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Spacio-temporal dynamics of insecticide resistance in leafhoppers *Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae) in cotton

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Abstract
In the present study, insecticide resistance acquired by leafhoppers *Amrasca biguttula biguttula* in cotton was assessed through bioassay for populations of Hanumanamatti, Dharwad and Annigeri in Karnataka. Among different insecticides a high degree of resistance was shown against neonicotinoids compared to organophosphates. Similarly resistance was relatively in Hanumanamatti population than Dharwad and less in Annigeri. The highest resistance of 0.25 ml/l as LC_{50} was observed against Imidacloprid 17.8 SL in Hanumanamatti population which is equal to recommended dosage. The LC_{50} for thiomethoxam was 0.27 ml /l which is higher than its recommended dosage. Leafhoppers responded better to selected organophosphates particularly to acephate with LC_{50} of 0.53 g / l. The resistance noticed against fipronil was least. At Dharwad and Annigeri locations LC_{50} values varied from (0.45 to 0.53 ml/l) and (0.42 to 0.49 ml/l) with seasonal mean LC_{50} values of 0.47 and 0.45 ml/l compared to recommended dosages 1.0 ml/l with respect to fipronil compared to LC_{50} 0.46 to 0.56 ml/l in LC_{50} Hanumanamatti population across season.

Keywords: Cotton leafhopper. *Amrasca*. resistance

1. Introduction

Cotton (*Gossypium* spp.) being a friendly fibre grown in more than 110 countries all along the world. In India it is cultivated in >11.00 million ha with a production of 33.50 million bales of seed cotton and productivity of 518 kg/ha [1]. Bt transgenic has occupied nearly 95% cotton acreages in India. Cultivation of cotton under diversified agro climatic situations made the crop to suffer a lot by different kinds of pests and diseases. Large area under rainfed situations and extensive replacement of conventional varieties with transgenic cultivars mostly not having a good host plant resistance made the crop easily vulnerable to many sap feeding insects and newer pests.[2] Treatment of seeds at source of production with imidacloprid seed dressing formulations to check early sucking pests could also be considered as a reason for grater survival of sucking pests acquiring resistance owing to pre-emptive disposal to neonicotinoids heavily. These sucking pests occur at all the stages of crop growth and responsible for indirect yield losses. The estimated loss is up to 21.2%. [3] With the advent of hybrid varieties and intensive cultivation farmers are relying more on pesticides for plant protection. This created serious upset and imbalance in the arthropod complex of the environment causing resurgence and resistance [4].

Among the key pests of cotton, the cotton leafhopper, *Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae) is an alarming pest throughout the crop growth.[5] The nymphs and adults suck the sap from leaves and cause phytotoxic symptoms known as hopper burn which results in complete desiccation of plants and has become one of the limiting factors in economic productivity of the crop [6]. Since cotton crop is exposed to heavy doses of insecticides, the cotton leafhopper has already developed resistance against four commonly used insecticides *viz.*, endosulfan, monocrotophos, phosphamidon and cypermethrin.[7] The pest remains active throughout the crop growth period and more often control failures are experienced by cotton growers.

Insecticide resistance has long been seen by many as the greatest threat to chemical means of controlling noxious organisms including insect-pests of agricultural crops. It could be believed that chemical methods will be severely curtailed as a result of resistance [4].

Due to indiscriminate use of insecticides in cotton especially for the control of bollworms, populations of whitefly, *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) and leaf hopper, *Amrasca biguttula biguttula* (Ishida), (Homoptera: Cicadellidae) had developed resistance to most of the commonly used insecticides [4]. Cotton leafhopper, *A. biguttula biguttula* has shown signs of resistance and control failures. Fenvalerate (0.15%), which is 30 times the recommended concentration of 0.05 per cent, provided only less than 20 per cent mortality of *A. biguttula biguttula*. [8] The pest problem is aggravated more rapidly due to control failures in many areas. Though control failures may be due to many factors, one of the major factors is the development of resistance to insecticides. It is quite possible that these leafhoppers must have developed great degree of resistance to insecticides like bollworms in recent past [9]. The present study was aimed at understanding the status of resistance in leafhoppers to various insecticides used in cottons grown in three diverse agro-climatic situations.

