The Andhra Agric. J 60(1): 107-113, 2013

Status of Insecticide Resistance in Rice Brown Plant Hopper, *Nilaparvata lugens* (Stal) in Certain Districts of Andhra Pradesh

N Mallikharjuna Rao, P Satyanarayana Reddy, G Ramachandra Rao, K V M Krishna Murthy and V Srinivasa Rao

Department of Entomology, Agricultural College, Bapatla 522 101, Andhra Pradesh

ABSTRACT

Experiments were conducted during 2008-09 and 2009-10 to determine the degree of resistance acquired by Rice brown planthopper, *Nilaparvata lugens* (Stal) to monocrotophos, acephate, phosphamidon and fenobucarb. The BPH populations of the three districts differed in the degree of resistance acquired by them to each of the test insecticides. The West Godavari strain of *N. lugens* was found to be 3.01 and 3.07; 2.80 and 2.79; 2.22 and 2.30; 1.39 and 1.69 folds resistant at LC_{50} and 1.31 and 1.49; 1.10 and 1.28; 1.40 and 1.40; 1.06 and 1.50 folds resistance at LC_{90} to monocrotophos, acephate, phosphamidon and fenobucarb, during 2008-09 and 2009-10, respectively compared to susceptible strain. The East Godavari strain of *N. lugens* acquired 2.37 and 2.50; 2.42 and 2.36; 1.98 and 2.04; 1.41 and 1.44 fold resistance at LC_{50} and 1.07 and 1.31; 0.00 and 1.19; 1.35 and 1.38; 1.12 and 1.26 fold resistant at LC_{90} to monocrotophos, acephate, phosphamidon, and fenobucarb during 2008-09 and 2009-10, respectively compared to susceptible strain. The Karimnagar strain of *N. lugens* showed 2.34 and 2.52; 0.00 and 1.31; 1.93 and 2.12; 1.28 and 1.33 fold resistance at LC_{50} and 1.08 and 1.31; 0.00 and 0.00; 1.51 and 1.53; 1.06 and 1.30 fold resistance at LC_{90} to monocrotophos, acephate, phosphamidon and fenobucarb during 2008-09 and 2009-10, respectively compared to susceptible strain.

Key words : BPH, Carbamates,Insecticide Resistance, *Nilaparvata lugens,* Organophosphates,Rice.

Rice is attacked by 385 species of insects causing 31.5 to 86.0 per cent losses in yield (Gunathilagaraj and Kumar, 1997). Among different insect pests attacking rice crop, planthoppers constitute one of the most important group causing substantial yield losses. Among various insect pests brown planthopper, *Nilaparvata lugens* (Stal) (Homoptera: Delphacidae), is an economically important insect pest of rice in Asia (Heinrichs, 1994). In early seventies and eighties organophosphates like monocrotophos and acephate, carbamates like carbaryl and fenobucarb and ether derivatives like ethofenprox have been extensively used in India as well as in other countries. As a result, these hoppers became resistant to these insecticides and the insecticide resistance has been reported to be in incipient stage in India (Sarupa *et al*., 1998 and Padma kumari *et al*., 2002). Hence, the present study has been carried out to assess the level of insecticide resistance in different BPH populations of Andhra Pradesh *viz*., East Godavari, West Godavari and Karimnagar districts of Andhra Pradesh.

MATERIAL AND METHODS

Collection of Test populations

The investigations were carried out under laboratory conditions at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari district, Andhra Pradesh during 2008-2009 and 2009-2010. Field populations of *Nilaparvata lugens* (Stal) were collected on rice crop from farmers' fields of East Godavari, West Godavari and Karimnagar districts of Andhra Pradesh and reared in polyhouse for subsequent generations and tested for phenotypic expression of susceptibility and for various other studies. The populations of BPH were reared for 3 generations on susceptible rice variety TN1 before testing with insecticide to ensure uniform and steady supply of insects. The population of BPH which was not exposed to any insecticide and continuously maintained on susceptible rice cultivars at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru was taken as susceptible population in the present studies.

