J. Cotton Res. Dev. **32** (2) 276-283 (July, 2018) **ISSN No. 0972-8619**

Tracking in season dynamics of insecticide resistance in aphids *Aphis gossypii* (Glover) in different cotton growing ecosystems

V.B.PHULSE AND S.S.UDIKERI*
Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad - 580 005
**E-mail : ssudikeri@gamil.com*

ABSTRACT: Season-long monitoring of insecticide resistance in Aphids *Aphis gossypii* infesting cottons in three different agro-ecological conditions represented by Hanumanamatti, Dharwad and Annigeri in Karnataka was assessed through leaf dip bioassay. Among different insecticides a high degree of resistance was shown against neonicotinoids compared to organo phosphates. The order of resistance to each insecticide was Hanumanamatti > Dharwad > Annigeri. LC_{50} for imidacloprid was 0.18 and 0.15 ml/l in Hanumanamatti and Dhawrad / Annigeri populations respectively. For thiamethoxam the LC_{50} was 0.17, 0.16 and 0.14 g/ml in for Hanumanamatti, Dhawrad / and Annigeri population. Irrespective of location and insecticides resistance increased from October onwards. The resistance was least to fipronil in all the three populations.

Key words : Aphid, cotton, insecticide, resistance

Cotton (*Gossypium* spp.) being a 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 (Anonymous, 2011). *Bt* transgenic has occupied nearly 95 per cent 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. (Udikeri *et al.,* 2011). 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 23 per cent. 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.

Cotton or melon aphid *Aphis gossypii* (Hemiptera: Aphididae) is an important sucking pest of all cultivated cotton species including Bt transgenic hybrids. There has been a negative shift in the level of susceptibility of *A. gossypii* to different insecticides. (Carletto *et al.*,2010). It is quite possible that these aphids must have developed great degree of resistance to insecticides like bollworms in recent past. The present study aimed at understanding the status of resistance in aphids to various insecticides used in cottons grown in three diverse agro-climatic situations.

The experiment for season-long resistance in aphids to various commonly used insecticides was carriedout at Entomology laboratory of Agricultural Research Station, Dharwad Farm during 2011-2012. The resistance study included populations from three distinct agro-ecological situations *viz.*, Dharwad, Annigeri and Haveri having different cultivation and plant protection practices of cotton also. Dharwad is located between 15° 17' 14" N latitude and 76° 46'6" 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°372 12"N latitude and 75°372 9" E longitude at an altitude ÿþ / of 605 meters above mean above sea level wherein cotton is grown as rainfed and irrigated crop as well. Haveri is said to be high pesticide usage area. Annigeri (Tq: Navalagund /Dt: Dharwad) is located between 15°342 3"N latitude and 75°222 10" E longitude at an altitudeÿþ / ÿþ ÿþ / 1of 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 aphids (Phulse and Udikeri, 2014 and 2017) and insecticide usage patter differ lot (Sagar *et al.*, 2013) amongst these localities.

Collection and transport of insects : Cotton variety DCH 32 was raised at ARS, Dharwad, Hanamanamatti and Annigeri in up-protected conditions to allow aphid infestation. The colonies of *A.gssypii* comprising mostly nymphs were collected along with infested leaves during early morning hours in bucket and transferred to laboratory at Dharwad immediately for bioassays. Such collections were made four times in the season for in season resistance studies. In the laboratory at Dharwad the insects were shifted with zero number camel hair brush to fresh untreated leaves for toxicity assays.

Test insecticides : The degree of resistance acquired by aphids to nine commonly used insecticides by cotton farmers *viz.* clothianidin 50WDG (Dantop), imidacloprid 17.8SL (Confidor), thiomethoxam 25WG (Renova), acetamiprid 20SP (Pride), monocrotophos 36SL (Monostar), dimethoate 30EC (Rogar), acephate 75SP (Strathene), fipronil 5SC (Regent) and oxydemeton methyl 25EC (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 per cent mortality considered for bio-assays based on pilot scale testing.

