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STATUS OF INSECTICIDE RESISTANCE IN RICE BROWN PLANTHOPPER, *NILAPARVATA LUGENS* STAL. - A REVIEW

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ABSTRACT

The status of insecticide resistance in rice brown planthopper (BPH) *Nilaparvata lugens* (Stal) in major rice growing countries like Japan, China Taiwan, Philippines and Malaysia and the meagre evidence available from India is presented in the review. In China and Taiwan, BPH developed resistance to isoprocarb, MTMC, carbaryl, carbofuran, malathion and monocrotophos and even to synthetic pyrethroids like permethrin and phenothrin. The resistant strains had higher carboxylesterases and decreased sensitivity of Acetylcholineesterase (AchE) than susceptible strain. In Japan, the insect developed resistance to fenthion, fenitrothion, cyanofenphos, malathion as well as many carbamate compounds. However, the degree of resistance was dependant on the origin of immigrants and extent of utilisation of these insecticides. In Philippines, the resistance against BPMC and MTMC was evident. The evidence available from India suggested that insecticide resistance in BPH from Godavari delta of Andhra Pradesh (A.P.) is in incipient stage. The importance of initiating more studies on this aspect in India is discussed.

Rice, the staple food of nearly half of world's population is cultivated in 149.8 million hectares (FAO, 1999). However, 90 per cent of rice is grown and consumed in thickly populated Asian countries like China, India, Japan, Taiwan, Pakistan, Bangladesh, Indonesia, Malaysia, Philippines, Myanmar, Vietnam, Thailand etc. Barring Japan, all these countries are a part of the developing world.

The insect pests are one of the major limiting factors in rice production in these countries. Many species of stem borers like *Scirpophaga incertulas, Chilo suppressalis, Sesamia inferens*, gall midge (*Orseolia oryzae*), brown planthopper (*Nilaparvata lugens*), white-backed planthopper (*Sogatella furcifera*), green leafhoppers (*Nephotettix virescens, N. nigropictus* and *N. cincticeps*), smaller brown planthopper (*Laodelphax striatellus*) are the most important insect pests in Asia. To check these insect pests, insecticides were used since 1960's. However, Japan was the leader in insecticide usage against rice insect pests, partly because of the country's determination to be self sufficient in rice production and also the availability of the technologies of insecticide production. Another important factor was the cultivation of high 'N' responsive Japonicas from 1950's. This trend was followed by Korea, Taiwan and China. As a result of intensive application of insecticides like organochlorines, organophosphates and carbamates the insecticide resistance was widespread in green leafhopper *Nephotettix cincticeps*, striped stem borer, *Chilo suppressalis,* small brown planthopper *Laodelphax striatellus* and brown planthopper (BPH), *Nilaparvata lugens*. The details have been reviewed by Nagata and Mochida (1984). However, *Nilaparvata lugens* is the only insect pest from among the above, which is important in the Indian context.

In India, brown planthopper, *Nilaparvata lugens* was not familiar even to the students of rice entomology, let alone to farming community until 1971 when it was first reported to damage the crop in Kerala. By mid 1970's the pest became wide spread in almost all the major double cropped areas of India particularly in Southern and Eastern regions. By 1980's *N. lugens* became number one pest of rice in the country. The changed crop architecture, intensive cultivation and high 'N' fertilization were the major contributing factors for ascent of BPH as number one pest in India. These were also the conditions which existed during 1960's in Japan and Korea, later in 1970's in Taiwan and China. Therefore, we have to take lessons from these countries with regard to the management of BPH. From 1980's farmers in India have started using insecticides in a large scale in all BPH endemic areas. In the beginning HCH dust was used in a large scale. Later it was replaced by organophosphates like phorate, monocrotophos and chlorpyriphos and carbamates such as carbaryl and carbofuran. However, there is no systematic information available on the status of insecticide resistance in BPH in India. Therefore, the present humble attempt has been made to review the information available from other countries along with meagre evidence from India.

The information is arranged for the sake of convenience under different heads as follows :

I. Survey of insecticide resistance in field populations of BPH, in various countries.
II. Selection of resistant strains, mechanism of resistance and strategies for over coming resistance.
III. Methodologies for detecting resistance.
IV. Present status in India and future considerations.