Bioassay

The technical grade insecticides of monocrotophos, phosphamidon, acephate, and fenobucarb were used for bioassay studies. Initially a 1.0 per cent stock solution was prepared by dissolving the required quantities of technical grade insecticides in acetone. Triton X-100 (1.0%) used as emulsifier. The individual working concentrations

for each of the test insecticides were prepared from the 1.0 per cent solution through serial dilution technique using distilled water as solvent. To assess the relative toxicity of insecticides to BPH populations of different locations, the insecticides sprayed on 40 days old susceptible rice cultivars in serial concentrations. Immediately after drying of the spray deposit, 7-9 day old nymphs of the BPH (20 nos.) released with aspirator and confined with the help of mylar cages. A control was also carried out with distilled water alone on the nymphs of BPH and control mortality assessed (Krishnaiah *et al*., 2002 and Krishnaiah *et al*., 2004). The data on mortality was recorded at 24, 48 and 72 hours after spray.Three replications were maintained. The pooled mortality at 72 hours after spray was subjected to statistical analysis. Those insects that fall on their back and unable to recover normal posture were counted as dead.

Statistical analysis

Whenever mortality was recorded in the control, the treatmental data was subjected to Abbot's correction (Abbott, 1925) .Wide range concentrations of insecticide solutions initially and narrow ranges subsequently were tested. The data of each test insecticide in the range of 5 to 90 per cent mortality was subjected to probit analysis (Finney, 1971) using the MLP software (Ross, 1987).

The level of insecticide resistance acquired by different populations was assessed by computing resistance ratios (RR) adopting standard (FAO, 1979).

$$\text{Resistance Factor} = \frac{LC_{50}/LC_{90} \text{ of resistant population}}{LC_{50}/LC_{90} \text{ of susceptible population}}$$

The degree of resistance acquired by the different populations of *N. lugens* was calculated by comparing the LC_{50} and LC_{90} values obtained in the present study with the corresponding values of the susceptible population, baseline data and field recommended concentrations.

RESULTS AND DISCUSSION

Resistance to monocrotophos

During 2008-09, a comparison of LC_{50} and LC_{90} values of monocrotophos against BPH populations of the three districts (Table 1) revealed that the population of West Godavari district has developed 3.01, 1.29 and 1.27 fold relative resistance at LC_{50} and 1.31, 1.21 and 1.22 fold relative resistance at LC_{90} as compared with the BPH populations of susceptible, Karimnagar and East Godavari districts, respectively. The BPH population of East Godavari district has acquired 2.37 fold resistance at LC_{50} and 1.07 fold resistance at LC_{90} in comparison with susceptible population. The Karimnagar population has developed 2.34 fold resistance at LC_{50} and 1.08 fold resistance at LC_{90} in comparison with susceptible population, respectively. Considering the base line data i.e., LC_{50} of E.G = 135.30 ppm (0.01353%); LC_{50} (W.G) = 146.60 ppm (0.0146%) (Jhansilakshmi *et al.,* 2010), the West Godavari and East Godavari populations have developed 4.75 and 4.02 fold relative resistance at $LC_{50,}$ respectively. A comparison of recommended concentration of monocrotophos (0.0792%) with it's LC_{50} values against the three BPH populations revealed that all the three populations have not developed resistance. But at LC_{90} all the three populations acquired 1.51, 1.24 and 1.25 fold resistance, respectively.

During 2009-10, a comparison of LC_{50} and LC_{90} values of monocrotophos against BPH populations of the three districts (Table 1) revealed that the population of West Godavari district has developed 3.07, 1.20 and 1.21 fold relative resistance at LC_{50} and 1.49, 1.13 and 1.13 fold relative resistance at LC_{90} as compared with the BPH populations of susceptible, Karimnagar and East Godavari districts, respectively. The BPH population of East Godavari district has acquired 2.5 fold resistance in comparison with susceptible population at LC_{50} and 1.31 fold resistance at LC_{90} in comparison with susceptible population, respectively.