Bio assay for *A. gssypii* resistance to insecticides : The apterous aphids (nymphs/ adults) collected in bucket from each locations were exposed to graded concentrations of each test insecticide following leaf dip method which was slight modification over leaf disc method adopted by Herron and Wilson., 2011 compromising with method # 1 of Insecticide Resistance Action Committee (IRAC). 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. These leaves were then dipped in different concentrations of each insecticide formulation for five seconds and left for drying in the open air (approximately 5 min). A small piece of damp cotton wool was placed around the petiole of each leaf to maintain the turgidity of leaf. About 50 apterous aphids were released per leaf of DCH-32 in petri dishes. A control was run which was sprayed with distilled water. Observations were taken for mortality after 24 hrs of treatment. Moribund insects were also considered as dead. The entire set up was replicated four times. The treatment mortality data were corrected using Abbott's formula. 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± 1°C, 70 ± 5 per cent RH and a 14h photoperiod. Using corrected mortality the LC_{50} for each insecticide was workedout by probit analysis as described Finny and using MS Excel software. While workingout the corrected mortality the data from set up showing < 10 and > 90 per cent mortality in any insecticides concentrations and > 10 per cent mortality in untreated control were ignored, further subjecting for repetition. 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. 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.

Within season dynamics of insecticides resistance in cotton aphids of each cotton eco-system has been presented in different tables. The data clearly indicates variations in insecticide resistance among three populations with limited in-season dynamics. At the beginning of the season the resistance was relatively less and increased with advancement of the season. For neonicotinoids especially against imidacloprid 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 higher resistance than Dharwad and Annigeri in the order. The tracking *A. gossypii* resistance in Hanumanamatti population against nine commonly used insecticides indicated (Table 1) gradual increase in LC_{50} values with advancement of season. At first observations (August FN-II) itself the resistance recorded for imidacloprid 17.8 SL was 0.16 ml/l in terms of LC_{50} with steady increase in the season with a maximum LC_{50} of 0.20 ml/l. The seasonal mean resistance was 0.18 ml/l by LC_{50}. The initial LC_{50} value for acetamiprid 20 SP was 0.14 g/l with slight variation with advancement of season. The LC_{50} value in Nov FN-II was 0.17 g/l with seasonal mean (0.15 g/l). For thiamethoxam 25 WG the LC_{50} observed was 0.16 g/l in August with drastic increase in each succeeding tracking. The season end (Nov FN-II) LC_{50} values was 0.19 g/l which was very close to recommended dosage (0.20 g/l) and seasonal mean LC_{50} values was 0.17 g/l. The LC_{50} values observed for clothianidin 50 WDG was 0.046 g/l (Aug FN-II) to 0.051 g/l (Nov FN-II) with seasonal mean resistance LC_{50} 0.049 g/l. Throughout season LC_{50} value was less compared to recommended dosage (0.075 g/l). The resistance recorded as LC_{50} for monocrotophos 36 SL was 0.69 (Aug FN-II) to 0.84 (Nov FN-II) ml/l with seasonal mean of 0.69 ml/l against the recommended dosage of 1.0 ml/l. Thus aphids appeared responding to monocrotophos. At the beginning of the season the resistance to dimethoate 30 EC was 1.49 ml/l as LC_{50}.The last assay (Nov FN-II) revealed LC_{50} 1.74 ml/l which was higher than seasonal mean LC_{50} value was 1.60 ml/l. The tracking of resistance to oxydemeton methyl 25 EC indicated seasonal mean LC_{50} of 1.21 ml/l with maximum of 1.32 ml/l in Nov FN-II which was higher than the seasonal mean. At the beginning it was 1.12 ml/l. The slight increasing trend was however indicated as case of other insecticides. The initial LC_{50} value for acephate 75 SP was 0.62 g/l with slight variation along the season. The LC_{50} value in Nov FN-II was 0.75 g/l which was higher than the seasonal mean 0.68 g/l as LC_{50} against a recommended dosage of 1.0 g/l. For fipronil 5 SC the LC_{50} value was 0.59 ml/l in Aug FN-II with slight increase in each succeeding trackings. The season end (Nov FN-II) LC_{50} value was 0.63 which was higher than the seasonal mean resistance LC_{50} value 0.61 ml/l against the recommendation of 1.0 ml/l.

