7	1.6
24	29.5	21.6	88.6	81.9	35.2
25	29.2	21.3	86.7	79.1	18.0
26	29.4	21.5	87.7	77.4	9.6
27	27.4	20.8	85.1	84.9	21.4
28	30.2	20.9	86.1	64.4	0.0
29	27.8	20.8	90.0	83.4	24.0
30	54.5	20.8	94.4	86.9	96.8
31	26.3	20.8	92.3	79.7	35.1
32	28.4	20.9	90.6	73.3	6.4
33	28.9	20.8	92.1	72.0	14.8
34	27.6	20.7	94.3	77.0	95.2
35	25.8	20.4	95.7	78.4	68.2
36	23.5	20.7	92.0	80.6	8.1
37	23.5	20.2	93.1	71.4	4.8
38	23.5	19.5	88.0	85.1	62.6
39	23.5	20.5	92.6	73.9	71.6
40	30.0	19.9	90.3	65.4	69.6
41	29.7	20.1	89.7	67.1	9.4
42	27.3	20.4	92.4	72.3	37.6
43	28.7	19.1	85.7	73.7	58.2
44	19.6	17.9	84.4	61.9	21.6
45	23.0	19.5	92.0	73.9	47.6
46	29.3	19.6	91.3	59.3	0.2
47	29.2	18.9	86.9	70.4	25.6
48	28.4	17.1	85.0	50.4	0.0
49	27.3	16.1	87.3	52.0	0.0
50	26.7	15.1	83.0	64.8	0.6
51	27.3	11.7	65.6	44.9	0.0
52	28.2	16.2	81.0	52.0	0.0

**Appendix VI. Weekly Meteorological data of MainAgricultural Research Station,
Dharwad for the year 2011**

Std. Week No.	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Afternoon	
1	27.8	13.4	86.7	51.4	0.0
2	28.6	11.1	65.0	58.7	0.0
3	29.9	13.1	75.3	44.1	0.0
4	29.8	12.4	67.3	26.3	0.0
5	30.4	13.2	65.6	24.1	0.0
6	31.1	12.1	55.6	20.4	0.0
7	30.6	14.2	68.0	29.6	0.0
8	30.7	15.4	84.6	32.9	21.6
9	32.5	16.5	70.9	28.1	0.0
10	35.5	17.7	48.0	18.3	0.0
11	35.0	18.4	53.0	18.9	0.0
12	35.6	18.8	76.1	24.0	0.0
13	36.0	20.6	80.7	26.9	0.8
14	35.4	17.9	70.1	20.1	0.0
15	34.2	20.2	81.3	34.0	40.4
16	34.6	20.7	85.0	35.7	35.2
17	34.9	21.7	88.1	34.4	1.8
18	35.5	21.4	84.3	31.7	7.2
19	35.1	21.0	83.7	28.3	6.6
20	35.2	21.8	89.6	35.7	17.2
21	34.4	21.3	85.0	40.0	15.8
22	32.6	21.2	92.4	58.7	83.4
23	27.0	21.4	94.6	81.9	27.2
24	26.3	20.8	92.9	78.9	38.0
25	27.1	21.2	92.4	71.3	47.6
26	27.7	21.3	93.1	71.4	23.6
27	27.6	20.4	93.3	76.9	42.2
28	27.1	20.3	94.1	75.3	11.0
29	25.9	21.1	94.6	81.9	36.8
30	26.7	20.8	94.6	77.4	33.0
31	26.2	20.4	94.9	82.7	41.8
32	26.7	21.2	93.6	77.1	14.2
33	26.9	20.7	93.3	77.0	8.4
34	28.2	20.5	93.0	72.4	24.4
35	24.9	20.6	97.0	88.8	57.2
36	26.0	20.7	95.3	80.7	45.8
37	28.9	20.3	91.4	66.9	4.8
38	28.2	19.5	90.0	64.1	7.0
39	30.0	18.6	87.9	53.3	5.4
40	30.0	19.5	89.7	63.7	39.2
41	29.9	20.2	92.0	58.4	132.8
42	29.8	20.1	93.5	57.3	44.3
43	29.8	19.0	84.4	54.0	2.0
44	30.0	18.2	88.9	54.7	2.6
45	30.6	15.7	69.9	31.3	0.0
46	30.2	15.0	62.4	32.4	0.0
47	29.7	13.0	64.6	33.7	0.0
48	29.1	19.0	86.7	52.9	3.4
49	30.5	14.7	74.4	35.7	0.0
50	29.9	14.9	74.3	51.0	0.0
51	28.3	11.8	72.1	36.4	0.0
52	29.2	12.7	68.0	35.1	0.0

