Diversity of Hemipteran Pests of Cotton *(Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them

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VIJAY SINGH KIRAR

Thesis

Master of Science in Agriculture

(Entomology)

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DEPARTMENT OF ENTOMOLOGY

RAJASTHAN COLLEGE OF AGRICULTURE

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Dated: / /2013

This is to certify that **Mr. Vijay Singh Kirar** has successfully completed the Comprehensive Examination held on 21/06/ 2013 as required under the regulation for the degree of **Master's degree in Agriculture** (Entomology).

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This is to certify that the thesis entitled **"Diversity of Hemipteran Pests of cotton *(Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them"** submitted for the degree of **Master of Science in Agriculture** in the subject of **Entomology,** embodies bonafide research work carried out by **Mr. Vijay Singh Kirar** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the Advisory Committee on _______________.

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This is to certify that **Mr. Vijay Singh Kirar o**f the **Department of Entomology**, Rajasthan College of Agriculture, Udaipur has made all corrections/ modifications in the thesis entitled, "**Diversity of Hemipteran Pests of cotto**n ***(Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them**" which were suggested by the External Examiner and the Advisory Committee in the oral examination held on __________. The final copies of the thesis duly bound and corrected were submitted on __________ are enclosed herewith for approval.

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Enclose: One original and two copies of bound thesis forwarded to the Director Resident Instructions, Maharana Pratap University of Agriculture and Technology, Udaipur, through the Dean, Rajasthan College of Agriculture, Udaipur.

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“Diversity of Hemipteran Pests of Cotton (*Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them”

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ABSTRACT

The investigation on “**Diversity of Hemipteran Pests of Cotton (*Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them**” was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur during *kharif* season (June to November 2012), with the objectives of studying their seasonal incidence, species diversity and evaluating the relative bio-efficacy of newer insecticides. The major sap-sucking insect pests recorded on cotton, included the cotton jassids (*Amrasca biguttula biguttula* Ishida.), aphids (*Aphis gossypii* Glover), whitefly (*Bemisia tabaci* Genn.), red cotton bug *(Dysdercus koenigii* Fabricius), dusky cotton bug (*Oxycarenus laetus* Kirby) and thrips (*Thrips tabaci* Linnman). The hemipteran species diversity comprised 6 different insects *viz*., the cotton jassid (*Amrasca biguttula biguttula*), aphid (*Aphis gossypii* Glover), whitefly (*Bemisia tabaci*), red cotton bug (*Dysdercus koenigii koenigii*), the dusky cotton bug (*Oxycarenus laetus*) and the predatory pyrrhocorid bug (*Antilochus coqueberti* Fabricius). The population peak for thrips (33.87 thrips/plant) was noted during second week of August, those for jassid (21.87 jassids/plant) and whitefly (20.33 whiteflies/plant) were recorded during fourth week of August; whereas, for aphids (36.27 aphids/plant), was recorded during last week of august, 2012. The peak population levels for red cotton bug (15.33 red cotton bug /plant) and dusky cotton bug (14.27 dusky cotton bug/plant) were observed during last week of October and first week of November 2012, respectively. The linear relationship between abiotic factors of environment and population of sap-sucking insect pests showed significant positive correlation with mean relative humidity for jassid and whitefly; but significant negative correlation for red cotton bug. The dusky cotton bug population showed a significant negative correlation with mean atmosphere temperature.

The relative bio-efficacy of the tested insecticides showed that three sprays of imidacloprid 200 SL @ 125 ml ha^{-1} at ten days interval resulted in maximum mean reduction of aphid population with 89.44 per cent, acetamiprid 20 SP (100 g a.i. ha^{-1}) caused maximum mean reduction of whitefly population 88.13 per cent and fipronil 200 SC (300 ml ha^{-1}) caused maximum mean reduction of jassid and thrips (89.52 and 90.09% population reduction), respectively. Dimethioate 30 EC @ 660 ml ha^{-1} was least effective against jassids (69.83% population reduction), whitefly (70.80% population reduction) and thrips (77.86% population

reduction) and spiromesifen 240 SC @ 500 ml ha^{-1} against aphids (69.68% population reduction).

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1. INTRODUCTION

Cotton (*Gossypium hirsutum*) the 'White Gold', is one of the most important commercial/cash crops playing a key role in Indian agriculture and economics. It is cultivated in varied agro-climatic conditions across nine major states of India covering 12.20 m ha area with the production and productivity of 37.10 m bales and 484 kg per hectare, respectively. In Rajasthan, this crop occupies an area of 5.30 lakh hectares with production of 17.10 lakh bales and productivity of 548 kg per hectare, respectively (Annual Report of CAB, 2011-12).

Cotton is known to be infested by 1326 insect pests all over the world (Hargreaves, 1948 and Santham, 1997); however, only 166 of them are known to cause damage to the crop in India and of these only 12 have been recorded as major pests due to their recurrent occurrence almost every year in serious proportion in one or other agro-climatic zones. These important insect pests are aphid, (*Aphis gossypii* Glover; Aphididae, Hemiptera) (Leclant and Deguine, 1994); green leaf hopper, *(Amrasca biguttula biguttula* Ishida; jassidae: Hemiptera) (Metthews, 1994) whitefly, (*Bemisia tabaci* Gennadius; Aleyrodidae: Hemiptera) (Butler and Hennerberry, 1994); cotton thrips, (*Thrips tabaci* Linnman, Thripidae: Thysanoptera) (Bournier,1994); red cotton bug, *(Dysdercus koenigii* Fabricius, Pyrrhocoreidae: Hemiptera); dusky cotton bug, (*Oxycarenus laetus* Kirby, Lygaeidae: hemiptera); bollworm complex *viz.*, spotted bollworm, (*Earias vittela* Fabricius, Noctuidae: Lepidoptera); spiny bollworm, *(Earias insulana* Bolsduval, Noctuidae: Lepidoptera); pink bollworm, (*Pectinophora gossypiella* Saunders, Gelechiidae) (Patil and Bheemanna, 1998); American bollworm, (*Helicoverpa armigera* Hübner, Noctuidae: Lepidoptera); leaf worms *viz.*, semi-looper (*Anomis flava* Walker, Noctuidae: Lepidoptera); leaf roller (*Sylepta derogata* Fab., Pyraustidae: Lepidoptera) and army worm (*Mythimna separata* Walker, Noctuidae: Lepidoptera).

The adoption of Bt cotton has drastically reduced the lepidopteran insect problem leading to an increase in cotton area. In 2011-12, the adoption of Bt cotton in India, for the first time soared past the 10 million hectare milestone, reaching or 88% of the 12.1 million hectare. The adoption of Bt cotton also has exhibited a consistent and significant downward trend in the pesticide consumption in cotton agro ecosystem. Since the introduction of Bt cotton in 2002-03. Notably, Bt cotton halved insecticide uses from 46% of total insecticides used in 2001-02 to 21% of total insecticide used in India in 2010. The increase in Bt cotton has changed the insect pest spectrum leading to increase in sap-sucking insect pests that happen to cause serious losses at vegetative stage. (Ravichandran, 2012).

Among the sucking pests, jassids, *A. biguttula biguttula* (Ishida); thrips, *Thrips tabaci* (Linn.); aphids, *A. gossypii* (Glover); and whiteflies, *B. tabaci* (Genn.) are important from seedling stage and cause heavy losses to the tune of 21.20 to 22.86 per cent (Kulkarani *et al.*, 2003 and Satpute *et al.*, 1990) and also vectors for a number of viral diseases (Sreedhar *et al.*, 1999). The yield loss in *Gossypium hirsutum* cotton due to sucking pests, bollworms and both has been recorded up to 8.45, 16.55 and 17.35 quintal ha^{-1}, respectively whereas, out of 14 per cent losses recorded in total agriculture due to insect pests, 84 per cent is reported in cotton (Oerke *et al* 1994).

The heavy infestation of nymphs and adults of sucking pests results in leaf yellowing, wrinkled leaves, leaf distortion, oily spots on leaves and retarded growth and development of the plant due to sucking the cell sap from surface of leaves, ultimately the plant dried due to loss of cell sap. They also secrete honey dew which helps in the development of sooty mould fungus on leaves. The fungus inhibits the photosynthetic activity of the plants resulting into chlorosis which reduced the seed cotton yield. Moreover, whitefly also transmits leaf curl disease in cotton and act as a vector. The pest populations are being maintained below economic injury levels using different control tactics. The indiscriminate and unregulated use of insecticides has resulted in to severe problems like development of resistance by insects to insecticides, resurgence of pests outbreak of secondary pests, problem of residues, toxicity to non target organisms, environmental pollution etc. However, in spite of these, newer insecticides have come to stay in our modern farming, which may not be dispensed off due to their efficacy and economic. In order to avoid adverse consequences of use of persistence insecticides it becomes necessary to evaluate the new molecules against insect pests for their host specificity and safety to natural enemies which manage the pest without ill effects. Keeping the above mentioned facts in view, the present investigation was carried out with following objectives:

i. To study the seasonal incidence of hemipteran pests of cotton.

ii. To record the species diversity of hemipteran pests of cotton.

iii. To evaluate the bio-efficacy of some newer insecticides against the hemipteran pests.

2. REVIEW OF LITERATURE

The available literature on seasonal incidence, species diversity and bio-efficacy of some newer insecticides against the hemipteran insect-pests (sap-sucking) of cotton has been compiled here below in this chapter.

2.1. SEASONAL INCIDENCE OF HEMIPTERAN PESTS OF COTTON:

2.1.1 Jassids [*Amarsca biguttula biguttula*(Ishida)

The pest attacks crop during the first 50 days after sowing and is severe in early winter. Both adults and nymphs of jassids suck sap from underside of the leaves which show symptoms of "hopper burn" such as yellowing, curling, bronzing and sometimes drying up.

Bishnoi *et al*. (1996) reported 27-34^{0}C temperature and 52 – 82% humidity range for built up the jassid population in cotton, while for whitefly the respective values were 25-30^0 C and 40 – 58%. Sharma and Sharma (1997) observed that jassid population showed negative correlation with the maximum temperature and positive correlation with the minimum temperature and average relative humidity. The activity of jassid in Karjan (Gujarat) was started from second week of August and continued till third week of January with peak activity in August, whereas at Chanod and Timbarva villages of Shinortaluka of Gujarat the pest remained above ETL throughout the crop season (Anon., 2000).

Raja *et al.* (2004) recorded the activity of jassid on Bt cotton cultivar MECH-162 Bt from 3 to 19 weeks after sowing with a peak population of 32.97/15 leaves. Bairwa *et al.* (2005) conducted field experiment on effect of date of sowing on the incidence of jassids and whitefly on okra. They observed that infestation of pests increased with delay in sowing and highest yield of 32.02q/ha was obtained under the earliest sowing. Mohan *et al.* (2005) revealed that the Bt cotton was attacked by the jassid from the third week of August to third week of October (30th to 42nd SMW). Singh *et al.* (2005) observed the incidence of jassid from third week of August to last week of December. The highest population density was recorded during the first week of November, when average temperature and RH were 22.5˚C and 69.0 per cent, respectively.

Purohit *et al.* (2006) found negative association between all abiotic factors and aphid, while it was positive with jassid and whitefly in cotton cultivar GH-8. As par the report of Aheer *et al.* (2006) maximum temperature exerted significant and negative effect on the nymphal population of jassid while, minimum and average temperature and relative humidity showed positive and significant correlation with the adult population of jassid with r-values of 0.592, 0.532 and 0.581, respectively. The impact of average temperature and rainfall was also significant and positive on adult population of jassid. The incidence of jassid started from second week of June and reached at peak (90/30 leaves) in the month of August in cotton variety RST-9 at Tonk, Rajasthan (Dhaka and Pareek, 2008). In Haryana, the peak incidence of jassid (2.58/3 leaves) was found during 30th SMW in Bt cotton *cv.* MRC 6304 hybrid (Jeyakumar *et al.,* 2008).

Mohapatra (2008) reported that three major sucking-pests i.e. leaf hopper, aphid and whitefly infest the crop from 30th standard week to 50th standard week. Peak population of leaf hopper, whitefly and aphid was attained during 41st std. week (Oct. 8-14), 44th std. week (Oct. 29-Nov. 4) and 35th std. week (Aug. 27-Sept. 2), respectively. Among the weather parameters, temperature showed a positive correlation with leaf hopper and aphid. The mean RH favoured the activity of leaf hopper and aphid. Effect of rainfall was adverse on aphid but was favourable for the activity of leaf hopper. As per the report of Prasad *et al.* (2008) the peak incidence of leaf hoppers was observed from the 37th to 47th SMW (mid September to November). The highest population of jassid was observed during second week of July on cotton in Pakistan (Shuaib *et al.,* 2008).

Shitole and Patel (2009) reported the higher incidence of jassid (5/3 leaves) during last week of August *i.e.* 35th SMW in cotton *cv*. Hy-10. Meena *et al.* (2010) conducted field experiment on the incidence of jassid and whitefly and their correlation with temperature, relative humidity and rainfall. They observed that the incidence of jassid and whitefly was started in the first week of August and touched peak during second half of September. They further reported that the correlation between pest population and abiotic factors was non significant. Zanwar and Deosarkar (2011) reported varied incidence of jassid from low to moderate throughout the cropping season of cotton.

Kumar and Sharma (2012) observed that jassid remained active throughout the cropping season with its peak during 30th (1.3/3 leaves) and 31st (1.0/3 leaves) SMW. The jassid population exhibited negative correlation with morning and mean relative humidity and rainfall, while other parameters showed positive influence on the jassid population.

2.1.2 Aphid [*Aphis gossypii* (Glover)]

It is a major insect pest of cotton and infests the crop during entire growing duration. Aphids are usually found on the stems, terminals and underside of the leaves, resulting in upward curling and twisting of leaves. Each aphid makes several punctures and excretes honeydew, which encourages development of sooty mold on the twigs and leaves, and this makes plants look blackish. Honeydew attracts ants and sooty mold, aiding to the development of pathogenic bacteria.

Senapati and Mohanty (1980) reported that *A. gossypii* infests cotton during August to February. The incidence was high during August to January. Gupta *et al.,* (1997) recorded the incidence of *A. gossypii* at the fourth week stage of the cotton crop. The peak population was recorded during the last week of July to mid August (at 24.8 – 30.1˚C Temp. and above 87% RH). El-Jadd *et al.* (2000) reported two periods of rapid resurgence of *A. gossypii i.e.*, June-July and September with the highest density reaching later in the month accompanied by considerable indirect economic loss. They also reported that resurgence on cotton depends mainly on the date and density of contamination flights. The activity of aphid was recorded on Bt cotton (MECH-162) from 3 to 9 weeks after sowing with peak population of 310.56/15 leaves (Raja *et al.*, 2004). According to Kengegowda *et al.* (2005) the incidence of aphid started from third week of October and attained peak in the last week of November on cotton.