Similarly Dharwad of *A. gossypii* (Table 2) also indicated gradual increase in LC_{50} with advancement of season. The data on LC_{50} values of imidacloprid 17.8 SL indicated that there was slight difference in LC_{50} with in the season. The maximum LC_{50} value of 0.17 ml/l was recorded during end of season (Nov FN-II) which was higher than the seasonal mean resistance LC_{50} value 0.15ml/l against recommended dosage (0.25 ml/l). The lowest LC_{50} value 0.14 ml/l was recorded in Aug FN-II. The resistance recorded as LC_{50} for acetamiprid 20 SP was 0.12 (Aug FN-II) to 0.15 g/l (Nov FN-II) with seasonal mean of 0.13 g/l against the recommended dosage of 0.2 g/l. The initial LC_{50} values for thiamethoxam 25 WG was 0.14 g/l with slight variation with advancement of season. The LC_{50} of Nov FN-II was 0.18 g/l which was slightly higher than seasonal mean (0.16 g/l). In the first assay LC_{50} for clothianidin was

Table 1. Insecticide resistance in cotton aphid Aphis gossypii to Hanumanamatti population

Insecticides	LC_{50} (Lower – Upper Fiducial Limits)				
	Aug FN –II	Sept FN -II	Oct. FN –II	Nov. FN -II	**Season Mean**
Imidacloprid 17.8 SL	0.16(0.13-0.20)	0.17(0.14-0.20)	0.18(0.15-0.22)	0.20(0.16-0.24)	**0.18(0.15-0.22)**
Acetamiprid 20 SP	0.14(0.11-0.17)	0.15(0.12-0.18)	0.16(0.13-0.1)	0.17(0.14-0.21)	**0.15(0.13-0.19)**
Thiamethoxm 25 WG	0.16(0.13-0.19)	0.16(0.13-0.20)	0.18(0.15-0.21)	0.19(0.16-0.23)	**0.17(0.14-0.21)**
Clothianidin 50 WDG	0.046(0.04-0.052)	0.048(0.041-0.052)	0.049(0.042-0.056)	0.051(0.043-0.058)	**0.049(0.042-0.055)**
Monocrotophos 36 SL	0.69(0.58-0.82)	0.73(0.61-0.86)	0.78(0.65-0.92)	0.84(0.70-0.99)	**0.69(0.64-0.90)**
Dimethoate 30 EC	1.49(1.28-1.7)	1.54(1.33-1.76)	1.63(1.41-1.87)	1.74(1.52-1.98)	**1.60(1.38-1.83)**
Oxydemeton Methyl 25 EC	1.12(0.4-1.31)	1.16(0.7-1.36)	1.24(1.04-1.45)	1.32(1.11-1.55)	**1.21(1.01-1.42)**
Acephate 75 SP	0.62(0.52-0.78)	0.65(0.54-0.76)	0.69(0.58-0.82)	0.75(0.62-0.89)	**0.68(0.56-0.89)**
Fipronil 5 SC	0.59(0.48-0.70)	0.61(0.51-0.72)	0.62(0.52-0.73)	0.63(0.53-0.75)	**0.61(0.51-0.73)**

0. 045 g/l (Aug FN-II) and maximum 0.049 g/l during November FN-II which was higher than seasonal mean resistance 0.047 g/l. Throughout season LC_{50} value was less compared to recommended dosage (0.075 g/l). The LC_{50} for monocrotophos 36 SL was 0.60 (Aug FN-II) to 0.79 (Nov FN-II) ml/l with seasonal mean of 0.67 ml/l against the recommended dosage of 1.0 ml/l. Thus aphids appeared responding to monocrotophos. At the beginning of the season the resistance to dimethoate 30 EC was 1.18 ml/l as LC_{50}. The last assay (Nov FN-II) revealed LC_{50} 1.42 ml/l which was higher than seasonal mean LC_{50} value of 1.30 ml/l. The tracking of resistance to oxydemeton methyl 25 EC indicated seasonal mean LC_{50} of 1.13 ml/l with maximum of 1.23 ml/l in Nov FN-II. At the beginning it was 1.06 ml/l. The slight increasing trend was however indicated as in case of other insecticide. The initial LC_{50} value for acephate 75 SP was 0.59 g/l with slight variation with advancement of season. The LC_{50} value in Nov FN-II was 0.69 g/l which was higher than the seasonal mean 0.63 g/l as LC_{50} against a recommended dosage of 1.0 g/l. For fipronil 5 SC the LC_{50} value was 0.58 ml/l in Aug FN-II with slight increase in further assays. The season end (Nov FN-II) LC_{50} value was 0.63, which was higher than the seasonal mean resistance LC_{50} (0.60ml/l) against the recommendation of 1.0 ml/l.