2. Materials and Methods

2.1 Experimental and insect population locations

The present experiment for season long resistance in leafhoppers to various commonly used insecticides was carriedout at Entomology laboratory of Agricultural Research Station, Dharwad Farm during 2011-2012. The resistance study included leafhopper populations from three distinct places viz., Dharwad, Annigeri and Haveri having different cultivation and plant protection practices of cotton. Dharwad is located between 15.17° N latitude and 76.46° E longitude at an altitude of 678 meters above mean above sea level where cotton is an exclusive rainfed crop with moderate insecticide pressure. Hanumanamatti (Dt: Haveri) is located between 14°37′N latitude and 75°37′E longitude at an altitude of 605 meters above mean above sea level which has largest acreges of cotton in Karnataka grown rainfed and irrigated crop as well. It is known has high pesticide usage area. Annigeri (Tq: Navalagund /Dt: Dharwad) is located between 15°34′N latitude and 75°22′E longitude at an altitude of 578 meters above mean above sea level. This is non-traditional area of cotton wherein Bt cottons have entered recently. The incidence and usage of pesticides is low in this area. Dharwad and Hanumanamatti (Dt: Haveri) belongs to Northern transitional zone wherein a good rainfall is assured where as Annigeri belongs to Northern dry zone characterized by low rainfall. The incidence pattern of leafhoppers [10,11] and insecticide usage patter differ lot amongst these localities. [12]

2.2 Collection and transport of insects

The populations of cotton leafhopper, *A. b. biguttula* nymphs were collected from un-sprayed cotton plots specifically raised for this purpose at, ARS, Dharwad, Hanamanamatti and Annegiri during early morning hours in buck*et al*ong with leaves and transferred to laboratory at Dharwad immediately. The collections were made four times in the season. Then insects were sorted with zero number camel hair brush to fresh untreated leaves for further use in toxicity assays.

2.3 Test Insecticides

The degree of resistance acquired by leafhopper to nine commonly used insecticides by farmers on cotton *viz.* clothianidin 50 WDG (Dantop), imidacloprid 17.8 SL (Confidor), thiomethoxam 25 WG (Renova), acetamiprid 20 SP (Pride), monocrotophos 36 SL (Monostar), dimethoate 30 EC (Rogar), acephate 75 SP (Strathene), fipronil 5 SC (Regent) and oxydemeton methyl 25 EC (Metasystox) was assessed by following leafdip assay method. All the insecticides were procured as market samples and the dilutions required were prepared from the formulated products of the insecticide using distilled water. One liter of every required concentration was prepared and stored in cool dark place. There were five concentrations for each test insecticide rendering mortality between 20 to 80% mortality considered for bio-assays based on pilot scale testing.

2.4 Bio- assay for *A. biguttula biguttula* resistance to insecticides.

The leafhopper nymphs collected from each locations were exposed to graded concentrations of each test insecticide following leaf dip method (method No. 8) recommended by Insecticide Resistance Action Committee (IRAC). Two cups were used, *i.e.* one as inner test chamber and the other as outer water reservoir. The cup which serves as the inner test chamber was taken and a hole was made in the centre of the bottom side of the cup. Then unsprayed DCH-32 (raised in separately in small block) cotton leaves were selected and the petiole was cut to a length of approximately 4cm. The leaves were dipped in insecticide solutions for five seconds. Then the leaves left for drying in the open air (approximately 5 min). The petiole of the test leaf was passed through the inner cup until it protrudes by approximately 1.0 cm. In each such inner cup 50 leafhopper nymphs were released. Then perforated lid of the cup was placed. Care was taken to avoid escape of nymphs. A small amount of water was placed in a second cup and the test cup placed inside that, so that it was supporting the protruding petiole. After 48 hours of the treatment, the treated leaf was carefully taken out from the cups and the mortality of leafhoppers was recorded. Moribund insects were also considered as dead. A control was also maintained at each time of experimentation where in the leaves were dipped in distilled water. The entire set up was replicated four times. In general the 50 insects/concentration of each insecticide were used and entire set up was replicated four times. The environmental conditions in the laboratory were 25± 1ºC, 70 ± 5% RH and a 14h photoperiod. The experimental setup of bioassay was maintained separately from every location viz. Dharwad, Haveri and Annegiri. Such toxicity assays were conducted four times to track in-season changes in resistance.