Mohan *et al.* (2005) revealed that the Bt cotton attacked by the aphid from third week of August to third week of October. In Rajasthan, the incidence of aphid was started in the first fortnight of July and reached at peak during fourth week of August during 2004 on cotton. (Purohit *et al.*, 2006) reported that the higher activity of aphid was observed from the 35th to 37th Standard Meteorological Week (SMW) i.e. in September during 2001-03, while it was from the 32nd to 34th SMW (August) in the succeeding years. The peak incidence of pest varied widely among various seasons from the 33rd to 2nd SMW (mid August to mid January). The aphid infestation was at peak during mid August in cotton (Anon., 2008b). Shitole and Patel (2009) observed that the incidence of aphid was maximum (7.0/3 leaves) during last week of August i.e. 35th SMW on cotton *cv*. Hy-10.

Shitole and Patel (2009) observed that aphid, jassid and thrips population exhibited significant positive correlation with average temperature, relative humidity (maximum, minimum and average), rainfall, rainy days and wind velocity whereas, temperature, relative humidity, sunshine hours and evaporation failed to establish any significant impact on the population of whitefly. Shivanna *et al.* (2009) observed that aphids remain active throughout the year except in July, August and September which received high rainfall. The peak incidence was observed in three leaves in second fortnight of May. The minimum temperature and rainfall was negatively correlated with aphid population and with relatively humidity it was not significant.

Soujanya *et al.* (2010) recorded the initial incidence of aphids during 34th standard week (4th week of August) and the peak incidence during 39th standard week (4th week of September) to 46th standard week (3rd week of November). Bhute *et al.*, (2012) reported that the incidence of aphids was highest (86.45/aphids/3 leaves) during 37th MW of *kharif* 2007-08. While in *kharif* 2008-09 the peak incidence of aphids (75.40 / 3 leaves) was observed in 35th MW. The weather parameters viz., rainfall, rainy days, morning RH and evening RH showed significant and negative correlation with aphid population.

2.1.3 Whitefly [*Bemisia tabaci* (Gennadius)]

The nymph found in large numbers on the under surface of leaves and drain of sap due to sucking in case of severe infestation results in premature defoliation, development of sooty mould on honey dew excreted and shedding of buds and bolls and bad boll opening.

Borah (1995) reported the incidence of whiteflies on cotton along with the 12 species of other pests, major among them were *Amrasca biguttula biguttula, B. tabaci* and *A. gossypii* throughout the growing period. Abou-Elhagag (1998) reported that whitefly occurred in relatively lower numbers during early season and later on disappeared from cotton fields, which reappeared and increased again in relatively higher numbers during the second half of the growing season. Patel *et al*. (1999) reported the first appearance of whitefly in cotton at nine weeks after sowing. Farman *et al.* (2004) observed that white fly was first observed in mid May that reached its peak in July. The lowest population was observed in the end of September. Mohan *et al.* (2005) revealed that Bt cotton was found to be attacked by whitefly from the third week of August to third week of October. Purohit *et al.* (2006) reported that whitefly appeared in the first week of July and attained its peak during second week of August (12/3 leaves) followed by third week of September (11.58) on cotton cultivar GH-8. Acharya and Singh (2007) reported that whitefly population remained very low up-to last week of July and thereafter increased gradually and reached its peak in the month of September and then declined irrespective of sowing date. The population was higher in late sown crop as compared to early sown crop throughout the season.

The peak infestation of whitely was recorded between mid August and September at Nagpur (Anon., 2008c). Dhaka and Pareek (2008) observed that incidence of whitefly on cotton cultivar RST-9 was started from the second week of June and reached to its peak in first week of October and remained active throughout the growth period of the crop. Jeyakumar *et al.* (2008) observed that the whitefly population was higher (more than 3 whitefly adults per three leaves) during 31st, 33rd, 36th and 37th SMW. The population reached at its peak at during 37th SMW in cotton *cv.* NCS 913 (4.98/3 leaves) followed by RCH 314 Bt (4.6).

The peak incidence of whiteflies was observed from the 44th to 48th SMW (November) in Andhra Pradesh, India (Prasad *et al*., 2008). Shuaib *et al.* (2008) observed that the peak population of whitefly (6.66 per leaf) was recorded during first week of July in Khanewal, Pakistan. Anita and Nandihalli (2008) reported that the incidence of jassids, aphids and whitefly was started in first of April and touched its peak during last week of June, first week of July and last week of April, respectively. Shuaib *et al.* (2008) reported that temperature had a positive effect on the population of whitefly (r = 0.5649), thrips (0.4428) and jassid (0.7204) whereas, relative humidity did not showed significant effect on these insect pests. The incidence of whitefly was started at 35th SMW and reached at peak (3.8/3 leaves) during 39th SMW i.e. fourth week of September (Shitole and Patel, 2009). Whereas, Shivanna *et al.* (2009) reported whitefly from April to May. During second forthnight of April, 2008, a peak with 29.50 whteflies per leaves was observed. Population declined below ETL from June first fortnight onwards and similar trend was continued up to January. The maximum temperature also correlated positively with whitefly population. Magar and Nirmal (2010) reported that date of sowing had significantly affect the incidence of yellowing vein mosaic disease, whitefly population and yield of okra. The further observed that the crop sown in the month of August had last insect damage and the highest yield in comparison with early sowing crop.

Sana Ashfaq Khan *et al.* (2011) recorded the population dynamics of different insect pests of cotton and found that the densities of insect pests and natural enemies peaked from June to October while, highest density of 5.78 *B. tabaci* leaf^{-1} was recorded on 10th August. Mohammad *et al.* (2012) reported the maximum whitefly population, 21.33 $\pm$ 2.85/leaf. Selvaraj and Ramesh (2012) observed the effect of ecological factors on the incidence and development of whitefly, *B. tabaci* at five different date of sowing on three varieties of cotton. The pest population was started from first week of March on five weeks old crop and acquired its peak in fourth week of July on thirteen weeks old crop. Maximum pest population (7.99/3 leaves) was build up at temperature ranged from 26 ^{0}C to 35 ^{0}C, relative humidity ranges from 84 and 67 per cent, zero rainfall and Whitefly population showed a significant and positive correlation with maximum and minimum temperature whereas, it was significant and negative correlation with evening relative humidity.

2.1.4 Thrips [*Thrips tabaci* (Lindeman)]

The nymphs and adults suck sap from the lower surface of the leaves lacerating the leaf tissues. Upper side of the older leaves turns brown and the lower side becomes silvery white. Leaves become curled, wrinkled and finally get dried. Control of thrips generally results in early crop maturity. The pest is active during May- September.

In an investigation conducted on population dynamics of different pests of cotton revealed that the thrips remained active from September to December being highest during the last week of November (Anonymous, 1991). Patel (1992) reported that thrips infested chilli plants right from the seedling stage in nursery to the entire crop period. Thrips population remained low due to rains during July-August and showed a peak in September to October. Temperatures of 24 to 26 ^{o}C and 63 to 85 per cent relative humidity proved favorable for fast multiplication. However, rainfall and temperature showed negative correlation with the thrips population. In Madhya Pradesh, incidence of thrips (*Thrips tabaci*) on cotton cultivars H-4, H-6, JKH- 1, DCH-32 and AHH-468 was started from 4th week age of cotton crop and observed two peaks; first during second fortnight of August and second during first fortnight of October (Gupta *et al.*, 1997).

Panickar and Patel (2001) reported the activity of *T. tabaci* from second week of August to first week of January in cotton. Deligeorgidis *et al.* (2002) recorded the highest population density of thrips during July and August in cotton. In Andhra Pradesh, the higher activity of thrips was observed in fourth week of September and second week of October on cotton cultivars MECH-162 Bt, MECH-162 non-Bt and NHH-44 (Kengegowda *et al.*, 2005). Mohan *et al.* (2005) revealed that *Bt* cotton is attacked by thrips from third week of August to third week of October. Prasad *et al.* (2008) observed that peak incidence of thrips was observed from the 35^{th} to 39^{th} SMW (September). Peak infestation of thrips was observed during second fortnight of August and on the first week of November in cotton (Anon., 2008c). According to Shuaib *et al.* (2008) peak incidence of thrips (7.5/leaf) was found on 3^{rd} CESA i.e. first week of July.

As par the report of Shitole and Patel (2009) the incidence of thrips was started from last week of August *i.e.* 35^{th} SMW and remained active throughout crop season except in 42^{nd} SMW. The pest reached at peak (8/3 leaves) during 36^{th} SMW in cotton. Shivanna *et al.* (2009) reported that the incidence of thrips was observed throughout the year except during July and August because of high rainfall. The maximum incidence of thrips population was recorded from April to May with a peak incidence of 26.81 thrips per three leaves, recorded in April second fortnight. The maximum temperature correlated positively with thrips population. Sitaramaraju *et al.* (2010) reported the higher activity of thrips during 38^{th} standard weeks. The correlation between thrips and morning relative humidity showed significant negative influence, whereas maximum and minimum temperatures were found positive and significant. Soujanya *et al.* (2010) also reported the peak incidence on 35th to 37th standard week for thrips and 44th to 48th standard week for white flies. Thrips showed positive correlation with maximum & minimum temperature, evening relative humidity and rainfall. The total influence of all the weather parameters was high and significant on the thrips (80.5%), while it was non-significant on whiteflies population. Bhute *et al.* (2012) also reported during 40th SMW thrips population reached at highest incidence (110.10 thrips/3 leaves) in 40th SMW. The maximum temperature showed positively significant correlation with thrips population.

2.1.5 Dusky Cotton Bug [*Oxycarenus laetus* (Kirby)]

Srinivas and Patil (2003) recorded the alternate host of dusky cotton bug (O. laetus) as bhendi (*Abelmoschus esculentus*) in June 2001-July 2001; Indian mallow (*Abutilon indicum*), groundnut, parthenium (*Parthenium hysterophorus*), pundi (*Hibiscus cannabinus*), Tridax procumbens, tulip tree (*Thespesia populnea*) and neem (*Azadirachta indica*). The period of occurrence on different alternate hosts was from May to November. The incidence of Dusky cotton bug, *Oxycarenus spp.*, on alternate hosts wild cherry (*Prunus cerasoides*), curry leaf (*Murraya koenigii*), parthenium and neem have been reported for the first time. The dusky cotton bug infestation started during the first week of December and peaked during April; the maximum and minimum temperature showed positive and significant correlation with the population (Srinivas and Patil, 2004). Similarly, a higher incidence of dusky cotton bug (*Oxycarenus laetus*) was recorded on MECH-184 (Bt cotton) from the 50th to the 5th international standard week (ISW), with peak incidence on the 52nd ISW (12.72 and 17.20 bugs per boll at the research station and farmer's field, respectively), compared to MECH-184 non-Bt and NHH-44 (Patil and Rajnnikantha, 2005).

2.2.1 SPECIES DIVERSITY OF HEMIPTERAN (SAP SUCKING) PESTS OF COTTON:

Insect pests were greatly abundant during the first crop of cotton, with low diversity indices than in second crop. The total species abundance of all 4 cotton cultivars/lines ranged from 10 (*Earias* sp.) to 11431 (*Amrasca biguttula*) in the first crop and from 11 (*Earias* sp.) to 1955 (*Amrasca biguttula*) in the second crop. The ranges of species diversity indices were from 0.27 for Sri Samrong 60 (SR 60) to 0.62 for Sarid 1 (SD1) in the first crop and from 0.61 for SR 60 to 0.83 for SD1 in the second crop. *A. biguttula* was the dominant species in both crops. Other insect pests with less obvious importance were *Thrips palmi*, *Bemisia tabaci*, *Aphis gossypii*, *Megacoelum biseratense* and *Carpophilus* sp. (Khaing *et al.*, 2002). During rainfed season the jassid population was maximum at Thiram Kallupatti (1163, 652, 638, 605, 1027, and 812 jassids per 20 plants in pure cotton, cotton+cowpea, cotton+black gram, cotton+green gram, cotton+sunflower, and cotton+sorghum ecosystems, respectively) and minimum at Aruppukottai (1054, 495, 515, 504, 828, and 652 jassids per 20 plants in the above ecosystems). The same trend was observed for maximum and minimum population in Thirumangalam during summer irrigated season. Among the various cropping systems, cotton+sunflower had the highest population (828, 931, and 1027 during the wet season and 932, 883, and 981 during summer irrigated season at Aruppukottai, Thirumangalam and ThiramKallupatti, respectively). The minimum population was recorded in cotton+cowpea (669, 663 and 721 in Aruppukottai, Thirumangalam and Thiram Kallupatti, respectively). The increase in population was recorded until the third week of December in all the ecosystems and locations during the wet season, while during the summer irrigated season, the peak populations was observed until mid-May (Saminathan *et al.*, 2002).

Michelotto and Busoli (2003) recorded 13 different species of winged aphids *R. padi* (52.6% of total), *A. spiraecola* (26.4%), *A. gossypii* (8.9%), *Rhopalosiphum maidis* (Fitch) (5.3%), *Geopemphigus floccosus* (Moreira) (3.1%), *Uroleucon ambrosiae* (Thomas) (1.5%), *Rhopalosiphum rufiabdominalis* (Sasaki) (1.3%), *Myzus persicae* (Sulzer) (0.4%), *Sipha flava* (Forbes) (0.3%), *Pentalonia nigronervosa* Coquerel (0.1%), *Tetraneura nigriabdominalis* (Sasaki) (0.1%), *Lizerius melanocallis* (Quednau) (0.1%) and *Toxoptera citricidus* (Kirkaldy) (0.1%) collected in water-pan traps; alate and wingless forms of 3 species (*A. gossypii*, *A. spiraecola* and *R. padi*) by direct sampling and 4 species (*R. padi*, *A. spiraecola*, *A. gossypii* and *R. maidis*) in Moerick’s traps from a cotton field.

Butani (1977) listed about 16 insect pest species that damage tomato in India. Important and major among them are: Jassid, *Amrasca biguttula bigtuttula* (Ishida) and *Amrasca punjabensis* (Pruthi); tomato fruit borer, *Helicoverpa armigera* (Hub.); tobacco caterpillar, *Spodoptera* litura (Fab.); thrips, *Thrips tabaci* (Lind.); aphids, *Aphis gossypii* (Clover); *Lipaphis erysimi* (Kalt.); *Myzus persicae* (Sulzer); white fly, *Bemisia tabaci* (Gendius); Epilachna beetle, *Epilachna duodecastigma* (Mulsant); green stink bug, *Nezara viridula* (Linn.) *Gallobelius crassicornis* (D.) and *Engytatus tenius* (R.); white tailed mealy bug, *Ferrisia virgata* (Cockerell). Parihar (2002) recorded *Myzus persicae* and *Aphis gossypii* infesting tomato from Bihar; the population of both the species remained low on tomato in the first fortnight of February and attained the peak during second fortnight of February. Various species of aphids, mostly *Aphis gossypii*, were recorded on tomato (Umeh *et al*., 2002; Reddy and Kumar, 2004).