I. Survey of insecticide resistance in field population of BPH

a) Studies in China and Taiwan: Lin and Sun (1978) reported that the insecticide resistance level of field collected BPH, *N. lugens* to isoprocarb (MIPC) and MTMC [3-methyl phenyl methylcarbamate] decreased slightly after rearing in the laboratory for 13 generations. Under increasing selection pressure with isoprocarb one of the field collected strains, developed 6.1 times more resistance after 6 generations. Under similar conditions, it developed 8 times more resistance to MTMC after 7 generations.

Sun and Dai (1984) reported up to 1000 fold resistance to permethrin as compared with a susceptible strain. in populations of *N. lugens* collected on rice in Taiwan in 1982. The levels of resistance to cypermethrin, deltamethrin and fenvalerate were much lower (10- 50 fold) and there was no resistance to DDT.

Sun *et al.* (1984a) showed that populations of *N. lugens* collected on rice in Taiwan were found to possess a high level of resistance to malathion and various levels of resistance to isoprocarb and some other insecticides. In the next year, Sun *et al.* (1984b) reported that in Taiwan, this delphacid pest of rice had become highly resistant to synthetic pyrethroids of primary alcohol esters such as permethrin and phenothrin. Resistance to pyrethroids of secondary alcohol esters, such as cypermethrin, was low or moderate. In monitoring studies on insecticide resistance in the delphacid on rice in Taiwan, Wang and Ku (1984) compared the toxicities of 14 insecticides in 1977-83 with those in 1976. In 1980, resistance to carbaryl increased 8.4-fold and that to carbofuran 14.8- fold, resistance to malathion and monocrotophos reached a record high level. In 1981 and 1982, esistance to most carbamates and organophosphates decreased gradually, but in 1983 resistance to all 14 insecticides was again high. In 1982, resistance to 4 insecticides varied from 2.4- to 15.5- fold in 6 localities and in 1983 the variation was from 2.4- to 6.4- fold. Monthly changes in insecticide resistance in planthoppers collected in September-November 1983 varied significantly, suggesting that migration was one of the factors affecting resistance.

Wang *et al.* (1988a) studied the local variations in resistance to the insecticides carbaryl, carbofuran, malathion and monocrotophos between 1982 and 1984 in the rice delphacid *N. lugens*, of Central Taiwan.

The ratio of maximum to minimum LC_{50} varied from 2.4- to 15.5- fold for BPH collected during the autumn in 1982-84, but only 2.3 to 2.9 fold in surveys carried out during the spring crop of 1984. In further studies, Cheng and Wang (1993) monitored insecticide resistance of *N. lugens* in China in 1986-89, considering the local and annual variations. Wang *et al.* (1997) monitored the susceptibility of *N. lugens* to insecticides in the lower Yangtze valley from 1991-1995 and concluded that the resistance varied little though there was fluctuation in the LD_{50} values.

b) Studies in Japan: Kilin *et al.* (1981) compared the susceptibility of immigrant population of *N. lugens* in Japan in 1976 with those obtained in 1967, the development of resistance was evident. The LD_{50} for MTMC, carbaryl and isoprocarb (MIPC) has increased 10- fold. Ten fold to 30- fold increases in organophosphate resistance were also recorded. Nagata (1982) studied development of insecticide resistance in the rice pest BPH. His studies showed that resistance in *N. lugens* to HCH (BHC) is closely associated with its long-distance migration. The quick establishment of an HCH- resistant population by insecticide pressure, its extinction during the winter and the subsequent appearance of susceptible migrants in the following year was evident from the fluctuating levels of resistance in individuals taken from rice fields in Japan at different times of the year. A gradual increase in the level of resistance was observed when data from 1976 was compared with those from 1967. Ozaki and Kassai (1982) showed that some individuals with resistance to organophosphate insecticides were produced in populations of *N. lugens* collected in rice fields in Kagoshima and Kagawa prefectures in Japan, in 1967-69. The development of resistance was very slow between 1967 and 1972, but a relatively large increase in resistance was observed in 1975. Thereafter, the level increased gradually each year and two field populations collected in Kagawa prefecture in 1979 were highly resistant to fenthion (30- to 32- fold) fenitrothion (22- to 23- fold), cyanofenphos (145- to 423- fold) and malathion (20- to 35- fold). The development of carbamate resistance was slower than that of resistance to organophosphates fenthion, fenitrothion or malathion. However, one population collected in Kagawa prefecture in 1979 had 5 to 18 fold resistance to almost all the carbamate compounds tested.