2.5 Statistical analysis

The treatment mortality data were corrected using Abbott's formula. While workingout the corrected mortality the data from set-up showing < 10% and > 90% mortality in insecticides concentrations and > 10% mortality in untreated control were ignored subjected for repetition. Using corrected mortality the median lethal concentrations (LC_{50}) for each insecticide were worked-out by probit analysis as described Finny and using MS Excel software. Lower and upper fudicial limits of each LC_{50} value and recommended dosages have been considered while discussing the results. The location-wise resistance data has been presented and discussed for every insecticide as changes in LC_{50} across the season and seasonal mean as well.

3. Results and Discussion

The season long toxicity data has been presented in Table 1, 2 and 3 for Hanumanamatti, Dharwad and Annigeri leafhopper populations respectively for all insecticides.

3.1 Resistance to neonicotinoides

The data clearly indicates inseason changes in the toxicity for each insecticide and across locations also. At the beginning of the season the resistance was relatively less increased with advancement of the season. For neonicotinoides especially against imodacloprid and thiamethoxam there was high level of resistance at the beginning of the season itself. Among the different locations Hanumanamatti population representing Haveri district had relatively higher resistance than Dharwad and Annigeri in the order.

The LC_{50} for imidacloprid in leafhopper population of Hanumanmatti varied from 0.19 to 0.25 ml/l in the season with a mean of 0.21ml/l (Table 1). Hanumanmatti population acquired 1.05 and 1.10 fold seasonal mean resistances to imidacloprid compared to Dharwad and Annigeri locations (Table 2 and 3). For Dharwad and Annigeri population LC_{50} varied from 0. 17 to 0.23 ml/l and 0.16 to 0.21 ml/l with seasonal mean 0.20 and 0.19 ml/l respectively (Table 2 and 3). Compared to recommended dosage (0.25 ml/l) and the bio assay results in the study a relatively high level resistance was evident. The present findings agree with previous observations in TamilNadu [13] and Maharashtra [14] wherein upto 23 folds of resistance to imidacloprid in cotton leafhoppers of compared to susceptible strain was reported. Such medium-level resistance to imidacloprid was believed to be due to extensive use of these insecticides for control of leafhoppers in all cotton growing areas in the country. Similarly intensive use of imidacloprid in the Almeria region was considered as the reason for the occurrence of resistance in whitefies.[15] With respect to acetamiprid, the leafhopper population from Hanumanmatti had LC_{50} range of 0.14 to 0.18 g/l in the season. The Hanumanmatti population acquired about 1.14 fold seasonal mean resistances to acetamiprid as LC_{50} over Dharwad and Annigeri populations. In Dharwad and Annigeri populations LC_{50} varied from (0.13 to 0.17 g/l) and (0.12 to 0.16 g/l) with seasonal mean of 0.21 and 0.19 g/l respectively. The LC_{50} value was almost equal to recommended dosage (0.20 g/l) in all populations. This study agree with report from Maharashtra wherein 19 fold resistance to acetamiprid was noticed in cotton leafhoppers over a susceptible strain due to extensive usage of this insecticide [14].

The LC_{50} for thiamethoxam in leafhoppers of Hanumanmatti varied from 0.19 to 0.27 g/l in the season with a mean of 0.23 g/l (Table 1). It acquired 1.09 and 1.21 fold seasonal mean resistances over Dharwad and Annigeri populations. The Dharwad and Annigeri population LC_{50} ranged from (0.18 to 0.23 g/l) and (0.17 to 0.23 g/l) with seasonal mean of 0.20 and 0.19 g/l respectively (Table 2 and 3). The recommended dosages for thiamehoxam (0.20 g/l) were in close proximity of resistance levels observed or higher in some instances. Thiamethoxam resistance in cotton leafhoppers has been observed in different populations of TamilNadu also which supports present study.[16] However it is likely that due to cross resistance phenomenon among neonicotinoids leafhoppers might have registered less susceptibility to thiamethoxam. Thiamethoxam is largely used chemical after imidacloprid as seed treatment chemical as well as spray. For clothianidin, the leafhopper population from Hanumanmatti could show LC_{50} varying from 0.46 to 0.56 g/l (Table 1). Thus 1.04 and 1.08 folds more resistance over Dharwad and Annigeri populations was evident (Table 2 and 3). There has been relatively low level of resistance to clothianidin as this insecticide is under use since last couple of years only.

