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Monitoring of insecticidal resistance in cotton jassid, *Amrasca biguttula biguttula* (ISHIDA) of Marathwada region of Maharashtra

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Abstract
Resistance to insecticides was investigated by collecting field population of cotton jassid from different locations of Marathwada region of Maharashtra, India. All the field populations of cotton jassid differed in their resistance to insecticides. In general, Osmanabad population of cotton jassids registered developed 20.37-fold resistance to imidacloprid 30.5 per cent SC which was higher than other field populations of jassid. The resistance ratios varied greatly among the populations *viz*., imidacloprid 17.8 per cent SL (3.50- to 2.06-fold), imidacloprid 30.5 per cent SC (20.37- to 9.00-fold), imidacloprid 70 per cent WG (5.46- to 3.53-fold), acetamiprid 20 per cent SP (11.36- to 8.36-fold), thiamethoxam 25 per cent WG (3.11- to 1.80-fold) and clothianidin 50 per cent WDG (3.04- to 1.89-fold). High resistance factor of imidacloprid 30.5 per cent SC, acetamiprid 20 per cent SP and imidacloprid 70 per cent WG against all field populations of cotton jassid indicated development of resistance against these insecticides. Amongst the neonicotinoid insecticides tested, imidacloprid 17.8 per cent SL, clothianidin 50 per cent WDG and thiamethoxam 25 per cent WG were exhibited highly toxic to all the field populations of cotton jassid evidenced low resistance ratio.

Keywords: *Amrasca biguttula biguttula*, Bioassay, Cotton, Insecticide resistance, Jassid, Neonicotinoids

Introduction
Cotton is the most important commercial crop known as "white gold" or "king of fiber" plays a prominent role in Indian economy. It is a natural gift known for its fiber since time immemorial. In India, apart from providing 60 per cent of the fiber used in textile industries, the crop is also a source for 11.5 lakh tones of oil, 90 lakh tones of animal feed and about 200 lakh tones of cotton stalk that is used for fuel and value addition as particle boards [10]. As per Cotton Advisory Board (CAB) in the current ongoing season (2017-18) of cotton, the estimated production is expected to touch 370 lakh bales with growth of 7.25%. Central zone to touch 209.5 lakh bales with 2.70% and southern zone to touch at 99 lakh bales of cotton with a growth of 10%. Gujarat would still be the topmost state in the production of cotton in the current season with growth of 9.47% to 104 lakh bales of cotton and would stake 28% share from the total production in the current cotton season and 50% share in the central zone. Cotton production in Maharashtra is expected to drop by -3.95% to 85 lakh bales and stake 23% from the total production. Maharashtra is the second highest cotton producing state in the country [9]. Cotton crop is subjected to damage by 162 species right from emergence till the final picking [17]. Introduction of *Bt* cotton technology solved the bollworm problem but continuous cultivation of *Bt* cotton has at some places led to increased incidence of sucking and other pests in the recent years [18]. The important sucking insect-pests attacking *Bt* cotton are jassid (*Amrasca biguttula biguttula* Ishida), thrips (*Scirtothrips dorsalis* Hood), aphid (*Aphis gossypii* Glover.), whitefly (*Bemisia tabaci* Gennadius) and mealy bug (*Phenacoccus solenopsis* Tinsley). Neonicotinoid insecticides are highly selective agonists of insect nicotinic acetylcholine receptors and provide farmers with invaluable, highly effective tools against sucking pests such as leafhopper, aphid, thrips and whitefly, world's most destructive crop pests. Today this class of insecticides comprises at least seven major compounds with a market share of more than 25 per cent of total global insecticide sales [8] However, the injudicious and over use of these molecules leads to the development of resistance. In this context, the present investigation was carried out to monitor the levels of insecticidal resistance in field populations of cotton jassid collected from different locations of Marathwada region of Maharashtra.

Materials and Methods

The present investigation was undertaken during the year 2014-2015 at Post Graduate Laboratory, Department of Agricultural Entomology, College of Agriculture, Latur (Maharashtra). The levels of resistance in field populations of cotton jassid collected from eight locations of Marathwada region against six neonicotinoid insecticides were assayed by leaf dip method. LC_{50} values obtained for field populations were compared with LC_{50} value of susceptible strain developed under protected condition without selection pressure of any insecticide.