Considering the base line data i.e., LC_{50} of E.G = 135.30 ppm (0.01353%); LC_{50} (W.G) = 146.60 ppm (0.0146%) (Jhansilakshmi *et al.,* 2010), the West Godavari and East Godavari populations have developed 4.48 and 3.98 fold relative resistance at $LC_{50,}$ respectively. A comparison of recommended concentration of monocrotophos (0.0792%) with their LC_{50} values against the three BPH populations revealed that all the three populations have not developed resistance. But at $LC_{90,}$ all the three populations acquired 1.50, 1.32 and 1.32 fold resistance, respectively. It was evident from the literature that the West Godavari population of *N. lugens* showed 0.71 fold resistance to monocrotophos during 1996 (Sarupa *et al*., 1998), 1.62 fold resistance to monocrotophos selected strain of BPH during 2002 (Krishnaiah *et al*., 2002), 1.11 fold resistance during 2006 (Jhansilakshmi *et al*., 2010), which were in conformity with the present findings. Wang and Ku (1984) observed a high level of resistance to monocrotophos observed in BPH

Table 1. Relative degree of resistance among the *N. lugens* populations of three districts to monocrotophos.

District	LC_{50} (%)	RF at LC_{50} in comparison with the *N. lugens* population of			LC_{90} (%)	RF at LC_{90} in comparison with the *N. lugens* population of			RF in comparison with	
									Base line data*	Recommended concentration (0.0792 %)
		SUS	KNR	EG		SUS	KNR	EG	LC_{50} (%)	LC_{90} (%)
2008-09										
W. Godavari	0.0694	3.01	1.29	1.27	0.1201	1.31	1.21	1.22	4.75	1.51
E. Godavari	0.0545	2.37	—	—	0.0985	1.07	—	—	4.02	1.24
Karimnagar	0.0540	2.34	—	—	0.0992	1.08	—	—	—	1.25
Susceptible	0.0230	—	—	—	0.0915	—	—	—	—	—
2009-10										
W. Godavari	0.0654	3.07	1.20	1.21	0.1190	1.49	1.13	1.13	4.48	1.50
E. Godavari	0.0539	2.50	—	—	0.1047	1.31	—	—	3.98	1.32
Karimnagar	0.0544	2.52	—	—	0.1047	1.31	1.31	—	—	1.32
Susceptible	0.0216	—	—	—	0.0797	—	—	—	—	—

EG – East Godavari. WG – West Godavari. KNR – Karimnagar . RF= Resistance Factor. SUS – Susceptible.
* (LC_{50}(E.G) = 135.30 ppm (0.01353%); LC_{50}(W.G) = 146.60 ppm (0.0146%); Jhansilakshmi *et al.,* 2010a).

Table 2. Relative degree of resistance among the *N. lugens* populations of three districts to acephate.

District	LC_{50} (%)	RF at LC_{50} in comparison with the *N. lugens* population of			LC_{90} (%)	RF at LC_{90} in comparison with the *N. lugens* population of			RF in comparison with	
									Base line data*	Recommended concentration (0.0792 %)
		SUS	KNR	EG		SUS	KNR	EG	LC_{50} (%)	LC_{90} (%)
2008-09										
W. Godavari	0.0640	2.80	1.54	1.15	0.1184	1.10	1.24	1.11	12.0	1.18
E. Godavari	0.0554	2.42	1.33	—	0.1060	—	1.11	—	9.89	1.06
Karimnagar	0.0415	—	—	—	0.0951	—	—	—	—	0.95
Susceptible	0.0228	—	—	—	0.1069	—	—	—	—	—
2009-10										
W. Godavari	0.0662	2.79	1.31	1.18	0.1256	1.28	1.28	1.08	12.49	1.26
E. Godavari	0.0560	2.36	1.10	—	0.1165	1.19	1.19	—	10.00	1.17
Karimnagar	0.0505	1.31	—	—	0.0980	—	—	—	—	0.98
Susceptible	0.0237	—	—	—	0.0980	—	—	—	—	—