2.2.2 DIVERSITY OF NATURAL ENEMIES IN COTTON:

Zhang, (1992) a study conducted on natural enemies of *Aphis gossypii* is a major pest of cotton. More than 48 species (belonging to 19 families in 9 orders) of natural enemies of this aphid have been found in cotton fields. Coccinellidae, Araneae and Neuroptera are the most important predators of aphids and other pests in cotton fields. Wang AnYuan and Wang LiPing (1996) observed that in the cotton fields there were abundant predators of cotton insects: 8 species of lady birds [Coccinellidae], 4 species of green lacewings [Chrysopidae], 10 species of spider mite [Acari], 4 species of *Epistrophe* spp. and 3 species of *Orius* spp. The population of predators had two peaks: 25 June-15 July and 25 July-15 August. Duran *et al.* (1998) recorded beneficial bugs (Heteroptera) found in cotton include 4 genera (*Orius, Nabis, Deraeocoris* and *Geocoris*) and 12 species. *Orius laevigatus* was the most abundant, followed by *O. albidipennis*. The genus *Orius* constitutes at present the principal natural enemy, playing an important role in the management of the key pest *Helicoverpa armigera*. Beneficial Heteroptera have two generations in cotton, with up to one million adults/nymphs per hectare,with populations up to 200000 ind./ha., control of the main cotton pests is possible.

Han Xu (2004) using pitfall traps from cotton fields and recorded eight species, belonging to 8 genera and 5 families. Which are believed to be important natural enemies of cotton pests. Shakila Mushtaq *et al.* (2005) the predation evidences directly recorded from an insecticide-free cotton plantation. The biodiversity and relative abundance of spiders predators as well as the feeding niches of nine coexisting spider species in cotton were computed and compared for niche breadth, and niche and specific overlaps. All overlap values were <=1.0, ranging from 0.42 to 0.72, indicating that each spider species had its own feeding niche in the cotton.

2.3 BIO-EFFICACY OF DIFFERENT INSECTICIDES AGAINST HEMIPTERAN (SAP-SUCKING) PESTS OF COTTON:

Saleem *et al.* (2001) evaluated thiamethoxam 25 WG @ 24 gm acre^{-1}, endosulfan 35 EC @ 1000 ml acre^{-1} and imidacloprid 200 SL @ 250 ml acre^{-1} against cotton jassid (*A. Biguttula*

biguttula) and thrips (*T. tabaci*) and reported that imidacloprid effectively managed jassid and thrips up to 7 days after spray, whereas thiamethoxam found effective only up to 7 days as in case of jassid. Bhargava *et al*. (2001) observed the effect of two formulations of imidacloprid, 600 FS and 70 WP, as seed dressers on okra at 5 and 9 ml/kg seeds and 5, 7.5 and 10 g/kg seeds, respectively, for the control of sucking pests during *kharif* season and found that both formulations had no adverse effect on the seed germination of okra. Imidacloprid 600 FS at 9 ml/kg seeds and 70 WP at 10 g/kg seeds were found to be promising against jassid (*Amrasca biguttula biguttula*) and whitefly (*Bemisia tabaci*). Higher yields were recorded for these treatments. Imidacloprid 70 WP at 10 g/kg seeds was at par with the lower rates with respect to almost all parameters. No treatment caused any phytotoxic symptoms on okra. Dhawan and Simwat (2002) reported that thiamethoxam 25 WG @ 25 g a.i. ha^{-1} was found most effective against jassid and reduced the pest population up to 94.53% in cotton. Sharma and Lal (2002) studied the bioefficacy of thiamethoxam (25 g a.i. ha^{-1}) in comparison with bita-cyfluthrin (18.75 g a.i. ha^{-1}), deltamethrin (20 g a.i. ha^{-1}), profenofos (500 g a.i ha^{-1}) and endosulfan (700 g a.i. ha^{-1}) against the leafhopper *Amrasca biguttula biguttula* and white fly *Bemisia tabaci*. Thiamethoxam was superior to other treatments against leafhopper and white fly.

Razaq *et al.* (2003) evaluated efficacy of Actara 25 WG (thiamethoxam) at 500 ml ha^{-1}, Polo 500 SC (diafenthiuron) at 825 ml ha^{-1}, Talstar 10 EC (bifenthrin) at 625 ml, Mospilan 20 SC (acetamiprid) at 312.5 g ha^{-1} and Confidor SL 200 (imidacloprid) at 500 ml ha^{-1}. All treatments were showed excellent toxicity against jassids at 72, 168 and 240 hrs after spray. The insecticides showed varying toxicity against thrips (first spray). Significant differences were observed among the insecticides only at 72 hrs after the second spray against the population of whitefly. Rathod *et al. (*2003) conducted an experiment to determine the efficacy of imidacloprid against jassids (*Amrasca biguttula biguttula*), aphids (*Aphis gossypii*), and thrips (*Thrips tabaci*) infesting cotton. The treatments comprised imidacloprid at 5, 7.5, and 10 g/kg; diafenthiuron 300 and 400 g ha^{-1}; and dimethoate at 1.25 litres ha^{-1}. The lowest mean population of jassids (0.99), aphids (4.41), and thrips (1.73) per 3 leaves were revealed with 10 g imidacloprid/kg, 300 g diafenthiuron/ha and 5 g imidacloprid/kg, respectively. Wadnerkar *et al.* (2003) reported that fipronil @ 50 and 75 g a.i. ha^{-1} was effective in reducing sucking pest population in cotton.

Jat *et al.* (2004) studied the bio-efficacy of some new chemicals, and revealed that the thiamethoxam at 100 g a.i. and difenthiuron at 300 and 400 g a.i. ha^{-1} significantly reduced whitefly population. Muhammad *et al.* (2004) evaluated seven insecticides, *viz.*, acetamiprid 20 SP @ 150 g acre^{-1}, imidacloprid 200 SL @ 250 ml acre^{-1}, bifenthrin 10 EC @ 250 ml acre $^{-1}$, carbosulfan 25 EC @ 500ml acre^{-1}, thiamethoxam 25 WG @ 24 g acre^{-1}, diafenthiuron 50 WP @ 200 ml acre^{-1} and methamidophos 60 SL @ 500 ml acre^{-1} for their efficacy against jassid, whitefly and thrips in cotton. Imidacloprid and acetamiprid against jassid; acetamiprid and thiamethoxam against whitefly; and acetamiprid, imidacloprid and methamidophos against thrips found most effective. As per the report of Srinivasan *et al.* (2004) seed treatment with thiamethoxam 70 WS @ 2.8 g/kg seeds and foliar spray of thiamethoxam 25 WG @ 50 g a. i. ha^{-1} recorded the lowest population of sucking pests compared to imidacloprid 70 WS @ 5 g/kg seeds and foliar spray of imidacloprid 200 SL @ 20 g a. i. ha^{-1}. Ulaganathan and Gupta (2004) evaluated the efficacy of different insecticidal spray schedules against the sucking pests of cotton, i.e. jassids, whiteflies and thrips. The spray schedule incorporated with six rounds of new synthetic insecticide molecules (acetamiprid, imidacloprid, beta-cyfluthrin, spinosad, bifenthrin/indoxacarb and lambda-cyhalothrin) was effective in reducing jassid, whitefly and thrips populations. Ameta and Sharma (2005) evaluated the bioefficacy of imidacloprid against *Aphis gossypii*, *Amrasca biguttula biguttula* and *thrips tabaci* infesting cotton cv.GH-8. It was observed that two sprays of 75 ml Cofidor 350 SC ha^{-1} at 15 days interval exhibited the highest reduction in *Aphis gossypii*, *Amrasca biguttula biguttula* and *T. tabaci* populations, which was at par with 125 ml Confidor 200 SL ha^{-1}. Both Confidor 350 SC and 200 SL did not cause any adverse effect on the grubs and adults of *Chrysoperla carnea* and *Coccinella* spp.

Misra (2005) among 10 insecticides imidacloprid at 25 g and acetamiprid at 20 g was found most effective against the white fly (*Bemisia tabaci*) infesting okra followed by dimethoate at 300 g. Choudhary *et al.* (2005) reported the bioefficacy of imidacloprid (Confidor 350 SC at 60 and 75 ml ha^{-1}and Confidor 70 WG at 30 and 35 g ha^{-1}) against sucking pests of cotton. The highest seed cotton yield was recorded from the plot treated with Confidor 350 SC at 75 ml ha^{-1} (1259.6 kg ha^{-1}), followed by Confidor 350 SC at 60 ml ha^{-1} (1188.8 kg ha^{-1}). Bhalala *et al.* (2006) examined the bio-efficacy of thiamethoxam 25 WG and recommended insecticides, endosulfan and monocrotophos against the sucking pest complex of okra. The okra crop sprayed with thiamethoxam 25 WG at two higher doses (50 and 37.5 g a.i. ha^{-1}) showed effective control of aphid, jassid, whitefly and mite population. Thiamethoxam (50 g a.i. ha^{-1}) yielded higher marketable fruits. Kanna *et al.* (2007) reported the bio-efficacy of acetamiprid 20 SP (10, 20, 40 and 80 g a.i. ha^{-1}) against *Aphis gossypii* and *Amrasca biguttula biguttula* infesting cotton *(Gossypium hirsutum*). Acetamiprid at 20 g a.i. ha^{-1} was highly effective. The biological efficacy increased with increasing rates from 40 to 80 g a.i. ha^{-1} and it did not cause phytotoxicity. Kumar *et al*. (2008) reported that spirotetramat 150 OD at 75 g a.i. ha^{-1} was highly effective in checking the pooulation of aphids and was on par with the standard check, imidacloprid 200 SL at 25g a.i./ha.

Duvaresch *et al*. (2008) conducted a field experiment to find out the efficacy of spirotetramat + imidacloprid in comparison to standard check acetamiprid against cotton aphids. They reported that plot treated with spirotetramat + imidacloprid @ 120 and 144 g a.i. ha^{-1} applied with addition of 0.25% of methylted soy oil was superior to all other treatments. Gosalwad *et al.* (2008) reported the imidacloprid 17.8 SL at 40 g a.i. ha^{-1} was found effective followed by imidacloprid 17.8 SL at 20 g a.i. ha^{-1} and acetamiprid 20 SP at 40 g a.i. ha^{-1} a treatments in the management of sucking pests, such as jassids, aphids, whiteflies and thrips, and also increased yield of okra fruits. Raghuraman *et al*. (2008) examined efficacy of acetamiprid 20% SP at 20, 40, 80 g a.i. ha^{-1} significantly reduced the population of jassid and whitefly up to nine days. All the insecticidal treatments were also found significantly effective against thrips. Bhosle *et al.* (2009) observed that acetamiprid 20 SP @ 100 g a.i. ha^{-1} was most effective in reducing thrips population up to 14 days and harvested higher seed cotton yield (1729.9 kg ha^{-1}). However, it was at par with thiamethoxam 25 WG @ 125 g a.i. ha^{-1}. Kolhe *et al*. (2009) observed that the seed treatment with imidacloprid, acetamiprid and thiamethoxam (at 10 g/kg seed) were the most and equally effective against the aphid, jassid and thrips infestation in cotton. Kumar *et al.* (2009) evaluated spirotetramat 150 OD against cotton whitefly. It was revealed that spirotetramat @ 75 g a.i. ha^{-1} reduced the whitefly population up to 89.7% over control. Imidacloprid @ 25 g a.i. ha^{-1} and acetamiprid @ 20 g a.i. ha^{-1} were also equally effective.

Patil *et al*. (2009) reported the efficacy of fipronil 5% SC @ 800 g ha^{-1} fipronil 40%+imidacloprid 200 SL @ 200 ml ha^{-1} acetamiprid 20 SP @ 100 g ha^{-1} and trizophos 40 EC @ 1500 ml ha^{-1} (standard checks) against sucking pests of cotton. Fipronil 5% SC @ 800 g/ha registered least number of thrips (8.47/3 leaves) found to be on par with acetamiprid 20 SP @ 100 g ha^{-1} (7.80/3 leaves).

Udikeri *et al.* (2009) studied the bio-efficacy of BY1 08330 150 OD (spirotetramat 150 OD) and SYN 13623 and combination product of thiamethoxam 141 SC+ lambda cyhalothrin 106 SC for sucking pests of cotton. The population of thrips, leafhoppers and aphids was brought below ETL with three sprays during 2006 and two sprays in 2007 with different dosages of new chemicals. Boricha *et al.* (2010) reported that thiamethoxam 0.008 per cent and acetamiprid 0.005 per cent were most effective against the cotton thrips and whitefly. Dhawan et al. (2011) reported the bioefficacy of seed treatments with imidacloprid 70 WS (Gaucho) and thiamethoxam 70 WS (Cruiser) against cotton jassid, *Amrasca biguttula* (Ishida). Out of eight treatments, seed treatment with imidacloprid (Gaucho) 70 WS @ 3 g/kg seed, followed by seed treatment of thiamethooxam (Cruiser) 70 WS @ 5 g/kg of seed were found effective in controlling cotton jassid in the early stage of crop and resulted in the highest yield. Kumar and kuttalam (2011) evaluated the bioefficacy of spirotetramat 150 OD alone and in combination with imidacloprid 200 SL (25 g a.i. ha^{-1}), chlorpyriphos 20 EC (300 g a.i. ha^{-1}), monocrotophos 36 SL (250 g a.i. ha^{-1}), carbendazim 50 WP (0.1%) and urea (2%), as foliar spray against sucking pests of cotton *viz*., aphids, thrips and whiteflies. Results revealed that after two consecutive applications of spirotetramat 150 OD @ 75 g a.i. ha^{-1} in combination with imidacloprid 200 SL @ 25 g a.i. ha^{-1} at 15 days interval brought down the aphids, thrips and whitefly population by 94.42, 79.31 and 91.38 per cent, respectively over control. Further, all the combinations were effective and significantly reduced the sucking pest population without causing any phytotoxicity to cotton plant. Shi XiaoBin *et al.* (2011) reported that imidacloprid has been a major neonicotinoid insecticide for controlling *Aphis gossypii*.

Sreekanth and Reddy (2011) examined the efficacy of six new insecticides viz., imidachloprid 200 SL, acetamiprid 20 SP, thiamethoxam 25 WG, diafenthiuron 500 SC, triazophos 40 SC and fipronil 5% SC for their efficacy against the sucking insect pests *viz*., aphid, leafhopper, whitefly and thrips in cotton. The results revealed that the most effective insecticides for aphids and leafhoppers up to seven days were imidachloprid and acetamiprid whereas; the insecticide triazophos was ineffective in controlling aphids. Against thrips, thiamethoxam and fipronil were found to be most effective insecticides while acetamiprid, triazophos and diafenthiuron provided better control of whitefly population. Zidan (2012) the bio-efficacy of three neonicotinoides was studied as seed treatment at two rates 2.45 and 4.9 g a.i./kg seed against early season sucking pests. Data obtained revealed that no insecticide tested as seed treatment provided 100% reduction at the tested rates against the sucking pests. On the other hand, imidacloprid seemed to be more effective than the two thiamethoxam exhibited excellent initial reduction within the 2nd week post treatment, evoking remarkably high reduction reached 89.9, 90.5, 100, 95, 96.3% for thrips, aphids, jassid, whitefly adult and immature, respectively when applying at the recommended rate. Late on, Gaucho exhibited satisfactory residual effectiveness and recorded an overall average reduction of 65.3, 53.7, 48.1, 64.2 and 75% for the prementioned sucking pests, respectively after 8 weeks.

3. MATERIALS AND METHODS

Present investigation on "**Diversity of Hemipteran Pests of Cotton (*Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them**" was carried out at Agronomy Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agricultural and Technology during the year 2012. The materials used and methods adopted during these studies are described here in this chapter.