3.2 Resistance to organophosphates

In respect of monocrotophos, the leafhopper population from Hanumanmatti population had LC_{50} 0.52 to 0.60 ml/l with advancement across season (Table 1). Thus 1.03 and 1.05 folds more seasonal mean resistance was evident compared to Dharwad and Annigeri populations. The Dharwad and Annigeri LC_{50} values varied from (0.52 to 0.57 ml/l) and (0.50 to 0.57 ml/l) with seasonal mean LC_{50} values of 0.54 and 0.53 ml/l compared to recommended dosage 1.0 ml/l respectively (Table 2 and 3). An earlier study has shown 36 folds high resistance for monocrotophos in cotton leafhoppers of Guntur district in Andhra Pradesh which was because of intensive use of monocrotophos by the cotton growers.[17] The present study indicated the variable susceptibility but less resistance compared to earlier report and neonicotinoids in the present study.

The leafhopper population of Hanumanmatti location acquired 1.05 and 1.07 fold seasonal mean resistances to dimethoate as LC_{50} compared to Dharwad and Annigeri populations. The resistance in Dharwad and Annigeri populations varied from 0.92 to 1.06 ml/l and 0.91 to 1.00 ml/l with seasonal mean LC_{50} of 0.97 and 0.95 ml/l respectively (Table 2and 3). In respect of oxydemeton methyl, the leafhopper population from Hanumanmatti location had LC_{50} variations from 1.05 to 1.14 ml/l along the season (Table 1). The Hanumanmatti population acquired 1.00 and 1.05 fold seasonal mean resistance to oxydemeton methyl as LC_{50} over Dharwad and Annigeri populations. The Dharwad and Annigeri LC_{50} values varied from (1.02 to 1.13 ml/l) and (1.00 to 1.08 ml/l) with seasonal mean LC_{50} values of 1.06 and 1.02 ml/l compared to recommended dosage 1.5 ml/l respectively (Table 2 and 3). A 6 and 8 folds resistance to dimethoate and oxydemeton methyl was evident in this species longback, [8] however now resistance for these insecticides is low as their usage is rare now. [12]The present study agrees with relatively lower resistance in cotton leafhoppers populations of Punjab to dimethoate and other organophoshates compared to neonicotinyles. [18]

Resistance to acephate, at Hanumanmatti varied from 0.45 to 0.53 g/l with seasonal mean of 0.47g/l as LC_{50} (Table 1). The Dharwad and Annigeri location LC_{50} values varied from (0.43 to 0.51 ml/l) and (0.41 to 0.50) with seasonal mean LC_{50} of 0.47 and 0.46 g/l compared to 1.0 g/l as recommended dosage (Table 2&3). Thus, there was no much variation in resistance level among three populations of leaf hoppers. There was varying and high level resistance in cotton leafhoppers earlier for acephate in Tamil Nadu populations [13], however its declined now.

3.3 Resistance to insect growth regulator

The leafhopper population of Hanumanmatti location varied from 0.46 to 0.56 ml/l with seasonal mean of 0.49 ml/l for fipronil resistance (Table 1). The Hanumanmatti location LC_{50} values acquired same fold seasonal mean resistance as LC_{50} values of Dharwad and Annigeri. The Dharwad and Annigeri population LC_{50} values varied from (0.45 to 0.53 ml/l) and (0.42 to 0.49 ml/l) with seasonal mean LC_{50} values of 0.47 and 0.45 ml/l compared to recommended dosages 1.0 ml/l (Table 2 and 3). Fipronil is also latest recommendation in cotton and hence the previous results are not available for comparison. As on IGR this insecticide has revealed better efficiency over leafhoppers.