EG – East Godavari. WG – West Godavari. KNR – Karimnagar. SUS – Susceptible. RF=Resistance Factor.
* (LC_{50}(E.G) = 56.93 ppm (0.0056%); LC_{50}(W.G) = 53.65 ppm (0.0053%); Jhansilakshmi *et al.,* 2010a).

population of Taiwan 2-4 fold resistance in carbaryl selected strain of BPH to monocrotophos and 6 fold resistance to monocrotophos in Niigata strain of Japan (Ghorpade, 1990).

Resistance to acephate

During 2008-09, the data presented in the (Table 2) revealed that the BPH population of West Godavari district developed 2.80. 1.54 and 1.15 fold resistance at LC_{50} and 1.10, 1.24 and 1.11 fold resistance at LC_{90} when compared with the BPH populations of susceptible, Karimnagar and East Godavari districts, respectively. The BPH population of East Godavari district has developed 2.42 and 1.33 fold resistance in comparison with susceptible and Karimnagar populations at LC_{50}; and 1.11 fold resistance at LC_{90} in comparison with Karimnagar population, respectively. Karimnagar population developed 1.82 fold resistance at LC_{50} in comparison with susceptible population. Considering the baseline data i.e., LC_{50} (E.G) = 56.93 ppm (0.0056%); LC_{50} (W.G) = 53.65 ppm (0.0053%) (Jhansilakshmi *et al.,* 2010), the West Godavari and East Godavari populations developed 12.0 and 9.89 fold resistance, respectively. A comparison of the LC_{50} and LC_{90} values of the three populations with the recommended concentration of acephate (0.1%) revealed that none of the populations studied have developed resistance at $LC_{50.}$ While, the West Godavari and East Godavari populations of BPH developed 1.18 and 1.06 fold resistance at $LC_{90,}$ respectively.

During 2009-10, on the basis of LC_{50} value of acephate against the BPH populations of the three districts (Table 2) the population of West Godavari district acquired 2.79, 1.31 and 1.18 fold relative resistance as compared with the BPH populations of susceptible, Karimnagar and East Godavari. The BPH population of East Godavari districts acquired 2.36 and 1.10 fold resistance at LC_{50} and 1.19 and 1.19 fold resistance at LC_{90} in comparison with the populations of susceptible and Karimnagar districts, respectively. The Karimnagar population has developed 1.31 fold resistance in comparison with susceptible population at $LC_{50.}$ A comparison of the LC_{50} and LC_{90} values of the three populations with the recommended concentration of acephate (0.1%) revealed that none of the populations studied have developed resistance at $LC_{50.}$ While at $LC_{90,}$ the BPH populations of West Godavari and East Godavari districts developed 1.26 and 1.17 fold resistance respectively. Studies conducted by Sarupa *et al.,* (1998) also did not indicate development of resistance to acephate in BPH populations of Godavari delta during late 1998, even though they have been in use since 1975. The reason for this might be moderate effectiveness of molecules against BPH as well as lack of gene alleles in BPH populations conferring resistance to organophosphates (Jhansilakshmi *et al.*, 2010).