Nagata (1983) observed resistance in immigrants of brown planthopper possibly resulting from changes in the origin of the migrants. Knowledge of geographical variation in this species is important to determine the source of migration. Nagata (1984) further noted that among insect pests of rice in Japan *N. lugens* has been relatively slow in developing resistance to insecticides. Comparisons of various immigrant populations revealed differences in insecticide resistance, together with differences in the relation between nymphal density and the proportion of brachypterous adults in laboratory rearings.

Endo *et al.* (1988a) studied the susceptibility of *N. lugens,* to various insecticides using population collected in Japan in 1980 and 1987. A comparison of the results obtained in these experiments with previous data collected in 1967 showed that the susceptibility of *N. lugens* to organophosphates in 1987 was greater than in 1980. The susceptibility to *p, p'*-DDT decreased with time, but susceptibility to lindane was almost same as in 1967. In further studies Endo *et al.* (1988b) assessed insecticide susceptibility of *N. lugens* collected in Bogor (Indonesia) and Chikugo (Japan) in the laboratory using several topically applied organophosphate, organochlorine, carbamate and pyrethroid insecticide formulations. LD_{50}'s of lindane, *p, p'*-DDT and ethofenprox for the Bogor strain of *N. lugens* were lower than those for the Chikugo strain. However, the Bogor strain was 2.7 times more resistant to malathion than the Chikugo strain.

Hirai (1993) studied recent trends of insecticide susceptibility in the BPH in Japan. The susceptibility to BPMC [fenobucarb] MTMC [metolcarb], MIPC [isoprocarb], carbaryl, carbofuran, diazinon, malathion and propaphos fluctuated greatly at levels which indicated some degree of resistance. Hirai (1994) reviewed current status of insecticide susceptibility to BPMC [fenobucarb], MTMC [metolcarb], carbaryl, carbofuran, diazinon, malathion and propaphos for immigrant *N. lugens* on rice in Nagasaki, kyushu, Japan. The pest had developed resistance to carbamates and organophosphates in the second half of the 1970's and had remained moderately resistant from the beginning of the 1980's to 1993.

c) Studies in Philippines: Heinrichs and Tetangco (1978) reported that in 1977, a field strain of *N. lugens* at the IRRI in the Philippines, exposed to carbofuran for several years had developed resistance to the compound. Both sexes were seven times as resistant to carbofuran as compared to a greenhouse strain not exposed to insecticides and 2-5 times as resistant as the greenhouse strain to other insecticides used to varying extents on the IRRI farm, including monocrotophos and isoprocarb [MIPC].

Mochida and Basilio (1983) found that insecticide induced mortality among populations of the BPH collected from IRRI farm in the Philippines is much lower than that among greenhouse populations. The development of resistance among the field populations has undoubtedly been favoured by the applications of a mixture of chlorpyriphos and BPMC since 1978 and of acephate since 1981. Fabellar and Mochida (1985) reported that field collected populations which had prior exposure to insecticides showed significant level of resistance to BPMC (Fenobucarb) but did not appear to have developed resistance to carbaryl, carbofuran or MTMC (metolcarb) as compared to greenhouse populations.

d) Studies in UK: Tranter and Emden (1984) compared susceptibility of 8 populations of the rice pest *N. lugens* in laboratory using 5 organophosphorus insecticides. The Queensland strain was the most susceptible while a strain from Japan showed the most resistance notably to malathion. Ghorpade (1990) compared 3 strains of *N. lugens* in the laboratory for tolerance to 5 insecticides. The Niigata strain (Ns) from Japan showed the broadest range of resistance to malathion [5- fold], MTMC [9-fold], monocrotophos [6- fold] and carbofuran [2- fold]. Philippines Strain showed intermediate tolerance, while another strain from Japan was the most susceptible to the 5 insecticides tested.

In further studies, Ghorpade (1993) tested females from 7 strains of *N. lugens* (originally collected from Japan, The Philippines, Australia, Indonesia and Sri Lanka) for tolerance to topically applied carbofuran, monocrotophos, MTMC (metolcarb), malathion and permethrin. The Japanese and Australian strains were the most susceptible to the above five insecticides.