3.1 FIELD PREPARATION AND SOWING:

The experimental field was prepared during the second week of June by ploughing with the help of disc plough followed by cross harrowing and planking. A well pulverized field was obtained for sowing the seed of cotton. The experiment was laid out in randomized block design having a plot size of 4.5 m × 4.5 m for each replication. The seeds of cotton variety GH-8 (Gujarat Hybrid-8) were sown on 23rd June, 2012 with row to row and plant to plant spacing of 90 cm x 90 cm respectively. Irrigation, hoeing, weeding and other cultural practices and application of FYM and fertilizers were followed as per the recommendations in package of practices for the zone.

3.2 METEOROLOGICAL DATA:

The meteorological data prevailing during the period of experimentation were obtained from the meteorological observatory of Agronomy Farm, Rajasthan College of Agriculture, Udaipur. The meteorological observations of the experimental period are presented in the Appendix-I

3.3 SPECIFIC DETAILS OF THE EXPERIMENT:

3.3.1 SEASONAL INCIDENCE OF HEMIPTERAN PESTS OF COTTON:

3.3.1.1 Layout of experiment:

The proposed investigation on seasonal incidence of insect pests of cotton was conducted during *kharif* 2012. Cotton variety GH-8 was sown at the Instructional Farm of Rajasthan

College of agriculture, Udaipur, Rajasthan. To record the seasonal incidence of insect pests infesting cotton crop, the experiment was laid in uniformly sized plots measuring 4.5m × 4.5m replicated three times. Variety GH-8 (Gujarat Hybrid) grown under natural conditions without spraying the insecticides were maintained at row to row and plant to plant spacing of 90cm × 90cm, respectively. Five plants per plot were selected randomly and tagged for recording the observations for insect pests and natural enemies.

Records of the following for each pest were maintained:

a) First appearance of insect pests

b) Peak period of influence

c) Lowest period of incidence

3.3.1.2 Observation:

Population of jassids, thrips, white flies, aphids, red cotton bug and dusky cotton bug were recorded after 7 days of germination at weekly interval from 5 tagged plants selected at randomly during morning hours between 6:30 a.m. to 8:00 a.m., when most of the insect species remain less active.

3.3.1.3 Sampling techniques:

The sampling techniques adopted for estimation of population of different insect pests was as given below:

(i) Jassids, Thrips and Whiteflies:

The population of jassids, thrips and whiteflies were recorded on three leaves, one each from the basal, middle and upper portion of the 5 tagged untreated plants. The population was estimated by gently holding the leaf between the halves of Petriplate (10 cm diameter) and then counting of adults and the nymphs within the Petriplate. However, when the nymphal stage exists direct counting of the population was done with the help of magnifying lens**.** An aspirator was used to collect the adults for identification**.**

(ii) Aphids:

The population of aphids was counted from the five tagged plants in each plot. The counting of aphids was done on three leaves chosen from the top, middle and bottom of each plant. For the purpose of recording the aphid's population marked leaf were grasped at the petiole by thumb and finger and turned until the entire under surface of leaf was clearly visible. With the help of magnifying lens, the aphids present were counted and population was expressed on a per plant basis.

(iii) Red Cotton Bug and Dusky Cotton Bug:

The adults and nymphs of both bugs were counted visually after gently shaking them off from the plants on to a blotting sheet placed underneath one randomly selected sympodial branch and the numbers were expressed on per plant basis.

B. Statistical analysis:

Population data of different insect pests thus obtained were subjected to statistical analysis to find out the coefficient of correlation with average temperature and relative humidity, which was obtained from the meteorological observatory, Rajasthan College of Agriculture, Udaipur. Following formula was used for calculating the correlation coefficient. A simple correlation was calculated between hemipteran insect population and abiotic factors.

$$r_{xy} = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{n}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{n}\right]}}$$

Where

r_{xy} = Simple correlation coefficient.

X = Variable i.e. abiotic component.

(Average temperature, relative humidity and rainfall)

Y = Variable i.e. mean number of insect pests.

n = Number of paired observation.

The correlation coefficient (r) values were subjected to the test of significance using t-test:

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

The calculated t-value obtained was compared with tabulated t-value at 5% level of significance.

3.4 SPECIES DIVERSITY OF HEMIPTERAN (SAP SUCKING) PESTS OF COTTON:

3.4.1 Jassids, whiteflies, and thrips:

Population of jassids, whiteflies, and thrips were observed by **Vortis Suction Sampler** at weekly intervals during morning hours from the 5 plants per replication, selected at random.

3.4.2 Natural enemies:

The associated natural enemies were recorded by the visual count technique from the same 5 plants per replication before using the suction sampler.

Estimation of the population density of insect pests and their natural enemies were done under natural condition or untreated plot and expressed as a percentage; where applicable, suitable diversity index was computed. The following mathematical/ statistical analysis was made towards estimating the species richness and diversity indices.

Mean density

$$\text{Mean density} = \frac{(\sum X_i)}{N} \times \mathbf{100}$$

Where

X_i = No of insects or natural enemies in i^{th} sample

N = Total no of plant sampled.

Relative Density (%)

$$RD\% = \frac{\text{Number of individual of one species}}{\text{Total number of individual of all species}} \times 100$$

Shannon –Weiner diversity index (H')

$$\text{Shannon – Weiner diversity index (H')} = -\sum pi \ln pi$$

Where

Pi = the decimal fraction of individuals belonging to i^{th} species.

3.5 BIO-EFFICACY OF SOME NEWER INSECTICIDES AGAINST HEMIPTERAN (SAP-SUCKING) INSECT-PESTS:

3.5.1 Preparation of layout

The experiment on bio-efficacy of newer insecticides against hemipteran of cotton was conducted during *kharif* 2012 in randomized block design. The layout of the experiment has been depicted in Fig.(1). The variety, plot size and planting distance were same as described in case of seasonal incidence. The details of different treatments are given in Table-1.

Table-1 Details of the treatments

S. No.	Treatments	Formulation	Quantity ml or g / ha	No. of sprays
1.	Fipronil	200 SC	300	3
2.	Spirotetramat	200 SL	1000	3
3.	Imidacloprid	200 SL	125	3
4.	Acetamiprid	20 SP	100	3
5.	Thiamethoxam	25 WG	100	3
6.	Dimethoate	30 EC	660	3
7.	Spiromesifen	240 SC	500	3
8.	Untreated control	-	-	-

There were 8 treatments including the control and each treatment was replicated three times. The spray was initiated at the economic threshold of test insect. First spray of treatments was done on August 01, second spray on August 11 and third spray on August 21 during 2012 in *kharif* season.

3.5.2 Observations:

The above mentioned treatments were applied thrice at 10 days interval when significant populations of jassids, thrips, whiteflies, and aphids were observed and records were made 1 day before; 1, 3,5 and 7 days after each application.

3.5.3 Sampling techniques:

The sampling techniques adopted for the estimation of population of different insect pests in the seasonal incidence was used for this experiment also.

3.5.4 Statistical analysis:

The experimental data was analyzed for the analysis of variance (ANOVA) using appropriate statistical tools. The data experimental was transformed to percentage reduction in population due to the insecticidal applications using the Henderson and Tilton (1952) equation as under:

$$\text{Percent reduction in population} = 100\left[1 - \frac{Ta \times Cb}{Tb \times Ca}\right]$$

Where;

Ta = Number of insects after treatment

Tb = Number of insets before treatment

Ca = Number of insects untreated check after treatment

Cb = Number of insects in untreated check before treatment

4. RESULTS

4.1 SEASONAL INCIDENCE OF HEMIPTERAN PESTS:-

During the course of investigation among the sucking insects jassids (*Amrasca biguttula biguttula* Ishida), aphids (*Aphis gossypii* Glover), whiteflies (*Bemisia tabaci* Gennadius), thrips (*Thrips tabaci* Linnman), red cotton bug *(Dysdercus koenigii* Fabricius) and dusky cotton bug (*Oxycarenus laetus* Kirby) were recorded as major sap-sucking pests of cotton. Their incidence has been described as under:

4.1.1 Jassids (*Amrasca biguttula biguttula* Ishida):-

The incidence of jassids was first noticed in the first week of July (SMW) (0.33 jassids/plant) that increased gradually and touched the peak (21.87 jassids/plant) in the fourth week of August (SMW). Thereafter, the population decreased gradually and reached to a minimum level of 1.33 jassids/plant during last week of November (SMW) (Table-3).

The mean atmospheric temperature, relative humidity and total rainfall during the peak period of incidence were 25.84°C, 75.65 per cent and 17.40 mm, respectively. The pest had a positive non-significant correlation with temperature (r_1 = 0.20), while with relative humidity the correlation was significantly positive (r_2 = 0.64) and total rainfall non-significant and positive (r_3 = 0.28).

4.1.2 Aphids (*Aphis gossypii* Glover):-

The infestation of aphids appeared in the first week of July (SMW) (0.67 aphids/plant) and reached to the peak (36.27 aphids/plant) during the last week of August (SMW), the population then decreased gradually and reached a minimum level of 9.67 aphids/plant during last week of November (SMW) (Table-3).

The mean atmospheric temperature, relative humidity and total rainfall during the peak period of incidence were 25.87 °C, 78.29 per cent and 58.60 mm, respectively. The aphid population had a negatively non-significant correlation with temperature (r_1 = -0.06); while with relative humidity (r_2 = 0.15) and total rainfall (r_3 = 0.11) it was positively non-significant.

4.1.3 Whitefly (*Bemisia tabaci* Gennadius.):-

Whitefly infestation initiated in the first week of July (SMW) (0.33 whiteflies/plant). Thereafter, their population increased gradually and touched its peak (20.33 whiteflies/plants) in the fourth week of August (SMW), the population decreased gradually and reached to a minimum level of 1.07 whiteflies/plant during last week of November (SMW) (Table-3).

The mean atmospheric temperature, relative humidity and total rainfall during the peak period of incidence were 25.84 $^{\circ}$C, 75.65 per cent and 17.40 mm, respectively. The whitefly population had a positively non-significant correlation with temperature (r_1 = 0.20) whereas, a positive and significant with relative humidity (r_2 = 0.69) and a positive non-significant correlation with total rainfall (r_3 = 0.28).

4.1.4 Thrips (*Thrips tabaci* Linnman):-

The data presented in Table-3 indicated that thrips were noticed in the first week of July (SMW) the population then increased suddenly and touched the peak (33.87 thrips/plants) in the second week of August (SMW). Thereafter, the population decreased gradually and reached to a minimum level of 0.33 thrips plant during the first week of November (SMW)

The mean atmospheric temperature, relative humidity and total rainfall during the peak period of incidence were 26.13 $^{\circ}$C, 70.49 per cent and 15.67 mm, respectively. The pest exhibited a non-significant negative correlation with temperature (r_1 = -0.28), while with relative humidity (r_2 = 0.44) the pest showed non-significant positive correlation and with total rainfall (r_3 = -0.15) the relationship was non-significant and negative.

4.1.5 Red Cotton Bug *(Dysdercus koenigii* Fabricius):-

The incidence of red cotton bug initiated in the fourth week of September (SMW) (1.67 red cotton bugs/plant) which increased gradually and touched the peak (15.33 red cotton bugs/plant) in the last week of October (SMW). Thereafter, the population decreased gradually and reached to a minimum level of 2.33 red cotton bugs/plant during last week of November (SMW) (Table-3).

The mean atmospheric temperature, relative humidity and total rainfall during the peak period of incidence were 21.44 $^{\circ}$C, 43.36 per cent and 0.0 mm, respectively. The pest had a negative non-significant correlation with temperature (r_1 = -0.17) and total rainfall (r_3 = -0.37), while with relative humidity the correlation was significantly negative (r_2 = -0.65).

4.1.6 Dusky Cotton Bug (*Oxycarenus laetus* Kirby):-

Dusky cotton bug infestation initiated in the first week of October (SMW) (1.33 dusky cotton bugs/plant). Thereafter, their population increased gradually and touched its peak (14.27 dusky cotton bugs/plant) in the first week of November (SMW), the population decreased gradually and reached to a minimum level of 4.36 dusky cotton bugs/plant during last week of November (SMW) (Table-3).

The mean atmospheric temperature, relative humidity and total rainfall during the peak period of incidence were 19.45 $^{\circ}$C, 50.36 per cent and 0.0 mm, respectively. The dusky cotton bug population had a negatively significant correlation with temperature (r_1 = -0.67), but negatively non-significant with relative humidity (r_2 = -0.45) and the total rainfall (r_3 = NA).

4.2 SPECIES-DIVERSITY OF HEMIPTERAN PESTS:-

The hemipteran species diversity (Plate I: depicting the pest insects) comprised 6 different insects belonging to 5 families *viz.*, the cotton jassid (*Amrasca biguttula biguttula*

Ishida: Cicadellidae), aphid (*Aphis gossypii* Glover: Aphididae), whitefly (*Bemisia tabaci* Gennadius: Aleyrodidae), red Cotton Bug (*Dysdercus koenigii* Fabricius: Pyrrhocoridae), the dusky Cotton Bug (*Oxycarenus laetus* Kirby: Laegidae) and the predatory pyrrhocorid bug, *Antilochus coqueberti* (Fabricius: Pyrrhocoridae). Among these, *A. coqueberti* was the only carnivorous species that was recorded to be associated with the red cotton bug as described in Plate II; whereas, the other 5 species as mentioned above were plant feeders. As depicted in Table-4 it can be observed that among all sap sucking insects (including *Thrips tabaci* Linnman: Thysanoptera), the Shannon Diversity Index was 1.68, the Relative Density values were the maximum for aphids (34.90 %), while minimum for whiteflies (10.09 %). While comparing the diversity among hemipteran insects it was observed that the Shannon Diversity Index was 1.47 and the Relative Density values were similarly the maximum for aphids (42.50 %) and minimum for whiteflies (12.28 %).

4.2.1 SPECIES-DIVERSITY OF ASSOCIATED NATURAL ENEMIES:-

The natural enemies, especially the predatory fauna, comprised the following different species *viz*., the coccinellids (*Coccinella septumpunctata* L., *Cheilomenes sexmaculata* (Fabr.), Coleóptera: Coccinellidae), chrysopids (*Chrysoperla* sp., Neuroptera: Chrysopidae), wasp (Hymenoptera: Vespidae), the predatory bugs, *Antilochus coqueberti* (Fabricius) (Hemiptera: Pyrrhocoridae) and *Geocoris* sp. (Hemiptera: Lygaeidae), preying mantid (Dictyoptera: Mantidae) and a spider (*Neoscona* sp., Araneae: Araneidae) in Plate- III.

As depicted in Table-5a and 5b it can be observed that among the predators, coccinellids (*C. septempunctata* and *Ch. sexmaculata*) had the highest numerical abundance during the entire season (3.67); whereas, spiders were the least in numbers (0.94). The Shannon Diversity Index was 1.96 and the Relative Density values were the maximum for coccinellids (22.11%) while minimum for spider (5.64%). Comparing the predator diversity excluding spiders, it was observed that the Shannon Diversity Index was 1.48 and the Relative Density values were the maximum for coccinellids (31.26 %) and minimum for preying mantid (8.52 %).