Appendix VII. Cost of inputs used in pest management studies

Sl. No	Technical name	Trade name	Cost of the chemical (Rs/l or kg)	Quantity required per hectare (1000 l/ha)
1	Thiacloprid 240 SC	Alanto	2200	200 ml
2	Thiamethoxam 25 WG	Actara	3700	300 g
3	Imidacloprid 70 WG	Admire	5600	300
4	Imidacloprid 17.8 SL	Confidor	2400	300 ml
5	Buprofezin 25 SC	Applaud	1100	2000 ml
6	Bifenthrin 10 EC	Talstar	1000	1000 ml
7	Profenophos 50 EC	Probate	450	2000 ml
8	Dimethoate 30 EC	Rogor	400	1700 ml
9	Dichlorvos 76 EC	Nuvan	450	700 ml
10	Neem oil	-	150	20 l
11	Neem seeds	-	3	50 kg
12	<i>L. lecanii</i>	-	150	300 g
13	<i>M. anisopliae</i>	-	150	300 g
14	Dhanuvit	-	150	1000 ml
15	Fish oil rosin soap	-	150	5000 ml
16	Labours (Spraying)	-	200	4 Nos.

BIOLOGY OF *Cryptolaemus montrouzieri* Mulsant AND MANAGEMENT OF GRAPEVINE MEALYBUG, *Maconellicoccus hirsutus* (Green)

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2013

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Major Advisor

ABSTRACT

The investigation on “Biology of *Cryptolaemus montrouzieri* Mulsant and management of grapevine mealybug, *Maconellicoccus hirsutus* (Green)” were conducted during 2009 to 2011.

The *C. montrouzieri* took 3.68, 4.68, 5.80 and 5.58 days to complete first, second, third and fourth instar by feeding 3.02, 7.52, 47.03 and 83.75 mealybugs, respectively. Predatory adult male and female survived for 58.18 and 62.48 days by feeding 38.00 and 42.97 mealybugs, respectively. Among the prediction models developed, the model $LW1=68.03 - 0.6X_3$ (X_3 = morning relative humidity) could be used by substituting current week's weather data, to predict mealybug population a week ahead. Seven predators four, two and one from coccinellids, dipterans and lepidopteran, respectively and twelve hymenopterans parasitoids were recorded on grape vine mealybug.

The laboratory experiment showed that, biology and feeding potential of first, second, third and fourth instar and adult male and female of *C. montrouzieri* was more when fed on second instar than third instar mealybugs. With respect to biorational studied under laboratory and field conditions, the efficacy of neem (NSKE and neem oil) based botanicals mixed with adjuvants with or without entomopathogens were showed higher per cent mortality of different instars of mealybugs as compared to other botanicals tested. Whereas, the different insecticides tested on mealybug were found more effective, among them bifenthrin, imidacloprid 70 WG, imidacloprid 17.8 SL and dichlorvos were highly effective in recording per cent mortality on mealybugs under laboratory and field condition. Regarding grape fruit yield, the imidacloprid 70 WG recorded highest fruit yield (37.92 t/ha), followed by bifenthrin (37.21 t/ha) and imidacloprid 17.8 SL (36.21 t/ha). Among the biorationals, the application of NSKE @ 5% + Dhanuvit @ 1 ml/l (29.82 t/ha), neem oil @ 2% + FORS @ 5 ml/l + *M. anisopliae* @ 2.0 g/l (29.69 t/ha) and neem oil @ 2% + Dhanuvit @1 ml/l (29.51 t/ha) registered highest fruit yield.