Rearing of susceptible population

The susceptible population of cotton jassid was developed by maintaining jassid population on cotton plots protected with net separately without selection pressure of any insecticide for minimum five generations to get relatively homogenous susceptible population of jassid.

Preparation of insecticidal solution

All the insecticides were procured as market samples and dilutions required were prepared from the formulated product only with distilled water. Each insecticide was used in five concentrations (two lower and two higher) rendering 20 to 80 per cent mortality in pilot tests. However, care was taken to retain the recommended dosage of each insecticide as one of the concentrations.

Table 1: Insecticides used for jassids bioassay

Sr. No.	Insecticides	Trade Name	Name of company	Recommended dosages (per litre water)
1	Imidacloprid 17.8 SL per cent	Confidor	Bayer Crop Science	0.2 ml
2	Imidacloprid 30.5 per cent SC	Super Confidor	Bayer Crop Science	0.12 ml
3	Imidacloprid 70 per cent WG	Admire	Bayer Crop Science	0.07 g
4	Acetamiprid 20 per cent SP	Dhanpreet	Dhanuka Agritech Ltd.	0.1 g
5	Thiamethoxam 25 per cent WG	Actara	Syngenta Group of Company	0.2 g
6	Clothianidin 50 per cent WDG	Dantosu	Sumitomo Pvt. Ltd.	0.2 g

Plate 1: Maintenance of susceptible strains of cotton jassid under protected net in field

Plate 2: Jassid bioassay set up (IRAC Method No-8)

Bio-assay for *Amrasca biguttula biguttula* (Ishida) resistance to insecticide

The leafhopper or jassid 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 plastic containers were used, i.e. one as inner test chamber and the other as outer water reservoir. The plastic container which serves as the inner test chamber was taken and a hole was made in the center of the bottom side of the container. Then unsprayed (raised in separately in small block) cotton leaves were selected and the petioles were cut to a length of approximately 4 cm. 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 test chamber (inner plastic container) until it protrudes by approximately 1.0 cm. In each such test chamber (inner plastic container) 10 leafhopper nymphs were released. Then perforated lid of the test chamber (inner plastic container) was placed. Care was taken to avoid escape of nymphs. A small amount of water was placed in a second plastic container or outer water reservoir and the test chamber (inner plastic container) placed inside that, so that it was supporting the protruding petiole. After 48 hours of the treatment, the treated leaves were carefully taken out from the plastic containers 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 of treatments was replicated three times.

The setup of bioassay was maintained separately for every location. The mortality data of each treatment were corrected with respect to control mortality as per Abbott (1925) for leafhopper bioassays.[1] Leora Software (2006) POLO-Plus 1.0 Probit and Logit Analysis. LeOra Software. [2]

Abbott's formula

$$\text{Corrected per cent mortality} = \frac{T-C}{100-C} \times 100$$

Where,
T- Per cent mortality in treatment.
C- Per cent mortality in control

Median lethal concentration (LC_{50})

The value median lethal concentration (LC_{50}) for each insecticide was worked out using profit analysis by Finney (1971) and by computer software Polo plus 1.0 (Leora software) Similarly LC_{50} values of these insecticides against the susceptible population of cotton jassid was calculated. LC_{50} values of field collected population was compared with the LC_{50} values of susceptible strain to know the level of resistance.

Resistance ratio

The resistance intensity of insect population to particular insecticide is quoted as Resistance Ratio (RR). Sometimes it is also called Resistance Factor (RF) [3] which was calculated

by following formula:

$$\text{Resistance Ratio (RR)} = \frac{LC_{50} \text{ of Resistance Strain (RS)}}{LC_{50} \text{ of Susceptible Strain (SS)}}$$

Scale of Resistance factor or ratio

Insecticide resistance levels were described using RFs. [13] [16] [23] as follows: susceptibility (RF=1), decreased susceptibility (RF= between 3-5), low resistance (RF= between 5-10), moderate resistance (RF= between 10-40), high resistance (RF= between 40-160) and very high resistance (Resistance fold >160).