4.2.2 Morphological characterization of *Antilochus coqueberti* (Fabricius):

General Description:

Colouration of body vividly red with membrane black; antennae, tibiae and tarsi black; femora and the knee-joint red; fore femora moderately thickened with a single row of small tubercles; clavus and corium uniformly bright red; labium extending to mid-coxae with apex dark; ventre of abdomen red, intersegmental sutures narrow and black. (Plate: II).

Behaviour:

A very active bug, almost always captured from cotton plants where *Dysdercus* spp. abound.

Earlier reported as a specific predator of the red cotton bug, *Dysdercus* spp., recorded to feed on *Dysdercus cingulatus* (Kohno, 2003) and *Dysdercus koenigii* (Kamble, 1974).

4.3 BIO-EFFICACY OF NEWER INSECTICIDES AGAINST HEMIPTERAN PESTS:-

4.3.1 MEAN POPULATION REDUCTION

The bio-efficacy of different management schedules *viz.,* three sprays of fipronil 200 SC @ 300 ml ha^{-1}, spirotetramate 200 SL @ 1000 ml ha^{-1}, imidacloprid 200 SL @ 125 ml ha^{-1}, acetamiprid 20 SP @ 100 g a.i. ha^{-1}, thiamethoxam 25 WG @ 100 g a.i. ha^{-1}, dimethoate 30 EC @ 660 ml ha^{-1} and spiromesifen 240 SC @ 500 ml ha^{-1} was studied against sucking insect-pests of cotton under present investigation. The first spray was done at 40 days after sowing (first week of August) and the subsequent spray was done at ten days interval. The data have been presented in Tables 6-9. The comparative bioefficacy of insecticides against hemipteran pests of cotton (I, II and III spray) have been in figures 2-4 and population reduction trend of jassids, aphids, whitefly and thrips after treatments on cotton have been presented in figures 5-8.

4.3.1.1 Jassids (*Amrasca biguttula biguttula* Ishida):-

As given in Table-6 from the observation taken 1, 3, 5 and 7 days after first spray of the tested insecticides, it became evident that fipronil 200 SC @ 300 ml ha^{-1} was most effective showing 61.60 to 80.22 per cent mean reduction of the jassids population. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} with 57.79 to 72.92 per cent mean population reduction. The Fig.-5 indicates an increasing level in population from 1 DAS (Days After Spray) to 5 DAS, thereafter, showing a decreasing trend 7 DAS. Dimethoate 30 EC @ 660 ha^{-1} was least effective with 45.55 to 51.04 per cent population reduction. Likewise, after second spray, fipronil 200 SC @ 300 ml ha^{-1} was most effective 1, 3, 5 and 7 DAS evincing a population reduction from 66.34 to 82.05 per cent. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} with 62.81 to 76.81 per cent mean population reduction. The Fig. 5 also depicts a similar increasing trend in the per cent population reduction up to 5 DAS and later a decreasing trend 7 DAS. The third spray results were also similar to the first two sprays showing maximum population reduction of jassids by fipronil 200 SC @ 300ml ha^{-1} (73.23 to 89.52 %). It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} (71.04 to 85.58 %) and with an increasing trend up to 5 DAS followed by a decrease 7 DAS.

4.3.1.2 Aphids (*Aphis gossypii* Glover):-

As notable in Table-7 it becomes evident from the observation recorded at 1, 3, 5, and 7 days after the first spray that imidacloprid 200 SL @ 125 ml ha^{-1} was most effective against aphids affording 65.22 to 78.44 per cent population reduction. It was followed by thiamethoxam 25 WG @ 100 g a.i. ha^{-1} conferring 62.87 to 76.29 per cent population mean reduction. However, spiromesifen 240 SC @ 500 ml ha^{-1} happened is show lowest efficiency with 52.11 to 56.98 per cent mean population reduction. Similarly, second spray also imidacloprid 200 SL @ 125 ml ha^{-1}

was most effective registering 71.71 to 85.11 per cent mean population reduction. It was followed by thiamethoxam 25 WG @ 100 g a.i. ha^{-1} with 67.82 to 80.42 per cent reduction, while spiromesifen 240 SC @ 500 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} being least effective 54.29 to 59.18 and 56.75 to 65.45 per cent population reduction, respectively. Likewise, after third spray, similar results were obtained and imidacloprid 200 SL @ 125 ml ha^{-1} was most effective with 77.76 to 89.44 per cent mean population reduction. However, spiromesifen 240 SC @ 500 ml ha^{-1} happened is show lowest efficiency with 55.61 to 69.68 per cent population reduction.

4.3.1.3 Whiteflies (*Bemisia tabaci* Genn.):-

The data presented in Table-8 depict the bio-efficacy of insecticides against whiteflies infesting cotton. Acetamiprid 20 SP @ 100 g a.i. ha^{-1} was most effective against whiteflies 1, 3, 5 and 7 days after first spray bringing about a maximum mean reduction in their population from 66.87 to 77.97 per cent. It was followed by spiromesifen 240 SC @ 500 ml ha^{-1} with 62.64 to 73.84 per cent reduction; while, spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} were least effective against whiteflies through causing 55.31 to 64.03 and 54.77 to 63.65 per cent population reduction, respectively. After second spray also acetamiprid 20 SP @ 100 g a.i. ha^{-1} was most effective 1, 3, 5 and 7 days after spray evincing 69.30 to 83.84 per cent population reduction. Similarly, after third spray of acetamiprid 20 SP @ 100 g a.i. ha^{-1} was most effective causing 74.50 to 80.13 per cent population reduction of whiteflies. While, dimethioate 30 EC @ 660 ml ha^{-1} was least effective with 59.99 to 70.80 per cent mean population reduction.

4.3.1.4 Thrips (*Thrips tabaci* Linnman):-

As given in Table-9 from the observation taken 1, 3, 5 and 7 days after first spray of the tested insecticides, it became evident that fipronil 200 SC @ 300ml ha^{-1} was most effective showing 69.62 to 82.55 per cent mean reduction of the thrips population. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} with 67.77 to 79.53 per cent mean population reduction. The Fig.-8 indicates and increasing level in population from 1 DAS to 5 DAS, thereafter, showing a decreasing trend 7 DAS. Dimethoate 30 EC @ 660 ha^{-1} was least effective with 54.36 to 63.87 per cent population reduction.Likewise, after second spray, fipronil 200 SC @ 300 ml ha^{-1} was most effective1, 3, 5 and 7 days evincing a population reduction from 73.29 to 84.98 per cent. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} with 70.51 to 81.75 per cent mean population reduction. The Fig.-8 also depicts a similar increasing trend in the per cent population reduction up to 5 DAS and later a decreasing trend 7 DAS. The third spray results were also similar to the first two spray showing maximum population reduction of thrips by fipronil 200 SC @ 300ml ha^{-1} (78.46 to 90.09 %). It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} (76.75 to 86.40 %) and with an increasing trend up to 5 DAS followed by a decrease 7 DAS.

4.3.2 CUMULATIVE EFFECTIVENESS:

4.3.2.1 Jassids (*Amrasca biguttula biguttula* Ishida):-

The data on cumulative effectiveness of different newer insecticides recorded during *kharif*, 2012 presented in Table-10 revealed that at one day after the three applications, fipronil 200 SC @ 300 ml ha^{-1} proved most found effective in mean reducing the population of jassids up to 67.06 per cent. It was closely followed by imidacloprid 200 SL @ 125 ml ha^{-1} 63.88 per cent population reduction. Spiromesifen 240 SC @ 500 ml ha^{-1}, thiamethoxam 25 WG @ 100 g a.i. ha^{-1} and acetamiprid 20 SP @ 100 g a.i. ha^{-1} were the next in order of effectiveness which caused cumulative population reduction of 60.16, 59.31 and 57.31 per cent, respectively. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 53.28 and 49.62 per cent population reduction and were least effective.

After studying the average of all three sprays at three days of spraying it was found that fipronil 200 SC @ 300 ml ha^{-1} was superior to all other treatments with 74.50 per cent population reduction. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} 69.85 per cent population reduction. Spiromesifen 240 SC @ 500 ml ha^{-1}, thiamethoxam 25 WG @ 100 g a.i. ha^{-1} and acetamiprid 20 SP @ 100 g a.i. ha^{-1} were the next in order of effectiveness which caused cumulative population reduction of 65.50, 65.01 and 64.31 per cent, respectively. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 58.25 and 53.40 per cent population reduction and were least effective.

At five days after spraying the data on cumulative effectiveness revealed that highest mean reduction in population of jassids was exhibited by fipronil 200 SC @ 300 ml ha^{-1} was 83.82 per cent. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} which exhibited 78.44 and 76.64 per cent reduction, respectively. Spiromesifen 240 SC @ 500 ml ha^{-1} and acetamiprid 20 SP @ 100 g a.i. ha^{-1} were next in order of effectiveness with 73.69 and 72.51 per cent reduction, respectively. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 67.75 and 61.76 per cent reduction and were least effective.

At seven days after spraying the data on cumulative effectiveness revealed that highest mean reduction in population of jassids was exhibited by fipronil 200 SC @ 300 ml ha^{-1} was superior to all other treatments with 79.59 per cent population reduction. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} 74.11 per cent population reduction. Thiamethoxam 25 WG @ 100 g a.i. ha^{-1}, spiromesifen 240 SC @ 500 ml ha^{-1} and acetamiprid 20 SP @ 100 g a.i. ha^{-1} were the next in order of effectiveness which caused cumulative population mean reduction of 72.43, 70.22 and 68.85 per cent, respectively. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 62.97 and 58.20 per cent population reduction and were least effective.

4.3.2.2 Aphids (*Aphis gossypii* Glover):-

The data on cumulative effectiveness of different newer insecticides recorded during *kharif*, 2012 presented in Table-11 revealed that at one day after the three applications, imidacloprid 200 SL @ 125 ml ha^{-1} proved most effective in mean reducing the population of aphids up to 71.56 per cent. It was followed by thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (67.77%) and spirotetramat 200 SL @ 1000 ml ha^{-1} (64.11%). Fipronil 200 SC @ 300 ml ha^{-1} and acetamiprid 20 SP @ 100 g a.i. ha^{-1} were the next in order of effectiveness which caused cumulative population reduction of 64.11 and 59.19 per cent, respectively. Dimethioate 30 EC @

660 ml ha^{-1} and Spiromesifen 240 SC @ 500 ml ha^{-1} exhibited 56.48 and 54.00 per cent population reduction and were least effective.

Spray of imidacloprid 200 SL @ 125 ml ha^{-1} provided the best results with mean reduction of 76.03 per cent. It was followed by thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (72.85%) and spirotetramat 200 SL @ 1000 ml ha^{-1} (68.35%). Acetamiprid 20 SP @ 100 g a.i. ha^{-1} and fipronil 200 SC @ 300 ml ha^{-1} were also showed good results with the mean population of 66.33 and 65.50 per cent, respectively. Dimethioate 30 EC @ 660 ml ha^{-1} and Spiromesifen 240 SC @ 500 ml ha^{-1} exhibited 60.58 and 56.04 per cent mean reduction and were least effective.

After five days of spray, imidacloprid 200 SL @ 125 ml ha^{-1} was found most effective that caused the maximum mean reduction of 84.33 per cent in aphids population. It was followed by thiamethoxam 25 WG @ 100 g a.i. ha^{-1} with 81.29 per cent mean reduction. Spirotetramat 200 SL @ 1000 ml ha^{-1} (75.49%), fipronil 200 SC @ 300 ml ha^{-1} (73.03%) and acetamiprid 20 SP @ 100 g a.i. ha^{-1} (70.19%) were moderately effective. Dimethioate 30 EC @ 660 ml ha^{-1} (65.94%) and spiromesifen 240 SC @ 500 ml ha^{-1} (61.95%) were found least effective treatments.

The efficacy of all treatments after seven days of spraying indicated that imidacloprid 200 SL @ 125 ml ha^{-1} was found most effective with mean reduction of 80.33 per cent in aphids population. It was followed by thiamethoxam 25 WG @ 100 g a.i. ha^{-1} with 78.14 per cent mean reduction of aphids population. Spirotetramat 200 SL @ 1000 ml ha^{-1}, fipronil 200 SC @ 300 ml ha^{-1} and acetamiprid 20 SP @ 100 g a.i. ha^{-1} were the next in order of effectiveness which caused cumulative population reduction of 72.51, 70.28 and 66.72 per cent, respectively. Dimethioate 30 EC @ 660 ml ha^{-1} and Spiromesifen 240 SC @ 500 ml ha^{-1} exhibited 63.53 and 59.53 per cent population reduction and were least effective.

4.3.2.3 Whiteflies (*Bemisia tabaci* Genn.):-

The data on cumulative effectiveness of different newer insecticides recorded during *kharif*, 2012 presented in Table-12 revealed that at one day after the three applications, acetamiprid 20 SP @ 100 g a.i. ha^{-1} was found most effective as it gave the maximum mean reduction of 70.22 per cent in whitefly population. It was followed by spiromesifen 240 SC @ 500 ml ha^{-1} and imidacloprid 200 SL @ 125 ml ha^{-1} with mean reduction of 66.46 and 65.26 per cent, respectively. Fipronil 200 SC @ 300 ml ha^{-1} (63.11%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (62.14%) were moderately effective. While spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} were found least effective among all the treatments which caused only 58.96 and 57.33 per cent mean population reduction of whitefly, respectively.

After three days of spray, acetamiprid 20 SP @ 100 g a.i. ha^{-1} was found most effective that caused the maximum mean reduction of 75.53 per cent in whitefly population. It was followed by spiromesifen 240 SC @ 500 ml ha^{-1} (71.62%) and imidacloprid 200 SL @ 125 ml ha^{-1} (69.04%). Fipronil 200 SC @ 300 ml ha^{-1} (66.01%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (64.89%) were moderately effective. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 62.79 and 62.43 per cent mean reduction and were found least effective.

Fifth days after spraying acetamiprid 20 SP @ 100 g a.i. ha^{-1} proved significantly superior over all other treatments as it resulted in 83.31 per cent mean reduction in population of whitefly. Spiromesifen 240 SC @ 500 ml ha^{-1} and imidacloprid 200 SL @ 125 ml ha^{-1} followed the above treatment with 80.34 and 78.79 per cent mean reduction, respectively. Fipronil 200 SC @ 300 ml ha^{-1} (72.64%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (71.65%) were moderately effective. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 68.51 and 67.79 per cent mean reduction and were found least effective.

After seven days of spray, acetamiprid 20 SP @ 100 g a.i. ha^{-1} was found most effective that caused the maximum mean reduction of 81.53 per cent in whitefly population. Spiromesifen 240 SC @ 500 ml ha^{-1} (78.28%) and imidacloprid 200 SL @ 125 ml ha^{-1} (76.54%) were statistically effective. The next effective treatments were fipronil 200 SC @ 300 ml ha^{-1} (70.68%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} with 68.96 per cent mean reduction. While spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} with 66.53 and 65.98 per cent, respectively and were found least effective.