Resistance to phosphamidon

During 2008-09, the data presented in the (Table 3) revealed that the BPH population of West Godavari district acquired 2.22, 1.14 and 1.12 fold resistance in comparison with susceptible, Karimnagar and East Godavari populations at LC_{50}; and 1.40 and 1.04 fold resistance at LC_{90} in comparison with susceptible and East Godavari populations, respectively. The BPH population of East Godavari district has developed 1.98 and 1.02 fold resistance in comparison with susceptible and Karimnagar populations at LC_{50}; and 1.35 fold resistance at LC_{90} in comparison with susceptible population, respectively. Karimnagar population developed 1.93 fold resistance in comparison with susceptible population; and 1.51 and 1.12 fold resistance at LC_{90} in comparison with susceptible and East Godavari populations, respectively. Considering the baseline data i.e., LC_{50} (W.G) =43 ppm (0.0043%);(Sarupa *et al.,* 1998), the West Godavari population developed 17.06 fold resistance. A comparison of the LC_{50} and LC_{90} values of the three populations with the recommended concentration of phosphamidon (0.08%) revealed that none of the populations studied have developed resistance at $LC_{50.}$ While, the West Godavari, East Godavari and Karimnagar populations of BPH developed 1.37, 1.32 and 1.48 fold resistance at $LC_{90,}$ respectively.

During 2009-10, on the basis of LC_{50} and LC_{90} values of phosphamidon against the BPH populations of the three districts (Table 3) the population of West Godavari district acquired 2.30, 1.09 and 1.12 fold relative resistance in comparison with susceptible, Karimnagar and East Godavari populations at LC_{50}; 1.40 and 1.01 fold resistance at LC_{90} in comparison with susceptible and East Godavari populations, respectively. The BPH population of East Godavari district developed 2.04 fold resistance at LC_{50} and 1.38 fold resistance at LC_{90} when compared with susceptible population. The Karimnagar population has developed 2.12 and 1.04 fold at LC_{50} and 1.53 and 1.11 fold resistance at LC_{90} when compared with the BPH populations of susceptible and East Godavari district. Considering the baseline data of West Godavari strain as per Sarupa *et al.* (1998) (LC_{50}=43 ppm (0.0043%) the

Table 3 .Relative degree of resistance among the *N. lugens* populations of three districts to phosphamidon.

District	LC_{50} (%)	RF at LC_{50} in comparison with the *N. lugens* population of			LC_{90} (%)	RF at LC_{90} in comparison with the *N. lugens* population of			RF in comparison with	
									Base line data*	Recommended concentration (0.0792 %)
		SUS	KNR	EG		SUS	KNR	EG	LC_{50} (%)	LC_{90} (%)
2008-09										
W. Godavari	0.0734	2.22	1.14	1.12	0.1095	1.40	—	1.04	17.06	1.37
E. Godavari	0.0657	1.98	1.02	—	0.1057	1.35	—	—	—	1.32
Karimnagar	0.0641	1.93	—	—	0.1184	1.51	—	1.12	—	1.48
Susceptible	0.0331	—	—	—	0.0784	—	—	—	—	—
2009-10										
W. Godavari	0.0722	2.30	1.09	1.12	0.1121	1.40	—	1.01	16.79	1.40
E. Godavari	0.0639	2.04	—	—	0.1103	1.38	—	—	—	1.38
Karimnagar	0.0665	2.12	—	1.04	0.1227	1.53	—	1.11	—	1.53
Susceptible	0.0313	—	—	—	0.1009	—	—	—	—	—

EG – East Godavari. WG – West Godavari. KNR – Karimnagar. SUS – Susceptible. RF= Resistance Factor.
* (LC_{50} (W.G) = 43 ppm (0.0043%); Sarupa *et al*., 1998).

Table 4. Relative degree of resistance among the *N. lugens* populations of three districts to fenobucarb.