Results and Discussion

Imidacloprid 17.8 per cent Soluble Liquid resistance

The data on levels of resistance acquired by *A. biguttula biguttula* from different locations of Marathwada region to imidacloprid 17.8 per cent SL are presented in Table 2. The LC_{50} values for nymphs of *A. biguttula biguttula* exposed to imidacloprid 17.8 per cent SL ranged from 0.154 to 0.091 ml/l. The Beed population recorded a maximum LC_{50} value to imidacloprid 17.8 per cent SL (0.154 ml/l) followed by populations from Hingoli (0.146 ml/l), Latur (0.141 ml/l), Jalna (0.135 ml/l), Aurangabad (0.101 ml/l), Parbhani (0.098 ml/l), Nanded (0.095 ml/l) and Osmanabad (0.091 ml/l). However, LC_{50} value for susceptible strain of *A. biguttula biguttula* was 0.044 ml/l. The resistance ratio was found to be highest in the population of Beed (3.50-fold) followed by Hingoli (3.31-fold), Latur (3.20-fold), Jalna (3.06-fold), Aurangabad (2.29-fold), Parbhani (2.22-fold), Nanded (2.15-fold) and Osmanabad (2.06-fold). The variations of resistance (1.69-fold between Beed and Osmanabad populations) observed among the field populations assayed. Compared with the susceptible strain 4 of 8 field populations (50 per cent) i.e., Beed, Hingoli, Latur and Jalna indicated decreased susceptibility while, other 4 field populations (50 per cent) i.e., Aurangabad, Parbhani, Nanded and Osmanabad showed less susceptible to imidacloprid 17.8 per cent SL.

Table 2: Insecticide resistance of Imidacloprid 17.8 per cent SL against cotton jassid of different locations

Sr. No.	Strain	LC_{50} ml/g/l	Fiducial limits at 50 %		LC_{90} ml/g/l	Slope ± S.E.	x^2	RR
			LL	UL				
1	Jalna	0.135	0.107	0.249	0.534	2.147 ± 0.659	0.3608	3.06
2	Aurangabad	0.101	0.078	0.145	0.445	1.994 ± 0.633	0.5001	2.29
3	Hingoli	0.146	0.112	0.367	0.670	1.939 ± 0.658	0.2236	3.31
4	Beed	0.154	0.119	0.357	0.622	2.113 ± 0.675	0.1715	3.50
5	Nanded	0.095	0.067	0.141	0.507	1.769 ± 0.626	0.3418	2.15
6	Latur	0.141	0.110	0.305	0.610	2.015 ± 0.658	0.2006	3.20
7	Parbhani	0.098	0.070	0.149	0.527	1.751 ± 0.626	0.5595	2.22
8	Osmanabad	0.091	0.067	0.122	0.406	1.980 ± 0.629	0.5535	2.06
9	Susceptible	0.044	0.020	0.058	0.132	2.665 ± 0.721	1.491	-

Imidacloprid 30.5 per cent Suspension Concentrate resistance

The degrees of resistance to imidacloprid 30.5 per cent SC in *A. biguttula biguttula* from different locations of Marathwada region were evaluated and shown in Table 3. The LC_{50} values of field populations of *A. biguttula biguttula* varied from 0.163 to 0.072 ml/l. The Osmanabad population evidenced a maximum LC_{50} value to imidacloprid 30.5 per cent SC (0.163 ml/l) followed by populations from Parbhani (0.116 ml/l), Latur (0.116 ml/l), Aurangabad (0.094 ml/l), Jalna (0.091 ml/l), Nanded (0.087 ml/l), Hingoli (0.086 ml/l) and Beed (0.072 ml/l). The susceptible strain of *A. biguttula biguttula* noted lowest LC_{50} value of 0.008 ml/l. The highest resistance ratio was found in the population of Osmanabad (20.37-fold) followed by Parbhani (14.50-fold), Latur (14.50-fold), Aurangabad (11.75-fold), Jalna (11.37-fold), Nanded (10.87-fold), Hingoli (10.75-fold) and Beed (9.00-fold). The variations of resistance (2.26-fold between Osmanabad and Beed populations) existed among the field populations assayed. Compared with the susceptible strain 7 of 8 field populations (87.50 per cent) i.e., Osmanabad, Parbhani, Latur, Aurangabad, Jalna, Nanded and Hingoli had developed moderate level of resistance to imidacloprid 30.5 per cent SC. While, only one field population (12.50 per cent) i.e., Beed documented low resistance to imidacloprid 30.5 per cent SC.