4.3.2.4 Thrips (*Thrips tabaci* Linnman):-

The data on cumulative effectiveness of different newer insecticides recorded during *kharif*, 2012 presented in Table-13 revealed that at one day after the three applications, fipronil 200 SC @ 300 ml ha^{-1} was found most effective as it gave the maximum mean reduction of 73.79 per cent in thrips population. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1}, spiromesifen 240 SC @ 500 ml ha^{-1} and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} with 71.68, 71.11 and 69.98 per cent mean reduction, respectively. Acetamiprid 20 SP @ 100 g a.i. ha^{-1} and spirotetramat 200 SL @ 1000 ml ha^{-1} were also good results showed 63.70 and 61.38 per cent, respectively. Among all the treatments dimethioate 30 EC @ 660 ml ha^{-1} was least effective with 59.82 mean reduction of thrips population.

After three days of spray, fipronil 200 SC @ 300 ml/ ha^{-1} was found most effective that caused the maximum mean reduction of 78.10 per cent in thrips population. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} (75.45%), spiromesifen 240 SC @ 500 ml ha^{-1} (73.31%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (73.15%). Acetamiprid 20 SP @ 100 g a.i. ha^{-1} with mean reduction of 67.17 per cent was moderately effective. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 63.56 and 62.63 per cent mean reduction and were least effective.

Fifth days after spraying fipronil 200 SC @ 300 ml ha^{-1} proved significantly superior over all other treatments as it resulted in 85.87 per cent mean reduction in population of thrips. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} (82.56%), spiromesifen 240 SC @ 500 ml ha^{-1} (79.98%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (79.49%). Acetamiprid 20 SP @ 100 g a.i. ha^{-1} (73.57%) was moderately effective. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} were found least effective among all the treatments which caused only 71.07 and 70.31 per cent mean reduction of thrips population, respectively.

Seven days after spray, fipronil 200 SC @ 300 ml ha^{-1} proved significantly superior over all other treatments as it resulted in 83.70 per cent mean reduction in population of thrips. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} (79.42%), thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (77.99%) and spiromesifen 240 SC @ 500 ml ha^{-1} (76.73%). Acetamiprid 20 SP @ 100 g a.i. ha^{-1} (70.36%) was moderately effective. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} were found least effective among all the treatments which caused only 67.69 and 66.21 per cent mean reduction of thrips population, respectively.

5. DISCUSSION

The results of the present investigations on "**Diversity of Hemipteran Pests of Cotton (*Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them**" are discussed here in the following pages:

5.1 Seasonal incidence of hemipteran (sap-sucking) insect pests of cotton:-

Studies conducted on the seasonal incidence of sap-sucking insect pests of cotton revealed that *Amrasca biguttula biguttula*, *Aphis gossypii*, *Bemisia tabaci*, *Thrips tabaci*, *Dysdercus koenigii* and *Oxycarenus laetus* were of regular occurrence and caused considerable damage to the crop under prevailing climatic conditions of Udaipur (Rajasthan).

5.1.1 Jassids (*Amrasca biguttula biguttula* Ishida):-

The pest population occurred throughout the crop season and attained a peak of 21.87 jassids/plant during the fourth week of August (SMW). The population exhibited a positive correlation with mean temperature, mean relative humidity and average rainfall. The results obtained in the present investigation are in close agreement with the earlier reports of Shitole and Patel (2009) who observed higher incidence of jassids during last week of August, which might be due to local weather conditions that prevailed during the study period. In the present investigation, it was found that temperature range of 21.96 to 29.71°C along with high relative humidity 75.65 per cent provided congenial conditions for the multiplication of jassids. This finding is in close conformity with the findings of Bishnoi *et al*. (1996) who reported that temperature ranging from 27.0 to 34.0°C with 52 to 82 per cent relative humidity was the most suitable conditions for jassids.

5.1.2 Aphids (*Aphis gossypii* Glover):-

The infestation of aphid commenced in the first week of July (SMW) and continued on the crop up to last week of November (SMW) during 2012. The population increased gradually and touched its peak with a mean of 36.27 aphids/plant during the last week of August (SMW). Thereafter, the population declined gradually and reached up to 9.67 aphids/plant.

The population exhibited a negative correlation with mean temperature while, the positive with mean relative humidity and average rainfall. The present findings are similar to the findings of Purohit *et al*. 2006 who observed the appearance of aphid population in the first fortnight of July and reached at peak during fourth week of August. The present findings are also gets full supports Butani (1970) who reported the appearance of aphid from July to till harvest. Similar results were also reported by Shitole and Patel (2009) who observed that the incidence of aphid was maximum (7.0/3 leaves) during last week of August i.e. 35th SMW on cotton *cv*. Hy-10.

5.1.3 Whiteflies (*Bemisia tabaci* Gennadius.):-

Bemisia tabaci appeared in the first week of July and reached to peak (20.33 whiteflies/plants) in the fourth week of August (SMW) and continued up to last week of November. The population increased gradually and touched its peak with mean population of 20.33 whiteflies/plant during fourth week of August. Thereafter, the population decline gradually and reached up to 1.07 whiteflies/plant during 23 to 29 November. The population exhibited positive correlation with mean temperature, mean relative humidity and total rainfall during the study year 2012. The present finding is in close conformity with the findings of Purohit *et al.* (2006) who reported that whitefly appeared in the first week of July and attained its peak in second week of August (12/3 leaves) in cotton cultivar GH-8.

Shitole and Patel (2009) reported that the incidence of whitefly was started during 35th SMW and reached at peak level (3.8/3 leaves) during 39th SMW *i.e.* fourth week of September. This might be due to variable climatic conditions of that particular region and time of cultivation that particular crop.

5.1.4 Thrips (*Thrips tabaci* Linnman):-

The infestation of thrips, *Thrips tabaci* was initiated in the last week of July and continued on the crop up to fourth week of October. The population increased gradually and touched its peak with a mean of 33.87 thrips/plant. There after the population declined gradually and reached up to 0.87 thrips/plant.

The population exhibited a negative correlation with mean temperature and total rainfall while, the correlation was positive with mean relative humidity. The results obtained in the present investigation are similar with the results of Gupta *et al.*, (1997), who reported maximum numbers of thrips (*T. tabaci*) on cotton cultivars H-4, H-6, JKH- 1, DCH-32 and AHH-468 during second fortnight of August. Similarly Patel (1992) also recorded negative correlation between thrips population and rainfall and temperature. The pest showed negative correlation with minimum temperature, vapour pressure and relative humidity.

5.1.5 Red Cotton Bug *(Dysdercus koenigii* Fabricius):-

Red cotton bug was first noticed in the fourth week of September (SMW) and touched the peak with a mean population of 15.33 red cotton bugs/plant in the last week of October (26 October to 1 November). There after the population declined gradually and reached up to 2.33 red cotton bug/plant. The population exhibited a negative correlation with mean temperature, mean relative humidity and total rainfall.

5.1.6 Dusky Cotton Bug (*Oxycarenus laetus* Kirby):-

Dusky cotton bug population was first observed in the first week of October (SMW) and touched its peak with a mean population of 14.27 dusky cotton bugs/ plant in the first week of November (SMW). There after the population declined gradually and reached up to 4.36 dusky cotton bug/plant. The population exhibited a negative correlation with mean temperature and mean relative humidity but it was not applicable with total rainfall.

The results obtained in the present investigation are in close conformity with the findings of Srinivas and Patil (2004) and Patil and Rajnnikantha (2005), who reported a higher incidence of dusky cotton bug (*Oxycarenus laetus*) on MECH-184 (Bt cotton) from the 50th to the 5th international standard week (ISW), with peak incidence on the 52nd ISW with a mean population of (12.72 and 17.20 bugs per boll at the research station and farmer's field, respectively.) compared to MECH-184 non-Bt and NHH-44.

5.2 SPECIES-DIVERSITY OF HEMIPTERAN PESTS:-

The hemipteran species diversity comprised 6 different insects, belonging to 5 families *viz*., the cotton jassid (*Amrasca biguttula biguttula* Ishida: Cicadellidae), aphid (*Aphis gossypii* Glover: Aphididae), whitefly (*Bemisia tabaci* Gennadius: Aleyrodidae), red Cotton Bug (*Dysdercus koenigii* Fabricius: Pyrrhocoridae), the dusky Cotton Bug (*Oxycarenus laetus* Kirby: Laegidae) and the predatory pyrrhocorid bug, *Antilochus coqueberti* (Fabricius: Pyrrhocoridae). Among these, *A*. *coqueberti* was the only carnivorous species that was recorded to be associated with the red cotton bug. Whereas, the other 5 species as mentioned above were plant feeders. It can be observed that among all sap sucking insects (including *Thrips tabaci* Linnman), the Shannon Diversity Index was 1.68, and the Relative Density values were the maximum for aphids (34.90 %), while minimum for whiteflies (10.09 %). While comparing the diversity among hemipteran insects it was observed that the Shannon Diversity Index was 1.47 and the Relative Density values were similarly the maximum for aphids (42.50 %) and minimum for whiteflies (12.28 %).

The results obtained in the present investigation are similar with the results of Khaing *et al.* (2002) and Michelotto and Busoli (2003) Khaing *et al.* (2002) who reported that insect pests were greatly abundant during the first crop of cotton, with low diversity indices than in second crop. The total species abundance of all 4 cotton cultivars. The ranges of species diversity indices were from 0.27 for Sri Samrong 60 (SR 60) to 0.62 for Sarid 1 (SD1) in the first crop and from 0.61 for SR 60 to 0.83 for SD1 in the second crop. *A. biguttula* was the dominant species in both crops. Other insect pests with less obvious importance were *Thrips palmi*, *Bemisia tabaci*, *Aphis gossypii*, *Megacoelum biseratense* and *Carpophilus* sp.

Michelotto and Busoli (2003) recorded 13 different species of winged aphids *R. padi*, *A. spiraecola*, *A. gossypii*, *Rhopalosiphum maidis, Geopemphigus floccosus, Uroleucon ambrosiae, Rhopalosiphum rufiabdominalis, Myzus persicae, Sipha flava*, *Pentalonia nigronervosa*, *Tetraneura nigriabdominalis*, *Lizerius melanocallis* and *Toxoptera citricidus* collected in water-pan traps; alate and wingless forms of 3 species (*A. gossypii*, *A. spiraecola* and *R. padi*) by direct sampling and 4 species (*R. padi*, *A. spiraecola*, *A. gossypii* and *R. maidis*) in Moerick's traps from a cotton field.

5.2.1 SPECIES-DIVERSITY OF ASSOCIATED NATURAL ENEMIES:-

The natural enemies, especially the predatory fauna, comprised the following different species *viz.*, the coccinellids (*Coccinella septumpunctata* L., *Cheilomenes sexmaculata* (Fabr.), chrysopids (*Chrysoperla* sp.), wasp (Hymenoptera: Vespidae), the predatory bugs, *Antilochus coqueberti* (Fabricius), (*Geocoris* sp.), preying mantid (Dictyoptera: Mantidae) and a spider (*Neoscona* sp., Araneae: Araneidae).

It can be observed that among the predators, coccinellids (*C. septempunctata* and *Ch. sexmaculata*) had the highest numerical abundance during the entire season (3.67); whereas, spiders were the least in numbers (0.94). The Shannon Diversity Index was 1.96 and the Relative Density values were the maximum for coccinellids (22.11%) while minimum for spider (5.64%). the predators, coccinellids (*C. septempunctata* and *Ch. sexmaculata*) had the highest numerical abundance during the entire season (3.67); whereas, spiders were the least in numbers (0.94). The Shannon Diversity Index was 1.96 and the Relative Density values were the maximum for coccinellids (22.11%) while minimum for spider (5.64%). Comparing the predator diversity excluding spiders, it was observed that the Shannon Diversity Index was 1.48 and the Relative Density values were the maximum for coccinellids (31.26 %) and minimum for preying mantid (8.52 %).

The findings of present investigation are in close conformity with the findings of Zhang (1992) Wang AnYuan and Wang LiPing (1996) Duran *et al.* (1998) and Shakila Mushtaq *et al.* (2005). Zhang (1992) reported that Coccinellidae, Araneae and Neuroptera are the most important predators of aphids and other pests in cotton fields. Wang AnYuan and Wang LiPing (1996) observed that that in the cotton fields there were abundant predators of cotton insects: 8 species of lady birds [Coccinellidae], 4 species of green lacewings [Chrysopidae], 10 species of spider mite [Acari], 4 species of *Epistrophe* spp. and 3 species of *Orius* spp. Duran *et al.* (1998) recorded recorded beneficial bugs (Heteroptera) found in cotton include 4 genera (*Orius, Nabis, Deraeocoris* and *Geocoris*) and 12 species. *Orius laevigatus* was the most abundant, followed by *O. albidipennis*. Shakila Mushtaq *et al.* (2005) recorded the predation evidences directly from an insecticide-free cotton plantation. The biodiversity and relative abundance of spiders predators in cotton were computed and compared for niche and specific overlaps. All overlap values were <=1.0, ranging from 0.42 to 0.72, indicating that each spider species had its own feeding niche in the cotton.

5.2.2 Morphological characterization of *Antilochus coqueberti* (Fabricius):

General Description:

Colouration of body vividly red with membrane black; antennae, tibiae and tarsi black; femora and the knee-joint red; fore femora moderately thickened with a single row of small tubercles; clavus and corium uniformly bright red; labium extending to mid-coxae with apex dark; ventre of abdomen red, intersegmental sutures narrow and black.

Behaviour:

A very active bug, almost always captured from cotton plants where *Dysdercus* spp. abound.

Earlier reported as a specific predator of the red cotton bug, *Dysdercus* spp. recorded to feed on *Dysdercus cingulatus* (Kohno, 2003) and *Dysdercus koenigii* (Kamble, 1974). This pyrrhocorid bug was reported as a predator of some hemipteran and lepidopteran pests on pulses and vegetable crops (Borah and Sharma, 2009).

5.3 BIO-EFFICACY OF DIFFERENT INSECTICIDES AGAINST HEMIPTERAN PESTS:-

5.3.1 Jassids (*Amrasca biguttula biguttula* Ishida):-

The result of effectiveness of newer insecticides against jassids showed that all the treatments were significantly superior over control in terms of reduction of jassids population.

Three applications of fipronil 200 SC @ 300 ml ha^{-1} was found significantly most effective, which caused highest mean reduction of 89.52 per cent in population of jassids. It was followed by imidacloprid 200 SL @ 125 ml/ ha^{-1} and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} which exhibited 85.58 and 82.01 per cent mean reduction in jassids population, respectively. Spiromesifen 240 SC @ 500 ml ha^{-1} with mean reduction of 78.95 per cent and acetamiprid 20 SP @ 100 g a.i. ha^{-1} (77.04%) were moderately effective and at par to each other. The lowest efficacy of 69.83 per cent was observed in dimethioate 30 EC @ 660 ml ha^{-1} which was at par with spirotetramat 200 SL @ 1000 ml ha^{-1} showing 74.36 per cent mean reduction in jassids population.

These findings are in close conformity with the findings Wadnerkar *et al.*, (2003) who reported that fipronil 5% SC @ 50, 75, 100, 200 and 400 g a.i./ha against insect pests of cotton *viz,* aphid, jassid, thrips and whitefly was significantly superior in reducing sucking pest (jassids) population in cotton.