The present findings of resistance in leafhopper to various insecticide used commonly clearly emerged as evidence for resistance in three populations of north Karnataka. There has been a significant resistance to neonicotinoid compounds *viz.,* imidacloprid, thiamethoxam and acetamiprid. The resistance to imidacloprid particularly would be a serious matter as it is being used a seed dresser widely and as spray molecule also heavily. Thus sucking pests are having pre-emptive exposure as well as high selection pressure imidacloprid. The inseason dynamics and geographical variation observed in the present study definitely has the influence of pesticide usage pattern in these locatliteis. [12] This would lead to cross resistance to other neonicotinoid molecules also. Such phenomenon has been witnessed already in brown plant hoppers of paddy.[19]The resistance has been recorded in the present study for organophosphate compounds also, however, their response have been still considerable compared to neonicotionids suggesting their fitness in alternate use pattern. However, their high degree of selectivity against natural enemies stands as hindrance to re-accept them widely. Hence there is scope for insecticides with IGR action or alternate chemistry. A combination of neonicotionids with other insecticides (may be OPs) would also be ideal. Couple of such combi products (imidacloprid 11% + acephate 5% SP) is already in market in this concern fetching attraction of users. The present study is an alarming bell suggesting cautious use of neonicotionids and OP compounds. It also suggested for logical sequential use of insecticides against sucking pests. Scope would be given to fungal pathogen and botanicals in such sequence. The use of neonicotinoid (imidacloprid / thiamethoxam / acetamiprid / clothianidin) should necessarily be avoided as first spray since there is 100 per cent seed treatment (imidacloprid/thiamethoxam) in India for cotton. The study also calls for continuous monitoring of insecticide resistance against sucking pests of cotton nationwide as addressed for bollworms. Then only window-wise resistance management strategies could be suggested for management of sucking insects successfully in cotton. The mechanism of resistance has to be addressed otherwise there will be another episode of resistance in cotton.

Table 1: Insecticide of resistance in cotton leafhopper *Amrasca biguttula biguttula* to Hanumanamatti population.

Insecticides	Recommended Dosages Per lit	LC$_{50}$ (Lower – Upper Fiducial Limits)				
		August	September	October	November	Season Mean
Imidacloprid 17.8 SL	0.25 ml	0.19 (0.16-0.23)	0.21 (0.17-0.25)	0.23 (0.19-0.23)	0.25 (0.21-0.30)	0.21 (0.18-0.25)
Acetamiprid 20 SP	0.20g	0.14 (0.11-0.16)	0.15 (0.13-0.18)	0.16 (0.14-0.20)	0.18 (0.15-0.22)	0.16 (0.13-0.19)
Thiamethoxm 25 WG	0.20g	0.19 (0.16-0.23)	0.22 (0.18-0.26)	0.25 (0.19-0.28)	0.27 (0.20-0.30)	0.23 (0.18-0.26)
Clothianidin 50 WDG	0.075g	0.053 (0.047-0.06)	0.057 (0.05-0.064)	0.059 (0.052-0.066)	0.063 (0.056-0.071)	0.057 (0.05-0.064)
Monocrotophos 36 SL	1.0ml	0.52 (0.44-0.61)	0.55 (0.47-0.65)	0.58 (0.49-0.67)	0.61 (0.51-0.70)	0.56 (0.47-0.65)
Dimethoate 30 EC	2.0ml	0.96 (0.81-1.11)	1.02 (0.86-1.18)	1.06 (0.89-1.23)	1.08 (0.91-1.25)	1.02 (0.86-1.18)
Oxydemeton Methyl 25 EC	1.5ml	1.05 (0.92-1.18)	1.08 (0.94-1.21)	1.12 (0.97-1.27)	1.14 (0.99-1.30)	1.07 (0.94-1.21)
Acephate 75 SP	1.0ml	0.45 (0.37-0.52)	0.47 (0.39-0.55)	0.50 (0.41-0.60)	0.53 (0.43-0.63)	0.47 (0.39-0.56)
Fipronil 5 SC	1.0ml	0.47 (0.38-0.55)	0.49 (0.40-0.59)	0.51 (0.41-0.62)	0.56 (0.45-0.67)	0.47 (0.40-0.59)

Table 2: Insecticide of resistance in cotton leafhopper *Amrasca biguttula biguttula* to Dharwad population.