Table 3: Insecticide resistance of Imidacloprid 30.5 per cent SC against cotton jassid of different locations

Sr. No.	Strain	LC_{50} ml/g/l	Fiducial limits at 50 %		LC_{90} ml/g/l	Slope ± S.E.	x^2	RR
			LL	UL				
1	Jalna	0.091	0.051	0.515	3.050	0.839 ± 0.298	0.6021	11.37
2	Aurangabad	0.094	0.054	0.508	2.896	0.860 ± 0.299	0.9901	11.75
3	Hingoli	0.086	0.049	0.406	2.730	0.852 ± 0.298	0.3784	10.75
4	Beed	0.072	0.040	0.290	2.684	0.815 ± 0.293	0.6409	9.00
5	Nanded	0.087	0.055	0.242	1.462	1.047 ± 0.308	1.5515	10.87
6	Latur	0.116	0.066	0.803	3.102	0.897 ± 0.307	0.9518	14.50
7	Parbhani	0.116	0.066	0.803	3.102	0.897 ± 0.307	0.9518	14.50
8	Osmanabad	0.163	0.090	1.399	2.960	1.019 ± 0.332	0.8588	20.37
9	Susceptible	0.008	0.001	0.015	0.110	1.103 ± 0.312	2.902	_

Imidacloprid 70 per cent Wettable Granule resistance

The data on the degrees of resistance acquired by *A. biguttula biguttula* from different locations of Marathwada region to imidacloprid 70 per cent WG are presented in Table 4. The field populations collected from different locations had varied resistance to this insecticide having (LC_{50}= 0.071-0.046 g/l).

The Jalna population recorded a maximum LC_{50} value (0.071 g/l) to imidacloprid 70 per cent WG followed by the populations from Nanded (0.066 g/l), Osmanabad (0.066 g/l), Parbhani (0.062 g/l), Aurangabad (0.060 g/l), Beed (0.056 g/l), Hingoli (0.052 g/l) and Latur (0.046 g/l). The susceptible strain had the highest susceptibility to this compound (LC_{50}= 0.013 g/l) among all the tested populations. The resistance ratio was found to be highest in the population of Jalna (5.46-fold) followed by Nanded (5.07-fold), Osmanabad (5.07-fold), Parbhani (4.76-fold), Aurangabad (4.61-fold), Beed (4.30-fold), Hingoli (4.00-fold) and Latur (3.53-fold). The variations of resistance (1.54-fold between Jalna and Latur populations) existed among the field populations assayed. The result showed that 3 of 8 field populations (37.50 per cent) i.e., Jalna, Nanded and Osmanabad had developed low resistance to imidacloprid 70 per cent WG as compared to the susceptible strain. However, remaining 5 field populations (62.50 per cent) i.e., Parbhani, Aurangabad, Beed, Hingoli and Latur evidenced decreased susceptibility to imidacloprid 70 per cent WG as compared to susceptible strain.

Similarly the reported LC_{50} values in Nagpur 0.10 ppm with in variability of 5 folds and 4.39 ppm in Amravati variability of 219.5 folds [14]. However, from Tamil Nadu [20] revealed that the levels of resistance in *A. biguttula biguttula* varied from 6.67 (Salem) to 15.38 (Srivilliiputhur) for imidacloprid. While, the reported 46.67 per cent mortality of leafhopper nymphs in imidacloprid with 0.007 LC_{50} [22]. In contrast, concluded that imidacloprid with minimum LC_{50} values (0.0012 0.0020 %) proved to be highly toxic to plant hoppers followed by acetamiprid [21].