Further, the resistance in aphids in Annigeri (Table 3) gradually increased in LC_{50} with advancement of season as in case of other populations. For imidacloprid 17.8 SL the maximum LC_{50} of 0.16 ml/l was recorded during November FN-II which was higher than the seasonal mean resistance 0.15ml/l. The lowest LC_{50} value 0.13 ml/l was recorded in Aug FN-II. The resistance recorded for acetamiprid 20 SP was LC_{50} 0.11 (Aug FN-II) to 0.14 g/l (Nov FN-II) with seasonal mean of 0.13 g/l against the recommended dosage of 1.0 g/l. The initial LC_{50} values for thiamethoxam 25 WG was 0.12 g/l with slight up swing along the season. The LC_{50} value in Nov FN-II was 0.16 g/l which was slightly higher than seasonal mean (0.14 g/l). Clothianidin resistance was 0. 043 g/l during Aug FN-II and maximum 0.047 g/l during Nov FN-II with a seasonal mean LC_{50} 0.045 g/l. Throughout season LC_{50} value was less compared to recommended dosage (0.075 g/l). The LC_{50} for monocrotophos 36 SL was 0.59 (Aug FN-II) to 0.72 (Nov FN-II) ml/l with seasonal mean of 0.64 ml/l. The aphid appeared responding to monocrotophos. At the beginning

Table 2. Insecticide resistance in cotton aphid *Aphis gossypii* to Dharwad population

Insecticides	LC_{50} (Lower – Upper Fiducial Limits)				
	Aug FN –II	Sept FN -II	Oct. FN –II	Nov FN -II	**Season Mean**
Imidacloprid 17.8 SL	0.14(0.11-0.17)	0.15(0.12-0.18)	0.16(0.13-0.19)	0.17(0.14-0.21)	**0.15(0.12-0.18)**
Acetamiprid 20 SP	0.12(0.10-0.14)	0.12(0.10-0.15)	0.13(0.11-0.16)	0.15(0.12-0.18)	**0.13(0.11-0.16)**
Thiamethoxm 25 WG	0.14(0.12-0.17)	0.15(0.12-0.18)	0.16(0.13-0.18)	0.18(0.15-0.22)	**0.16(0.13-0.19)**
Clothianidin 50 WDG	0.045(0.039-0.051	0.046(0.044-0.056)	0.047(0.041-0.054)	0.049(0.042-0.056)	**0.047(0.041-0.053)**
Monocrotophos 36 SL	0.60(0.50-0.71)	0.63(0.52-0.74)	0.67(0.56-0.80)	0.79(0.66-0.93)	**0.67(0.56-0.80)**
Dimethoate 30 EC	1.18(1.02-1.35)	1.27(1.09-1.46)	1.33(1.15-1.53)	1.42(1.23-1.62)	**1.30(1.12-1.49)**
Oxydemeton Methyl 25 EC	1.06(0.89-1.24)	1.08(0.9-1.27)	1.15(0.96-1.38)	1.23(1.03-1.45)	**1.13(0.94-1.33)**
Acephate 75 SP	0.59(0.49-0.69)	0.60(0.50-0.70)	0.64(0.53-0.76)	0.69(0.58-0.82)	**0.63(0.52-0.74)**
Fipronil 5 SC	0.58(0.47-0.69)	0.60(0.4-0.73)	0.62(0.52-0.73)	0.63(0.53-0.75)	**0.60(0.57-0.82)**