District	LC_{50} (%)	RF at LC_{50} in comparison with the *N. lugens* population of			LC_{90} (%)	RF at LC_{90} in comparison with the *N. lugens* population of			RF in comparison with	
									Base line data*	Recommended concentration (0.0792 %)
		SUS	KNR	EG		SUS	KNR	EG	LC_{50} (%)	LC_{90} (%)
2008-09										
W. Godavari	0.0075	1.39	1.09	—	0.0115	1.06	—	—	1.74	0.11
E. Godavari	0.0076	1.41	1.10	—	0.0122	1.12	1.05	—	0.93	0.12
Karimnagar	0.0069	1.28	—	—	0.0116	1.06	—	—	—	0.12
Susceptible	0.0054	—	—	—	0.0109	—	—	—	—	—
2009-10										
W. Godavari	0.0088	1.69	1.28	1.17	0.0158	1.50	1.16	1.20	2.04	0.158
E. Godavari	0.0075	1.44	1.09	—	0.0132	1.26	—	—	0.92	0.132
Karimnagar	0.0069	1.33	—	—	0.0136	1.30	—	1.03	—	0.136
Susceptible	0.0052	—	—	—	0.0105	—	—	—	—	—

EG – East Godavari. WG – West Godavari. KNR – Karimnagar. SUS – Susceptible. RF=Resistance Factor.
* (LC_{50} (E.G) = 81.39 ppm (0.0081%); LC_{50} (W.G) = 43.47 ppm (0.0043%); Jhansilakshmi *et al.,* 2010a

West Godavari population developed 16.79 fold resistance. A comparison of the LC_{50} and LC_{90} values of the three populations with the recommended concentration of phosphamidon (0.08%) revealed that none of the populations studied have developed resistance at $LC_{50.}$ While at $LC_{90,}$ the BPH populations of West Godavari, East Godavari and Karimnagar districts developed 1.40, 1.38 and 1.53 fold resistance respectively. The present findings are in conformity with Sarupa *et al*., (1998).

Resistance to fenobucarb

During 2008-09, the data presented in the table 4 revealed that the BPH population of West Godavari district developed 1.39 and 1.09 fold resistance in comparison with susceptible and Karimnagar populations at LC_{50}; and 1.06 fold resistance at LC_{90} in comparison with susceptible population, respectively. The BPH population of East Godavari district has developed 1.41 and 1.10 fold resistance at LC_{50}; and 1.12 and 1.05 fold resistance at LC_{90} in comparison with susceptible and Karimnagar populations, respectively. Karimnagar population has developed 1.28 and 1.06 fold resistance at LC_{50} and LC_{90} when compared with the susceptible population, respectively. A comparison with the baseline data i.e., LC_{50} (E.G) = 81.39 ppm (0.0081%); LC_{50} (W.G) = 43.47 ppm (0.0043%) (Jhansilakshmi *et al.,* 2010), the BPH populations of West Godavari and East Godavari districts have developed 1.74 and 0.93 fold resistance at LC_{50}, respectively. A comparison of the LC_{50} and LC_{90} values of the three populations with the recommended concentration of fenobucarb (0.1%) revealed that none of the BPH populations studied have developed resistance.

During 2009-10, on the basis of LC_{50} value of fenobucarb against the BPH populations of the three districts (Table 4) the population of West Godavari district acquired 1.69, 1.28 and 1.17 fold relative resistance at LC_{50} as compared with the BPH populations of susceptible, Karimnagar and East Godavari. The BPH population of East Godavari district acquired 1.44 and 1.09 fold resistance in comparison with susceptible and Karimnagar populations at $LC_{50;}$ and 1.26 fold resistance at LC_{90} in comparison with susceptible population, respectively. The Karimnagar population has developed 1.33 fold resistance in comparison with susceptible population at LC_{50}; and 1.30 and 1.03 fold resistance at LC_{90} in comparison with susceptible and East Godavari populations. A comparison with the baseline data i.e., LC_{50} (E.G) = 81.39 ppm (0.0081%); LC_{50} (W.G) = 43.47 ppm (0.0043%) (Jhansilakshmi *et al.,* 2010), the BPH populations of West Godavari and East Godavari districts have developed 2.04 and 0.92 fold resistance at LC_{50}, respectively. A comparison of the LC_{50} and LC_{90} values of the three populations with the recommended concentration of fenobucarb (0.1%) revealed that none of the BPH populations studied developed resistance. The present findings are in conformity with Matsumura *et al*., (2009) who compared the LD_{50} values for the BPH strains collected from 2005 to 2007 in Japan for BPMC with those obtained before 2001 and no significant changes were observed.