Table 4: Insecticide resistance of Imidacloprid 70 per cent WG against cotton jassid of different locations

Sr. No.	Strain	LC_{50} ml/g/l	Fiducial limits at 50 %		LC_{90} ml/g/l	Slope ± S.E.	x^2	RR
			LL	UL				
1	Jalna	0.071	0.049	0.350	0.393	1.720 ± 0.593	0.0964	5.46
2	Aurangabad	0.060	0.043	0.198	0.335	1.720 ± 0.573	0.2707	4.61
3	Hingoli	0.052	0.039	0.131	0.294	1.701 ± 0.558	0.2843	4.00
4	Beed	0.056	0.040	0.183	0.343	1.625 ± 0.559	0.5171	4.30
5	Nanded	0.066	0.047	0.258	0.356	1.754 ± 0.589	0.1368	5.07
6	Latur	0.046	0.035	0.104	0.280	1.640 ± 0.547	0.3153	3.53
7	Parbhani	0.062	0.044	0.220	0.348	1.712 ± 0.575	0.4737	4.76
8	Osmanabad	0.066	0.047	0.223	0.329	1.836 ± 0.595	0.2289	5.07
9	Susceptible	0.013	0.006	0.017	0.038	2.701 ± 0.663	2.950	_

Acetamiprid 20 per cent Soluble Powder resistance

The data on levels of resistance developed in *A. biguttula biguttula* to acetamiprid 20 per cent SP from different locations of Marathwada region presented in Table 5. The LC_{50} values of field populations of *A. biguttula biguttula* varied from 0.125 to 0.092 g/l. The Parbhani population evidenced a maximum LC_{50} value to acetamiprid 20 per cent SP (0.125 g/l) followed by populations from Nanded (0.118 g/l), Osmanabad (0.118 g/l), Beed (0.109 g/l), Hingoli (0.105 g/l), Latur (0.099 g/l), Aurangabad (0.099 g/l) and Jalna (0.092 g/l). The susceptible strain recorded lowest LC_{50} value (0.011 g/l) to acetamiprid 20 per cent SP. *A. biguttula biguttula* population of Parbhani noticed highest resistance ratio to acetamiprid 20 per cent SP (11.36-fold) followed by Nanded (10.72-fold), Osmanabad (10.72-fold), Beed (9.90-fold), Hingoli (9.54-fold), Latur (9.00-fold), Aurangabad (9.00-fold) and Jalna (8.36-fold). The variations of resistance (1.35-fold between Parbhani and Jalna populations) existed among the field populations assayed. Compared with the susceptible strain 3 of 8 field populations (37.50 per cent) i.e., Parbhani, Nanded and Osmanabad had developed moderate resistance to acetamiprid 20 per cent SP. While, the five field populations (62.50 per cent) i.e., Beed, Hingoli, Latur, Aurangabad and Jalna showed low resistance to acetamiprid 20 per cent soluble powder.

These results are analogous to the findings who reported that the benefit of seed treatment with chloronicotinyls (imidacloprid, acetamiprid and thiamethoxam) was short lived and rarely extended beyond 20-30 days after sowing of cotton. [14] Similarly, from Maharashtra documented moderate to high level of resistance to acetamiprid in *A. biguttula biguttula* with LC_{50} value of 420.36 ppm and the resistance ratio was 19.08-fold [15]. As similarly the jassid population of Hanumanmatti acquired highest level of resistance to acetamiprid, with LC_{50} values of 0.16 g/l compared to Dharwad and Annigeri populations of jassid.**[19]** However, from Tamil Nadu in revealed that the levels of resistance in *A. biguttula biguttula* varied from 5.00 (Bhavanisagar) to 20.00 (Srivilliputhur) for acetamiprid [20].

Table 5: Insecticide resistance of Acetamiprid 20 per cent SP against cotton jassid of different locations

Sr. No.	Strain	LC_{50} ml/g/l	Fiducial limits at 50 %		LC_{90} ml/g/l	Slope ± S.E.	x^2	RR
			LL	UL				
1	Jalna	0.092	0.055	0.516	1.832	0.986 ± 0.334	0.8127	8.36
2	Aurangabad	0.099	0.057	0.796	2.238	0.948 ± 0.334	0.8033	9.00
3	Hingoli	0.105	0.059	1.046	2.456	0.935 ± 0.335	1.1111	9.54
4	Beed	0.109	0.064	0.706	1.858	1.041 ± 0.345	0.7704	9.90
5	Nanded	0.118	0.067	1.099	2.245	1.002 ± 0.345	0.7630	10.72
6	Latur	0.099	0.057	0.796	2.228	0.948 ± 0.334	0.8033	9.00
7	Parbhani	0.125	0.072	0.973	1.931	1.079 ± 0.357	0.3747	11.36
8	Osmanabad	0.118	0.067	1.099	2.245	1.002 ± 0.345	0.7630	10.72
9	Susceptible	0.011	0.003	0.019	0.126	1.204 ± 0.330	2.699	-