of the season the resistance to dimethoate 30 EC was 1.12 ml/l as LC_{50}. The last assay (Nov FN-II) revealed LC_{50} 1.32 ml/l which was higher than seasonal mean LC_{50} 1.21 ml/l. The tracking of resistance to oxydemeton methyl 25 EC indicated seasonal mean LC_{50} 1.09 ml/l with maximum of 1.18 ml/l in Nov FN-II which was higher than the seasonal mean. At the beginning it was 1.00 ml/l.The initial LC_{50} value for acephate 75 SP was 0.55 g/l with slight variation with advancement of season. The LC_{50} value in Nov FN-II was 0.66 g/l which was higher mean LC_{50} 0.60 g/l against a recommended dosage of 1.0 g/l. For fipronil 5 SC the LC_{50} was 0.57 ml/l in Aug FN-II which increased slightly. The season end (Nov FN-II) LC_{50} value was 0.63 which was higher than the seasonal mean LC_{50} 0.60 ml/l. Thus based on changes in LC_{50} and comparison with recommended dosages the resistance appeared to be quite alarming to organophosphate *viz*., dimethoate, oxydemeton methyl and monocrotophos followed by neonicotinoid *viz*., imidacloprid and thiamethoxam in three aphid populations.

Thus aphid population of Hanumanmatti acquired 1.2 fold resistances to imidacloprid compared to LC_{50} Dharwad and Annigeri clones respectively which may be due to heavy usage of imidacloprid in Haveri district (Sagar *et al*., 2013). The Dharwad and Annigeri populations have same seasonal mean LC_{50} values of 0.15g/l as compared to recommended dosage. A high level of imidacloprid resistance in cotton aphids is already evident in other countries (Matsuura and Nakamura., 2014, Shi *et al*., 2011).

In respect of acetamiprid, the aphid population from Hanumanmatti developed 1.15 fold resistance over Dharwad and Annigeri location as $LC_{50,}$ which may be due to the consumption of higher quantity of neonicotinoids mainly imidacloprid exhibiting cross resistance as observed by Shi *et al.,* 2011. The aphid population of Hanumanmatti acquired 1.13 and 1.21 fold seasonal mean resistance to thiamethoxam as compared to Dharwad and Annigeri aphid collections. The Dharwad and Annigeri had more or less same seasonal mean LC_{50} of 0.15 and 0.14 g/l compared to recommended dosage (0.20 g/l). The present findings are agreement with the Herron and Wilson (2011) who observed variations in LC_{50} of aphids for thiamethoxam from different locations. In respect of clothianidin, the Hanumanmatti population of aphid acquired more or less same LC_{50} values as compared to Dharwad and Annigeri population. There was slight difference between LC_{50} values from all the three locations. As a new insecticide this study lacks previous reports for comparison; however cross-resistance from imidacloprid to thiamethoxam cannot be ruledout.

The aphid population of Hanumanmatti acquired 1.02 and 1.15 fold seasonal mean resistance to monocrotophos as LC_{50} compared to Dharwad and Annigeri locations. Similarly there was 1.23 and 1.32 fold higher seasonal mean resistance to dimethoate in Hanuamanamatti compared to Dharwad and Annigeri location. Further the resistance pattern hold good for other organophosphates like acephate also which could be due to cross resistance. Such resistance pattern across different insecticides viz., pyrethroids, neonicotinoids, OPs in cotton aphids is said to be common(Koo *et al*.,2 014).

Table 3. Insecticide resistance in cotton aphid *Aphis gossypii* to Annigeri population

Insecticides	LC_{50} (Lower – Upper Fiducial Limits)				
	Aug FN –II	Sept FN -II	Oct FN –II	Nov FN -II	**Season Mean**
Imidacloprid 17.8 SL	0.13(0.11-0.16)	0.14(0.11-0.17)	0.15(0.12-0.18)	0.16(0.13-0.20)	**0.15(0.12-0.18)**
Acetamiprid 20 SP	0.11(0.09-0.14)	0.12(0.10-0.15)	0.13(0.11-0.16)	0.14(0.10-0.17)	**0.13(0.10-0.15)**
Thiamethoxm 25 WG	0.12(0.10-0.15)	0.13(0.11-0.16)	0.15(0.12-0.18)	0.16(0.13-0.19)	**0.14(0.11-0.17)**
Clothianidin 50 WDG	0.043(0.038-0.057)	0.045(0.039-0.051)	0.046(0.040-0.052)	0.047(0.041-0.054)	**0.045(0.034-0.052)**
Monocrotophos 36 SL	0.59(0.48-0.71)	0.60(0.50-0.71)	0.64(0.53-0.76)	0.72(0.60-0.86)	**0.64(0.53-0.75)**
Dimethoate 30 EC	1.12(0.97-1.29)	1.17(1.02-1.34)	1.24(1.07-1.43)	1.32(0.97-1.29)	**1.21(1.07-1.39)**
Oxydemeton Methyl 25 EC	1.00(0.84-1.17)	1.05(0.87-1.23)	1.11(0.92-1.28)	1.18(0.91-1.44)	**1.09(0.90-1.27)**
Acephate 75 SP	0.55(0.46-0.65)	0.57(0.48-0.67)	0.61(0.51-0.73)	0.66(0.54-0.78)	**0.60(0.50-0.71)**
Fipronil 5 SC	0.57(0.47-0.68)	0.59(0.49-0.71)	0.61(0.53-0.78)	0.63(0.57-0.81)	**0.60(0.54-0.75)**