Similarily, the effectiveness of fipronil 5% SC @ 800 g/ha against jassids was also reported by Patil *et al*. (2009) in cotton. Dhawan et al. (2011) reported that the seed treatments with imidacloprid 70 WS (Gaucho) and thiomethoxam 70 WS (Cruiser) were also effective at different doses against cotton jassid, *Amrasca biguttula* (Ishida). Dhawan and Simwat (2002) reported that thiamethoxam 25 WG @ 25 g a. i. ha^{-1} was also found effective against jassid and reduced the pest population up to 94.53% in cotton.

5.3.2 Aphids (*Aphis gossypii* Glover):-

The result of effectiveness of newer insecticides against aphids showed that all the treatments were significantly superior over control in terms of mean reduction of aphids population. Three applications of imidacloprid 200 SL @ 125 ml ha^{-1} proved significantly superior over all other treatments as it resulted in 89.44 per cent mean reduction in population of aphids. Thiamethoxam 25 WG @ 100 g a.i. ha^{-1} and spirotetramat 200 SL @ 1000 ml ha^{-1} followed the above treatment with 87.16 and 82.03 per cent mean reduction, respectively in aphids population and were at par each other. Fipronil 200 SC @ 300 ml ha^{-1} followed the above treatments with 79.84 per cent mean reduction and was at par with acetamiprid 20 SP @ 100 g a.i. ha^{-1} with mean reduction of 75.65 per cent mean reduction. While dimethioate 30 EC @ 660 ml ha^{-1} and Spiromesifen 240 SC @ 500 ml ha^{-1} caused least mean reduction of aphids population with 71.05 and 69.68 per cent, respectively.

The present findings are in conformity with the findings of Ameta and Sharma (2005) who reported that the efficacy of imidacloprid commercial formulation against *Aphis gossypii, Amrasca biguttula biguttula* and *thrips tabaci* infesting cotton cv.GH-8, it was observed that two sprays of 75 ml Confidor 350 SC ha^{-1} at 15 days interval gave the highest reduction in *Aphis gossypii*, *Amrasca biguttula biguttula* and *T. tabaci* populations, which was at par with 125 ml Confidor 200 SL ha^{-1}. Kumar *et al*. (2008) reported that spirotetramat 150 OD at 75 g a.i. ha^{-1} was highly effective against the aphids.

5.3.3 Whiteflies (*Bemisia tabaci* Genn.):-

The result of effectiveness of newer insecticides against whiteflies showed that all the treatments were significantly superior over control in terms of mean population reduction of aphids. Three applications of acetamiprid 20 SP @ 100 g a.i./ha proved significantly superior over all other treatments as it resulted in 88.13 per cent mean reduction in population of whitefly. Spiromesifen 240 SC @ 500 ml ha^{-1} and imidacloprid 200 SL @ 125 ml ha^{-1} followed the above treatment with 85.95 and 84.93 per cent mean reduction, respectively. Fipronil 200 SC @ 300 ml ha^{-1} (78.79%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (77.03%) were moderately effective and at par to each other. While spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} were found least effective among all the treatments which caused only 71.21 and 70.80 per cent mean reduction of whitefly population, respectively. The results of present investigation are in agreement with the results of Jat *et al.* (2004) who reported that acetamiprid 20 SP @ 150 g $acre^{-1}$ and imidacloprid 200 SL @ 250 ml $acre^{-1}$, significantly reduced the population of whitefly on cotton.

The present finding also gets full support from earlier work of Raghuraman *et al*. (2008) who reported that acetamiprid 20% SP significantly reduced the population of jassid and whitefly up to nine days. Kontsedalov *et al.* (2009) reported the efficacy of spiromesifen against whitefly on cotton crop. Boricha *et al.* (2010) reported that the thiamethoxam 0.008 per cent and acetamiprid 0.005 per cent were also found most effective against the cotton thrips and whitefly. Misra (2005) reported that the imidacloprid at 25 g and acetamiprid at 20 g was most effective against the white fly (*Bemisia tabaci*).

4.3.1.4 Thrips (*Thrips tabaci* Linnman):-

Fipronil 200 SC @ 300 ml ha^{-1} proved significantly superior over all other treatments as it resulted in 90.09 per cent mean reduction in population of thrips. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} (86.40%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (84.34%). Spiromesifen 240 SC @ 500 ml ha^{-1} followed the above treatments with 82.43 per cent mean reduction and was found at par with acetamiprid 20 SP @ 100 g a.i. ha^{-1} with 79.95 per cent mean reduction. Spirotetramat 200 SL @ 1000 ml ha^{-1} and dimethioate 30 EC @ 660 ml ha^{-1} exhibited 79.12 and 77.86 per cent mean reduction and were least effective.

The present findings are in conformity with the results of Wadnerkar *et al.* (2003) who reported fipronil @ 50 and 75 g a.i. ha^{-1} was most effective in reducing sucking pest population in cotton. The results are also comparable with the work of Patil *et al*. (2009) who reported the efficacy of fipronil 5% SC @ 800 g ha^{-1}, fipronil 40%+imidacloprid 200 SL @ 200 ml ha^{-1} and acetamiprid 20 SP @ 100 g ha^{-1} against sucking pests of cotton. Fipronil 5% SC @ 800 g ha^{-1} registered least number of thrips (8.47/3 leaves) found to be on par with acetamiprid 20 SP @ 100 g ha^{-1}, (7.80/3 leaves). Bhosle *et al.* (2009) observed that acetamiprid 20 SP @ 100 g a.i. ha^{-1} was most effective in reducing thrips population up to 14 days. Rathod *et al. (*2003) recorded similar results the efficacy of imidacloprid against jassids, aphids and thrips (*Thrips tabaci*) infesting cotton.

Sreekanth and Reddy (2011) reported that the efficacy insecticides viz., imidachloprid 200 SL, acetamaprid 20 SP, thiomethoxam 25 WG and fipronil 5% SC were also effective against the sucking insect pests viz., aphid, leafhopper, whitefly and thrips in cotton. Saleem *et al.* (2001) reported that thiamethoxam 25 WG @ 24 gm acre^{-1} and imidacloprid 200 SL @ 250 ml acre^{-1} against cotton jassid (*A. Biguttula biguttula*) and thrips (*T. tabaci*) and imidacloprid effectively managed jassid and thrips population up to 7 days after spray.

6. SUMMARY

The present investigations on "Diversity of Hemipteran Pests of Cotton (*Gossypium hirsutum*) and Relative Bio-efficacy of Newer Insecticides on them" was carried out at Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur during *kharif* (June to November 2012).

Six sap-sucking pests viz., jassids (*Amrasca biguttula biguttula* Ishida.), aphids (*Aphis gossypii* Glover), whiteflies (*Bemisia tabaci* Genn.), thrips (*Thrips tabaci* Linnman), red cotton bug *(Dysdercus koenigii* Fabricius) and dusky cotton bug (*Oxycarenus laetus* Kirby) were recorded on cotton.

The incidence of jssids, aphids, whitefly and thrips were started during the first week of July, while red cotton bug and dusky cotton bug appeared late i.e. the last week of October and the first week of November during 2012, respectively. The peak population of jassids and whiteflies with a mean of 21.87 jassids/plant and 20.33 whiteflies/plant, respectively was recorded during the fourth week of August. The population of aphids reached at its peak during the last week of August with a mean population of 36.27 aphids/plant. The population of thrips reached at its peak during the second week of August with a mean population of 33.8 thrips/plant. Similarly the peak population of red cotton bug and dusky cotton bug with a mean of 15.33 red cotton bug/plant and 14.27 dusky cotton bug/plant was recorded during the last week of October and first week of November, respectively. The correlation coefficient between jassids and whitefly population and abiotic factors was positive but it was significant with mean relative humidity. The correlation coefficient study reveals that the aphid population was negative correlated with mean temperature while, the correlation was positive with mean relative humidity and average rainfall. Only the population of thrips exhibited negative correlation with mean temperature and total rainfall while, the correlation was positive with mean relative humidity. The population of red cotton bug and dusky cotton bug exhibited negative correlation with mean temperature, mean relative humidity and total rainfall. The hemipteran species diversity comprised 6 different insects *viz*., the cotton jassid (*Amrasca biguttula biguttula* Ishida), aphid (*Aphis gossypii* Glover), whitefly (*Bemisia tabaci* Gennadius), red Cotton Bug (*Dysdercus koenigii* Fabricius), the dusky Cotton Bug (*Oxycarenus laetus* Kirby) and the predatory pyrrhocorid bug (*Antilochus coqueberti* Fabricius). Among these, *A. coqueberti* was the only carnivorous species that was recorded to be associated with the red cotton bug. Whereas, the other 5 species as mentioned above were plant feeders. The species diversity can be observed that among all sap sucking insects (including *Thrips tabaci* Linnman), the Shannon Diversity Index was 1.68, the Relative Density values were the maximum for aphids (34.90 %), while minimum for whiteflies (10.09 %). While comparing the diversity among hemipteran insects it was observed that the Shannon Diversity Index was 1.47 and the Relative Density values were similarly the maximum for aphids (42.50 %) and minimum for whiteflies (12.28 %) and natural enemies, especially the predatory fauna, comprised the following different species *viz.*, the coccinellids (*Coccinella septumpunctata* L., *Cheilomenes sexmaculata* (Fabr.), chrysopids (*Chrysoperla* sp.), wasp (Hymenoptera: Vespidae), the predatory bugs, *Antilochus coqueberti* (Fabricius), (*Geocoris* sp.), preying mantid (Dictyoptera: Mantidae) and a spider (*Neoscona* sp., Araneae: Araneidae). The Shannon Diversity Index of natural enemies was 1.96 and the Relative Density values were the maximum for coccinellids (22.11%) while minimum for spider (5.64%). Comparing the predator diversity excluding spiders, it was observed that the Shannon Diversity Index was 1.48 and the Relative Density values were the maximum for coccinellids (31.26 %) and minimum for preying mantid (8.52 %).

The morphological characterization of Antilochus coqueberti (Fabricius) showed that the body colouration was vividly red with membrane black; antennae, tibiae and tarsi black; femora and the knee-joint red; fore femora moderately thickened with a single row of small tubercles; clavus and corium uniformly bright red; labium extending to mid-coxae with apex dark; ventre of abdomen red, inter segmental sutures narrow and black.

The bio-efficacy of different management schedules *viz.*, three sprays of fipronil 200 SC @ 300 ml ha^{-1}, spirotetramate 200 SL @ 1000 ml ha^{-1}, imidacloprid 200 SL @ 125 ml ha^{-1}, acetamiprid 20 SP @ 100 g a.i. ha^{-1}, thiamethoxam 25 WG @ 100 g a.i. ha^{-1}, dimethoate 30 EC @ 660 ml $ha^{-1}$and spiromesifen 240 SC @ 500 ml ha^{-1} was evaluated against the sap sucking insect pests of cotton.

The result of effectiveness of newer insecticides against hemipteran insect pests showed that all the treatments were significantly superior over control. Three spray of fipronil 200 SC @ 300 ml ha^{-1} was found most effective against jassids and thrips with mean reduction of 89.52 and 90.09 per cent, respectively. It was followed by imidacloprid 200 SL @ 125 ml ha^{-1} and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} which caused 85.58 and 82.01; 86.40 and 84.34 per cent reduction in jassids and thrips population, respectively.Three spray of imidacloprid 200 SL @ 125 ml ha^{-1} proved significantly superior over all other treatments as it resulted in 89.44 per cent mean reduction in population of aphids. Thiamethoxam 25 WG @ 100 g a.i. ha^{-1} and spirotetramat 200 SL @ 1000 ml ha^{-1} followed the above treatment with 87.16 and 82.03 per cent mean reduction, respectively in aphids population and were at par each other. Fipronil 200 SC @ 300 ml ha^{-1} was followed the above treatments with 79.84 per cent mean reduction and was found at par with acetamiprid 20 SP @ 100 g a.i. ha^{-1} with mean reduction of 75.65 per cent mean reduction.

Three spray of acetamiprid 20 SP @ 100 g a.i. ha^{-1} proved significantly superior over all other treatments as it resulted in 88.13 per cent mean reduction in population of whitefly. Spiromesifen 240 SC @ 500 ml ha^{-1} and imidacloprid 200 SL @ 125 ml ha^{-1} followed the above treatment with 85.95 and 84.93 per cent mean reduction, respectively. Fipronil 200 SC @ 300 ml ha^{-1} (78.79%) and thiamethoxam 25 WG @ 100 g a.i. ha^{-1} (77.03%) were moderately effective and at par to each other.

Table-6: Bio-efficacy of different treatments against Jassids on cotton
***Figures in parentheses are retransformed per cent values PTP = Pre treatment population DAS = Day/days after spray**

Treatments	Doses/ha (g or ml)	PTP /plant	Mean reduction (%) in Jassids population days after spray									
			First spray				Second spray				Third	
			1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS
Fipronil 200 SC	**300**	10.00	51.71 (61.60)*	55.60 (68.08)	63.59 (80.22)	58.53 (72.75)	54.54 (66.34)	59.30 (73.93)	64.93 (82.05)	62.39 (78.52)	58.84 (73.23)	64.51 (81.48)
Spirotetramat 200 SL	**1000**	11.00	44.25 (48.69)	47.03 (53.54)	52.69 (63.26)	49.28 (57.44)	47.83 (54.93)	50.31 (59.21)	54.10 (65.62)	50.93 (60.28)	48.22 (56.61)	51.94 (61.99)
Imidacloprid 200 SL	**125**	9.33	49.48 (57.79)	52.79 (63.43)	58.64 (72.92)	55.09 (67.25)	52.42 (62.81)	56.34 (69.28)	61.21 (76.81)	58.09 (72.06)	57.44 (71.04)	61.24 (76.85)
Acetamiprid 20 SP	**100**	9.67	46.30 (52.27)	50.95 (60.31)	55.63 (68.13)	51.38 (61.04)	49.95 (58.60)	52.55 (63.28)	58.28 (72.36)	56.59 (69.68)	51.75 (61.67)	56.38 (69.34)
Thiamethoxam 25 WG	**100**	11.00	47.79 (54.86)	51.07 (60.52)	57.93 (71.81)	54.43 (66.16)	50.54 (59.61)	53.34 (64.35)	60.74 (76.11)	58.31 (72.40)	52.81 (63.46)	57.81 (71.62)
Dimethoate 30 EC	**660**	12.67	41.87 (45.55)	44.24 (48.67)	47.96 (55.16)	45.62 (51.04)	45.42 (50.73)	47.69 (54.69)	50.94 (60.29)	48.63 (56.32)	46.48 (52.58)	48.94 (56.85)
Spiromesifen 240 SC	**500**	12.67	47.92 (55.09)	50.53 (59.59)	56.41 (69.39)	53.19 (64.08)	50.13 (58.91)	52.68 (63.24)	58.52 (72.73)	56.22 (69.09)	54.62 (66.48)	58.18 (72.20)
Untreated Control	**-**	14.67	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S. Em ±			1.01	1.29	1.23	1.05	1.70	1.33	1.17	1.40	1.00	1.54
C.D. at 5%			3.06	3.90	3.72	3.17	5.14	4.02	3.54	4.24	3.04	4.67