Thiamethoxam 25 per cent Wettable Granule resistance

The data on degree of resistance acquired by *A. biguttula* to thiamethoxam 25 per cent WG from different locations of Marathwada presented in Table 6. The LC_{50}

values of field populations of *A. biguttula biguttula* exposed to thiamethoxam 25 per cent WG varied from 0.140 to 0.081 g/l. The Beed population recorded highest LC_{50} value to thiamethoxam 25 per cent WG (0.140 g/l) followed by the populations from Parbhani (0.135 g/l), Aurangabad (0.119 g/l), Hingoli (0.114 g/l), Latur (0.104 g/l), Osmanabad (0.102 g/l), Nanded (0.091 g/l) and Jalna (0.081 g/l). The susceptible strain had the highest susceptibility to this compound (LC_{50}= 0.045 g/l) among all the tested populations. The resistance ratio was found to be highest in Beed field population (3.11-fold) followed by Parbhani (3.00-fold), Aurangabad (2.64-fold), Hingoli (2.53-fold), Latur (2.31-fold), Osmanabad (2.26-fold), Nanded (2.02-fold) and Jalna (1.80-fold). The field populations collected from different locations had varied resistance to thiamethoxam 25 per cent WG (1.72-fold between Beed and Jalna strain). Compared with susceptible strain 2 of 8 field populations (25 per cent) i.e., Beed and Parbhani strain had developed decreased susceptibility to thiamethoxam 25 per cent WG. However, other 6 of 8 field populations (75 per cent) i.e., Aurangabad, Hingoli, Latur, Osmanabad, Nanded and Jalna remained less susceptible to thiamethoxam 25 per cent WG.

These results finding are coincide with the work reported that the benefit of seed treatment with chloronicotinyls (imidacloprid, acetamiprid and thiamethoxam) was short lived and rarely extended beyond 20-30 days after sowing of cotton. **[14]** However, documented that Indore population of cotton leafhopper acquired resistance to thiamethoxam with LC_{50} of 0.5 ml/l however, Junagarh population noted very susceptible with LC_{50} of 0.0002 ml/l [4, 5, 6]. The resistance was 2500-fold for thiamethoxam. Analogously, Anonymous (2012) stated that cotton leafhopper population from Buldhana (Maharashtra) developed very high level of resistance to thiamethoxam with LC_{50} of 0.145 ml/l however, Bhatinda population noted very susceptible with LC_{50} of 0.00013 ml/l. According the jassid population of Hanumanmatti acquired highest level of resistance to thiamethoxam, with LC_{50} values of 0.23 g/l [19]. However, from Tamil Nadu in revealed that the levels of resistance in *A. biguttula biguttula* varied from 3.33 (Salem) to 15.09 (Srivilliiputhur) for thiamethoxam [20].

Table 6: Insecticide resistance of Thiamethoxam 25 per cent WG against cotton jassid of different locations

Sr. No.	Strain	LC_{50} ml/g/l	Fiducial limits at 50 %		LC_{90} ml/g/l	Slope ± S.E.	x^2	RR
			LL	UL				
1	Jalna	0.081	0.051	0.104	0.373	1.924 ± 0.628	0.4405	1.80
2	Aurangabad	0.119	0.092	0.231	0.604	1.818 ± 0.636	0.2804	2.64
3	Hingoli	0.114	0.088	0.203	0.573	1.828 ± 0.634	0.1202	2.53
4	Beed	0.140	0.108	0.324	0.643	1.936 ± 0.654	0.0845	3.11
5	Nanded	0.091	0.062	0.128	0.476	1.787 ± 0.626	0.1622	2.02
6	Latur	0.104	0.079	0.161	0.507	1.864 ± 0.630	0.2810	2.31
7	Parbhani	0.135	0.107	0.249	0.534	2.147 ± 0.659	0.3608	3.00
8	Osmanabad	0.102	0.076	0.159	0.526	1.800 ± 0.629	0.1400	2.26
9	Susceptible	0.045	0.021	0.060	0.139	2.639 ± 0.712	2.345	_