Chung *et al*. (1982) also reported that development of resistance to the carbamates by laboratory selection on BPH is generally slow as compared with those to organophosphates and pyrethroids. From the present investigations it is evident that the fenobucarb is still effective against BPH populations of all the districts tested.

LITERATURE CITED

Abbott W S 1925 A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology,* 18: 265-267.

Chung T C, Sun C N and Hung C Y 1982 Resistance of *Nilaparvata lugens* to six insecticides in Taiwan. *Journal of Economic Entomology,* 75:199-200.

Food and Agricultural Organization 1979 Recommended method for detection and measurement of Agricultural pests to pesticides. *FAO Plant Protection Bulletin* 127: 2-5.

Ghorpade S A 1990 Studies on oxidase activity in strains of rice brown planthopper, *Nilaparvata lugens* (Stal) resistant to insecticides. *Journal of Insect Science*, 6: 85-88.

Gunathilagaraj K and Kumar M G 1997 Extent of damage and pattern of emergence of overwintering larvae of rice stem borer in Punjab. *Indian Journal of Ecology*, 23: 104-108.

Heinrichs E A 1994 Impact of insecticides on the resistance and resurgence of rice planthopper. In R. F. Denno and T. J. Perfect (eds.) - *Planthoppers: Their Ecology and Management,* Chapman and Hall Publishers, New York. 571-614.

Jhansilakshmi V, Krishnaiah N V, Katti G, Pasalu I C and Vasantabhanu K 2010 Development of insecticide resistance in rice brown planthopper and whitebacked planthopper in Godavari delta of Andhra Pradesh. *Indian Journal of Plant Protection,* 38(1): 35-40.

Krishnaiah N V, Prasad A S R, Pasalu I C, Kumar K M and Lingaiah T 2002 Development of resistance in rice brown planthopper *Nilaparvata lugens* (Stal) and green leafhopper *Nephotettix virescens* (Dist) to Neem formulations. *Pesticide Research Journal,* 14 (1): 1-7.

Krishnaiah N V, Ramprasad A S, Lingaiah T and Lakshiminarayanamma V 2004 Comparative toxicity of Neonicotinoid and Phenyl Pyrazole insecticides against Rice hoppers. *Indian Journal of Plant Protection,* 32(1): 24-30.

Matsumura M, Takeuchi H, Satoh M, Morimura S S, Otuka A, Watanabe T and Thanh D V 2009 In K.L. Heong and B. Hardly (eds.). *Planthoppers: New threats to the sustainability of intensive rice production systems in Asia*, International Rice Research Institute, Los Banos, Philippines. 233-244.

Padmakumari A P, Sarupa M and Krishnaiah N V 2002 Status of insecticide resistance in rice brown planthopper, *Nilaparvata lugens* Stal- A review. *Agricultural Reviews,* 23 (4): 262-271.

Sarupa M, Krishnaiah N V and Reddy D D R 1998 Assessment of insecticide resistance in field population of Rice Brown Planthopper, *Nilaparvata lugens* (Stal) in Godavari Delta, (A.P.), India. *Indian Journal of Plant Protection,* 26(1): 80-82.

Sujatha, D and Regupathy, A. 2003 Development of resistance to carbofuran, phosphamidon and neem oil in rice BPH (*Nilaparvata lugens*) populations in Tamil Nadu, India. *Pesticide Research Journal*, 15(2): 194-197.

Wang S C and Ku T Y 1984 Development of insecticide resistance of brown plant hopper in central Taiwan. *Chinese Journal of Entomology,* 4(2): 131-138

(Received on 02.09.2011 and revised on 06.03.2012)