Insecticides	Recommended dosages Per lit	LC$_{50}$ (Lower – Upper Fiducial Limits)				
		August	September	October	November	Season Mean
Imidacloprid 17.8 SL	0.25 ml	0.17 (0.14-0.20)	0.19 (0.16-0.23)	0.21 (0.18-0.25)	0.23 (0.19-0.28)	0.20 (0.15-0.22)
Acetamiprid 20 SP	0.20g	0.13 (0.11-0.15)	0.14 (0.12-0.17)	0.15 (0.13-0.19)	0.17 (0.14-0.21)	0.15 (0.12-0.18)
Thiamethoxm 25 WG	0.20g	0.18 (0.15-0.21)	0.20 (0.16-0.23)	0.21 (0.17-0.24)	0.23 (0.19-0.27)	0.21 (0.16-0.23)
Clothianidin 50 WDG	0.075g	0.052 (0.047-0.058)	0.056 (0.058-0.062)	0.057 (0.051-0.063)	0.059 (0.052-0.065)	0.056 (0.05-0.062)
Monocrotophos 36 SL	1.0ml	0.52 (0.44-0.60)	0.54 (0.46-0.63)	0.55 (0.46-0.64)	0.57 (0.48-0.66)	0.54 (0.46-0.62)
Dimethoate 30 EC	2.0ml	0.92 (0.78-1.07)	0.97 (0.81-1.12)	0.99 (0.83-1.16)	1.06 (0.85-1.18)	0.97 (0.81-1.120
Oxydemeton Methyl 25 EC	1.5ml	1.02 (0.90-1.05)	1.06 (0.92-1.17)	1.10 (0.96-1.25)	1.13 (0.98-1.28)	1.06 (0.92-1.20)
Acephate 75 SP	1.0ml	0.43 (0.36-0.51)	0.46 (0.38-0.54)	0.48 (0.39-0.57)	0.51 (0.41-0.61)	0.47 (0.45-0.61)
Fipronil 5 SC	1.0ml	0.45 (0.37-0.53)	0.48 (0.39-0.57)	0.48 (0.40-0.57)	0.53 (0.43-0.64)	0.47 (0.39-0.56)

Table 3: Insecticide of resistance in cotton leafhopper *Amrasca biguttula biguttula* to Annigeri population.

Insecticides	Recommended Dosages Per lit	LC$_{50}$ (Lower – Upper Fiducial Limits)				
		August	September	October	November	Season Mean
Imidacloprid 17.8 SL	0.25 ml	0.16 (0.13-0.19)	0.17 (0.14-0.21)	0.19 (0.16-0.23)	0.21 (0.17-0.25)	0.19 (0.15-0.22)
Acetamiprid 20 SP	0.20g	0.12 (0.10-0.15)	0.13 (0.11-0.16)	0.14 (0.12-0.17)	0.16 (0.13-0.19)	0.14 (0.11-0.17)
Thiamethoxm 25 WG	0.20g	0.17 (0.15-0.20)	0.19 (0.16-0.22)	0.20 (0.18-0.25)	0.23 (0.19-0.27)	0.19 (0.16-0.22)
Clothianidin 50 WDG	0.075g	0.051 (0.045-0.056)	0.054 (0.048-0.06)	0.055 (0.049-0.061)	0.056 (0.050-0.063)	0.053 (0.047-0.059)
Monocrotophos 36 SL	1.0ml	0.50 (0.42-0.58)	0.53 (0.45-0.62)	0.55 (0.47-0.64)	0.57 (0.48-0.66)	0.53 (0.45-0.63)
Dimethoate 30 EC	2.0ml	0.91 (0.77-1.05)	0.95 (0.80-1.10)	0.96 (0.81-1.12)	1.00 (0.84-1.16)	0.95 (0.80-1.10)
Oxydemeton Methyl 25 EC	1.5ml	1.00 (0.87-1.13)	1.03 (0.90-1.17)	1.06 (0.92-1.21)	1.08 (0.93-1.24)	1.02 (0.89-1.16)
Acephate 75 SP	1.0ml	0.41 (0.34-0.49)	0.44 (0.37-0.52)	0.47 (0.38-0.55)	0.50 (0.40-0.59)	0.46 (0.37-0.52)
Fipronil 5 SC	1.0ml	0.42 (0.35-0.50)	0.44 (0.36-0.52)	0.45 (0.37-0.54)	0.49 (0.39-0.59)	0.45 (0.37-0.53)

4. Conclusion

Insecticide resistance in cotton leafhopper *A. biguttula biguttula* is eveident from the beginning of the season till end. The resistance is high neonicotinoides than organophosphates and nil to insect growth regulators. Resistance was evident across different conditions. Use of insecticides for spraying should be based on resistance would for effective management.

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