Clothianidin 50 per cent Wettable Dispersible Granule resistance

The data on the degrees of resistance acquired by *A. biguttula biguttula* from different locations of Marathwada region to clothianidin 50 per cent WDG are presented in Table 7. The LC_{50} values of field populations of *A. biguttula biguttula* exposed to clothianidin 50 per cent WDG varied from 0.146 to 0.091 g/l. Aurangabad population recorded maximum LC_{50} value (0.146 g/l) to clothianidin 50 per cent WDG followed by the populations from Nanded (0.135 g/l), Osmanabad (0.104 g/l), Latur (0.099 g/l), Beed (0.097 g/l), Hingoli (0.093 g/l), Jalna (0.091 g/l), and Parbhani (0.091 g/l). The susceptible strain had the highest susceptibility to this compound (LC_{50}= 0.048 g/l) among all the tested populations. The resistance ratio was found to be highest in the population of Aurangabad (3.04-fold) followed by Nanded (2.81-fold), Osmanabad (2.16-fold), Latur (2.06-fold), Beed (2.02-fold), Hingoli (1.93-fold), Jalna (1.89-fold) and Parbhani (1.89-fold). The field populations collected from different locations had varied resistance to clothianidin 50 per cent WDG (1.60-fold between Aurangabad and Parbhani strain). Compared with susceptible strain 1 of 8 field populations (12.50 per cent) i.e., Aurangabad strain had developed decreased susceptibility to clothianidin 50 per cent WDG. However, other 7 of 8 field populations (87.50 per cent) i.e., Nanded, Osmanabad, Latur, Beed, Hingoli, Jalna and Parbhani evidenced less susceptible to clothianidin 50 per cent WDG.

These findings are in conformity with the results who indicated high level of clothianidin resistance in BPH with the resistance ratios of 4.9 and 13.2-fold. **[12]** According the fining to all the field populations of BPH differed in their susceptibility to clothianidin (1.92 to 4.86-fold) **[7]**. While, reported the concluded that the per cent mortality of leafhopper nymphs was more in clothianidin (37.33 per cent) with 0.041 LC_{50} [22].

Table 7: Insecticide resistance of Clothianidin 50 per cent WDG against cotton jassid of different locations

Sr. No.	Strain	LC_{50} ml/g/l	Fiducial limits at 50 %		LC_{90} ml/g/l	Slope ± S.E.	x^2	RR
			LL	UL				
1	Jalna	0.091	0.062	0.128	0.476	1.787 ± 0.626	0.1622	1.89
2	Aurangabad	0.146	0.112	0.367	0.670	1.939 ± 0.658	0.2236	3.04
3	Hingoli	0.093	0.066	0.131	0.461	1.848 ± 0.627	0.3110	1.93
4	Beed	0.097	0.073	0.137	0.443	1.947 ± 0.631	0.1675	2.02
5	Nanded	0.135	0.107	0.249	0.534	2.147 ± 0.659	0.3608	2.81
6	Latur	0.099	0.075	0.143	0.459	1.930 ± 0.631	0.3432	2.06
7	Parbhani	0.091	0.062	0.128	0.476	1.787 ± 0.626	0.1622	1.89
8	Osmanabad	0.104	0.079	0.161	0.507	1.864 ± 0.630	0.2810	2.16
9	Susceptible	0.048	0.026	0.062	0.137	2.823 ± 0.713	1.952	_

Conclusion

The overall results concluded that high resistance factor of imidacloprid 30.5 per cent SC, acetamiprid 20 per cent SP and imidacloprid 70 per cent WG against all field populations of cotton jassids indicated development of resistance against these insecticides. Amongst the neonicotinoid insecticides tested, imidacloprid 17.8 per cent SL, clothianidin 50 per cent WDG and thiamethoxam 25 per cent WG were highly toxic to all the field populations of cotton jassids evidenced low resistance ratio. Thus, amongst the neonicotinoid insecticides, imidacloprid 17.8 per cent SL, clothianidin 50 per cent WDG and thiamethoxam 25 per cent WG can be used in rotation with the neonicotinoid insecticides to suppress the neonicotinoid resistant population of jassid in cotton ecosystem of Marathwada region.

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