Table-8: Bio-efficacy of different treatments against whiteflies on cotton

***Figures in parentheses are retransformed per cent values PTP = Pre treatment**

Treatments	Doses/ha (g or ml)	PTP /plant	Mean reduction (%) in Whiteflies population days after spra									
			First spray				Second spray				Third	
			1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS
Fipronil 200 SC	**300**	9.67	50.47 (59.49)*	51.44 (61.15)	54.76 (66.71)	53.57 (64.74)	52.00 (62.10)	54.22 (65.82)	58.33 (72.43)	57.54 (71.19)	54.18 (67.75)	57.46 (71.07)
Spirotetramat 200 SL	**1000**	10.33	48.05 (55.31)	50.57 (59.66)	53.15 (64.03)	52.64 (63.18)	50.07 (58.80)	53.00 (63.78)	56.98 (70.30)	55.09 (67.25)	52.40 (62.77)	53.67 (64.94)
Imidacloprid 200 SL	**125**	9.33	51.98 (62.06)	53.06 (63.88)	57.48 (71.10)	55.82 (68.44)	53.40 (64.45)	55.56 (68.02)	63.69 (80.35)	62.43 (78.58)	56.28 (69.18)	60.14 (75.21)
Acetamiprid 20 SP	**100**	10.67	54.86 (66.87)	57.71 (71.46)	62.01 (77.97)	60.71 (76.07)	56.35 (69.30)	60.26 (75.39)	66.30 (83.84)	65.21 (82.42)	59.67 (74.50)	63.24 (79.73)
Thiamethoxam 25 WG	**100**	9.67	50.21 (59.04)	51.72 (61.62)	54.27 (65.90)	52.73 (63.33)	51.76 (61.69)	53.09 (63.93)	58.06 (72.01)	57.20 (70.66)	54.14 (65.68)	56.25 (69.13)
Dimethoate 30 EC	**660**	10.33	47.74 (54.77)	50.06 (58.79)	52.92 (63.65)	51.49 (61.23)	49.16 (57.24)	52.99 (63.77)	56.11 (68.91)	54.98 (67.07)	50.76 (59.99)	53.57 (64.74)
Spiromesifen 240 SC	**500**	9.67	52.32 (62.64)	54.75 (66.69)	59.24 (73.84)	57.71 (71.46)	54.82 (66.81)	57.94 (71.82)	64.34 (81.25)	62.55 (78.75)	56.75 (69.94)	60.90 (76.35)
Untreated control	**-**	13.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S. Em ±			0.98	0.43	0.49	0.60	0.46	0.48	0.63	0.35	0.68	1.03
C.D. at 5%			2.97	1.31	1.48	1.81	1.41	1.45	1.90	1.07	2.07	3.11

population DAS = Day/days after spray

Table-7: Bio-efficacy of different treatments against Aphids on cotton
***Figures in parentheses are retransformed per cent value**

Treatments	Doses/ha (g or ml)	PTP /plant	Mean reduction (%) in Aphid population days after spray									
			First spray				Second spray				Third	
			1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS
Fipronil 200 SC	**300**	15.67	49.10 (57.13)*	51.22 (60.77)	54.46 (66.21)	53.31 (64.30)	51.16 (60.67)	53.39 (64.43)	58.71 (73.03)	56.62 (69.73)	54.18 (65.75)	57.60 (71.29)
Spirotetramat 200 SL	**1000**	14.67	50.41 (59.39)	52.64 (63.18)	56.80 (70.02)	55.76 (68.34)	53.44 (64.52)	55.41 (67.77)	59.62 (74.42)	57.26 (70.75)	55.81 (68.42)	59.41 (74.10)
Imidacloprid 200 SL	**125**	16.33	53.86 (65.22)	57.13 (70.54)	62.33 (78.44)	59.26 (73.87)	57.87 (71.71)	61.27 (76.89)	67.30 (85.11)	64.17 (81.02)	61.86 (77.76)	63.92 (80.67)
Acetamiprid 20 SP	**100**	15.33	47.94 (55.12)	50.50 (59.54)	53.76 (65.05)	51.08 (60.53)	49.50 (57.82)	54.40 (66.11)	56.71 (69.87)	54.00 (65.45)	53.51 (64.64)	55.44 (67.82)
Thiamethoxam 25 WG	**100**	17.33	52.46 (62.87)	55.67 (68.20)	60.86 (76.29)	57.57 (71.24)	55.44 (67.82)	59.11 (73.64)	63.74 (80.42)	62.06 (78.05)	58.44 (72.61)	61.15 (76.72)
Dimethoate 30 EC	**660**	18.33	47.19 (53.82)	48.50 (56.09)	51.54 (61.32)	49.15 (57.22)	48.88 (56.75)	51.82 (61.79)	54.00 (65.45)	52.30 (62.60)	50.11 (58.87)	53.03 (63.85)
Spiromesifen 240 SC	**500**	19.00	46.21 (52.11)	47.34 (54.08)	49.01 (56.98)	47.35 (54.10)	47.46 (54.29)	48.59 (56.25)	50.29 (59.18)	49.15 (57.22)	48.22 (55.61)	49.49 (57.80)
Untreated control	**-**	20.63	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S. Em ±			0.98	0.97	1.16	1.21	2.05	2.21	2.09	2.17	2.18	1.63
C.D. at 5%			2.98	2.93	3.51	3.67	6.22	6.71	6.34	6.57	6.62	4.93

Table-9: Bio-efficacy of different treatments against Thrips on cotton

Treatments	Doses/ha (g or ml)	PTP /plant	Mean reduction (%) in Thrips population days after spray									
			First spray				Second spray				Third	
			1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS
Fipronil 200 SC	**300**	15.33	56.55 (69.62)*	59.36 (74.03)	65.31 (82.55)	64.31 (81.21)	58.88 (73.29)	61.45 (77.16)	67.20 (84.98)	66.70 (84.35)	62.35 (78.46)	65.73 (83.10)
Spirotetramat 200 SL	**1000**	15.67	48.83 (56.66)	49.17 (57.25)	53.33 (64.33)	51.55 (61.33)	51.70 (61.59)	53.34 (64.35)	56.64 (69.76)	54.99 (67.08)	54.26 (65.88)	56.21 (69.07)
Imidacloprid 200 SL	**125**	15.33	55.41 (67.77)	57.30 (70.81)	63.10 (79.53)	61.68 (77.49)	57.11 (70.51)	60.09 (75.14)	64.71 (81.75)	62.03 (78.00)	61.17 (76.75)	63.73 (80.41)
Acetamiprid 20 SP	**100**	14.67	50.16 (58.96)	52.64 (63.18)	55.89 (68.55)	54.02 (65.48)	53.65 (64.87)	55.29 (67.58)	58.18 (72.20)	57.02 (70.37)	55.09 (67.26)	57.26 (70.75)
Thiamethoxam 25 WG	**100**	14.33	54.93 (66.99)	56.46 (69.47)	60.08 (75.12)	58.48 (72.67)	56.12 (68.92)	58.09 (72.06)	62.74 (79.02)	61.19 (76.78)	59.37 (74.04)	61.98 (77.93)
Dimethoate 30 EC	**660**	16.67	47.50 (54.36)	49.09 (57.11)	53.05 (63.87)	50.92 (60.26)	50.84 (60.12)	52.61 (63.13)	56.30 (69.21)	54.10 (65.62)	53.72 (64.99)	55.34 (67.66)
Spiromesifen 240 SC	**500**	16.00	55.33 (67.64)	56.74 (69.92)	61.53 (77.28)	59.71 (74.56)	56.92 (70.12)	59.26 (73.87)	63.59 (80.22)	60.71 (76.07)	60.37 (75.56)	60.76 (76.14)
Untreated control	**-**	17.93	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S. Em ±			0.48	1.31	0.99	0.95	1.38	1.13	1.16	1.59	0.45	0.53
C.D. at 5%			1.45	3.98	3.00	2.88	4.17	3.43	3.52	4.82	1.36	1.60

[*]Figures in parentheses are retransformed per cent values PTP = Pre treatment population DAS = Day/days after spray

Table-5b: Seasonal mean population abundance of predatory natural enemies in cotton during *kharif* 2012

Adult Predators	**Natural enemies (No. / plant)**	**Relative Density (%)**	
		All Predators	**Excluding Spider**
Coccinellids	3.67	22.11	31.26
Chrysopids	3.18	19.15	27.08
Preying Mantids	1.00	6.03	8.52
Predatoy Wasp	2.87	17.31	24.44
Bug	1.02	6.16	8.69
Spider	0.94	5.64	0.00
Shannon Index	1.96 (All Predators) 1.48 (Predators Excluding spider)		

Table-5a: Weekly mean population of natural enemies in cotton during *kharif* 2012

Date of observation during 2012	**Predatory Natural Enemies**							
	Coccinellids		Chrysopids		Mantids	Wasp	Spider	Bugs
	Grubs	Adults	Grubs	Adults				
12 July	0.13	0.87	0.23	1.00	0.13	1.33	0.13	0.13
19 July	0.33	1.00	0.33	1.33	0.23	2.00	0.23	0.23
26 July	0.67	1.67	0.67	1.85	0.33	2.33	0.33	0.33
02 August	0.87	2.33	0.95	2.00	0.67	2.57	0.57	0.57
09 August	1.33	2.57	1.50	2.33	0.87	2.89	0.87	0.67
16 August	1.87	3.50	2.00	3.00	1.00	3.23	1.00	0.87
23 August	2.00	4.00	2.33	3.50	1.33	3.50	1.50	0.89
30 August	2.50	4.67	2.87	4.00	1.87	4.00	2.00	0.97

06 September	2.87	4.87	3.00	4.50	1.93	4.33	2.33	1.13
13 September	3.00	5.67	3.33	5.00	2.00	4.50	2.50	1.33
20 September	3.13	6.03	3.67	5.50	2.33	4.67	1.50	1.87
27 September	4.50	8.33	4.00	6.00	2.00	5.00	1.33	2.50
04 October	4.00	7.23	3.50	5.33	1.50	4.00	1.00	2.00
11 October	3.30	5.67	2.00	4.00	1.00	3.50	0.87	1.50
18 October	3.13	4.37	1.67	3.87	0.87	3.00	0.53	1.33
25 October	3.00	4.00	1.00	3.33	0.67	2.00	0.33	1.13
01 November	2.87	2.33	0.87	3.00	0.57	1.63	0.23	1.00
08 November	2.00	1.87	0.67	2.50	0.33	1.33	0.67	0.97
15 November	1.00	1.37	0.37	1.00	0.23	1.00	0.57	0.67
22 November	0.50	1.00	0.33	0.50	0.13	0.60	0.23	0.33
Totals	43.00	73.35	35.29	63.54	19.99	57.41	18.72	20.42
Seasonal Mean	2.15	3.67	1.76	3.18	1.00	2.87	0.94	1.02
RD (%)	12.96	22.11	10.64	19.15	6.03	17.31	5.64	6.16

Table-4: Seasonal mean population abundance of sap sucking insect pests of cotton during *kharif* 2012

Insects	**Sap-sucking insect pests** **Numbers / plant**	**Relative Density (%)**	
		Hemiptera + Thysanoptera	**Hemiptera**

Aphids	195.56	34.90	42.50
Jassids	64.89	11.58	14.10
Whiteflies	56.52	10.09	12.28
Thrips	100.18	17.88	0.00
Red cotton bug	63.89	11.40	13.88
Dusky cotton bug	79.26	14.15	17.22
Shannon Index	1.68 (Hemiptera + Thysanoptera) 1.47 (Hemiptera)		

Date of observation (Periods)	Abiotic factors			Mean population of sap-sucking insect pests per plant					
	Mean temp. (^{0}C)	Mean R.H. (%)	Rain fall (mm)	Aphids	Jassids	Whiteflies	Thrips	R C B	D C B
29 June - 05 July	31.60	55.64	27.50	0.67	0.33	0.33	1.00	-	-
06 - 12 July	27.63	63.53	104.60	1.00	0.87	0.67	1.33	-	-
13 - 19 July	27.19	66.36	0.00	1.33	1.53	1.33	2.67	-	-
20 - 26 July	27.44	67.57	1.00	3.67	3.53	2.67	5.93	-	-
27 July - 02 Aug	22.34	70.57	13.60	4.87	7.80	8.87	20.67	-	-
03 - 09 Aug	26.13	70.49	15.67	15.67	8.00	9.33	**33.87**	-	-
10 -16 Aug	24.37	82.93	19.27	13.27	8.67	9.87	31.67	-	-
17 - 23 Aug	25.84	75.65	17.40	34.87	**21.87**	**20.33**	30.13	-	-
24 - 30 Aug	25.87	78.29	58.60	**36.27**	18.33	18.47	10.67	-	-
31 Aug - 06 Sept	27.53	78.08	69.80	32.53	14.67	13.67	10.00	-	-
07 - 13 Sept	24.55	90.00	193.0	27.73	10.06	9.33	0.33	-	-
14 - 20 Sept	26.03	75.93	0.40	27.00	7.27	6.87	0.87	-	-
21 - 27 Sept	26.22	68.08	34.00	33.87	7.73	6.33	0.67	1.67	-
28 Sept - 04	25.98	54.87	0.00	34.87	8.40	5.80	0.33	2.87	1.33

Oct									
05 - 11 Oct	26.00	51.15	0.00	26.00	4.93	4.53	2.00	4.13	2.67
12 - 18 Oct	24.41	47.89	0.00	25.87	5.60	3.80	0.53	11.40	4.33
19 - 25 Oct	24.19	46.94	0.00	25.33	4.40	3.60	0.87	8.00	4.87
26 Oct - 01 Nov	21.45	43.36	0.00	23.33	3.87	2.80	0.00	**15.33**	9.73
02 - 08 Nov	19.45	50.36	0.00	22.00	2.33	1.73	0.00	8.27	**14.27**
09 - 15 Nov	21.16	47.56	0.00	17.87	2.06	1.67	0.00	6.67	10.20
16 - 22 Nov	19.56	47.65	0.00	13.20	1.67	1.27	0.00	3.33	5.67
23 - 29 Nov	19.46	50.93	0.00	9.67	1.33	1.07	0.00	2.33	4.36
$\mathbf{r_1}$				-0.06	0.20	0.20	-0.28	-0.17	-0.67*
$\mathbf{r_2}$				0.15	0.64*	0.69*	0.44	-0.65*	-0.45
$\mathbf{r_3}$				0.11	0.28	0.28	-0.15	-0.37	NA

Table-3: Seasonal incidence of sap-sucking insect pests of cotton (GH-8) during 2012
R C B = Red Cotton Bug
D C B = Dusky Cotton Bug

*Significant at 5% level 't' value significant at 5% P= 0.05

$\mathbf{r_1}$ = Coefficient of correlation between mean temperature (^{0}C) and sap-sucking insect pests population

$\mathbf{r_2}$ = Coefficient of correlation between mean relative humidity (%) and sap-sucking insect pests population

$\mathbf{r_3}$ = Coefficient of correlation between rainfall (mm) and sap-sucking insect pests population

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