The present findings of aphid resistance to various commonly used insecticides particularly against imidacloprid clearly emerged as declining sensitivity in three populations of North Karnataka. It would be a serious matter as imidacloprid and thiamethoxam are being used as seed dressers widely and as spray molecule also heavily. Thus cotton aphids are having pre-emptive exposure as well as high selection pressure imidacloprid. This would lead to cross resistance to other neonicotinoid molecules also. Such phenomenon has been witnessed already in brown plant hoppers of paddy. 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 could be hindrance to re-accept them widely. Hence there is scope for insecticides with IGR action or alternate chemistry including fungal pathogens and botanicals for aphid management. Continuous monitoring of insecticide resistance in aphids may help in developing window-wise resistance management strategies.

REFERENCES

Anonymous, 2011. *"Annual Report 2010-11".* All India Co-ordinated Cotton Improvement Project. CICR, Coimbatore, India. www.cicr.org

Carletto,J. Martin, T. Flavie, V and Brevault,T. 2010. Insecticide resistance traits differ among and within host races in *Aphis gossypii*. *Pest. Manage. Sci.* **66** : 301-07

Herron, G.A. and Wilson, L.J. 2011. Neonicotinoid resistance in *Aphis gossypii* Glover (Aphididae : Hemiptera) from Australian cotton. *Australian J. Entomol* **50** : 93–98

Koo,H.N., An,J.J., Park.S.E., Kim,J.I. and Kim, G.H. 2014. Regional susceptibilities to 12 insecticides of melon and cotton aphid, *Aphis gossypii* (Hemiptera: Aphididae) and a point mutation associated with imidacloprid resistance. *Crop.Prot.* **55**:91-97

Matsuura, A. and Nakamura, M. 2014. Development of neonicotinoid resistance in the cotton aphid *Aphis gossypii* (Hemiptera: Aphididae) in Japan. Appl.Ent.Zool. **49** : 535–540

Phulse. V.B and Udikeri. S. S. 2014. Seasonal incidence of sucking insect pests and predatory arthropods in desi and Bt transgenic cotton *Karnataka J. Agril. Scie.*, **27** : 28-31

Phulse. V. B and Udikeri. S. S. 2017. Sucking pests and predator dynamics in *Bt* and non *Bt* cottons grown in traditional and nontraditional locations. *J. Cotton Res. Development.* **31**: 309-16

Sagar. D., Balikai.R. A., Patil.R .R., Udikeri. S. S. and Bheemanna.M. 2013. Insecticide usage pattern in major Bt cotton growing districts of Karnataka. *J. Experimental Zool. India.* **16** : 461-66

Shi, X.B., Jiang, L.L., Wang.H.Y., and Qiao.K., 2011. Toxicities and sublethal effects of seven neonicotinoid insecticides on survival, growth and reproduction of imidacloprid resistant cotton aphid, *Aphis gossypii Pest. Manage. Sci.* **67**: 1528-33.

Udikeri. S. S., Patil.S. B., S.Kranthi., K.R.Kranthi., N.Vandal., A.Hallad. S.Patil and B.M.Khadi. 2011. Species diversity, Pestiferous nature, bionomics and management of mirid bugs and flower bud maggots: the new key pests of Bt cottons. Proceeding *World Cotton Research Conference-5* Mumbai. India. 7th to11th, November, 2011. pp 203-209

Received for publication : March 2, 2018
Accepted for publication : June 16, 2018