Malaysia: Field populations of *N. lugens* sampled in 1982 were less susceptible to metolcarb (MTMC) than similar populations sampled in 1977. This was probably due to increased use of this compound for the control of the planthopper (Heong, 1983).

II. Selection of resistant strains, mechanism of resistance and strategies for overcoming resistance

a) Studies in China and Taiwan: Chung *et al.* (1981) studied the cross resistance pattern for malathion-resistant strain of BPH and found that resistance ratios were 1183 for malathion, 171 for permethrin, 82 for parathion methyl, 72 for propoxur, 22 for isoprocarb and five for fenvalerate. The corresponding ratio's for the isoprocarb resistant strain were 574, 122, 44, 76, 41 and 5 respectively. Chung and Sun (1981a) also determined the sensitivity of acetyl cholinesterases (AchE) of strains of *N. lugens* susceptible or resistant to isoprocarb (MIPC) to several carbamate insecticides including isoprocarb. The residual activity of AchE was measured with acetylcholine iodide as the substrate. The AchE of the resistant strain was 15.7 times less sensitive to isoprocarb than the susceptible strain. The AchE of the resistant strain was also less inhibited by several other carbamates (particularly propoxur, carbofuran and methomyl). A decrease in AchE sensitivity might be the primary cause of resistance to isoprocarb in the planthopper. A secondary cause is the degradation of isoprocarb mediated by esterases, since TBPT (S,S,S-tri butylphosphoro trithionate), an inhibitor of these enzymes, enhanced the toxicity of isoprocarb to the resistant strain.

Chung and Sun (1981b) investigated the effect of the esterase inhibitor TBPT on the toxicity of malathion, parathion methyl and parathion to 4th and 5th instar nymphs of a malathion - resistant strain of *N. lugens* in China. TBPT enhanced the toxicity of malathion 20 times, that of parathion- methyl 6 times and that of parathion 11 times, implying that enzyme -mediated detoxification is associated with insecticides resistance in this rice pest.

Chung *et al.* (1982) have made studies in Taiwan, in which a malathion - resistant strain of the rice pest *N. lugens* developed by continuous selection of a field strain for 9 generations in the laboratory, gained 1183-fold resistance (when compared with a susceptible strain). An isoprocarb (MIPC) resistant strain selected similarly for 16 generations developed 41- fold resistance. Both were equally and significantly resistant to propoxur and permethrin but remained susceptible to fenvalerate. Chung and Sun (1983) examined the possible contribution of hydrolytic and oxidative metabolism to malathion and isoprocarb (MIPC) resistance in the rice pest BPH by using synergists TBPT and piperonyl butoxide. The role of microsomal oxidases was unclear in malathion resistance and was generally limited in isoprocarb resistance. Esterase hydrolysis was closely involved in malathion resistance, and this was confirmed by spectrophotometry and electrophoresis. This hydrolytic degradation also contributed significantly to the resistance to isoprocarb and several other carbamates (although to varying extents). Little difference was detected in the sensitivity to malaoxon of acetyl cholinesterases of susceptible and malathion-resistant strains. However, the acetyl cholinesterases of the isoprocarb-resistant strain was 15.7 fold less sensitive to isoprocarb than that of the susceptible strain and also less sensitive to other carbamates to which resistance had developed.

Dai and Sun (1984) found that Taiwanese field strains of BPH resistant to many organophosphates (OPs) and carbamate insecticides and developed much higher resistance to pyrethroids without an alphacyano group. High esterase activity associated with OPs and carbamate resistance in *Nilaparvata lugens* conferred a major part of the resistance to permethrin and other primary alcohol ester pyrethroids. In addition, the ester linkage of these pyrethroids without an alpha cyanogroup might be vulnerable to oxidative cleavage. Permethrin, phenothrin and fenpropathrin were synergized by piperonyl butoxide and TBPT in the resistant strains, while only phenothrin was synergized in the susceptible strain. Cypermethrin was synergized only to a very limited extent, thus suggesting limited metabolism in these strains. Sun *et al.* (1984a) showed that all field collected strains as well as laboratory selected strains with resistance to malathion or isoprocarb has high levels of resistance to permethrin, though they were susceptible to fenvalerate. A survey in 1982 indicated that the planthopper was highly resistant to permethrin, with only low or moderate resistance to alpha-cyano-containing pyrethroids, cypermethrin, deltamethrin and fenvalerate. Both the synergists piperonyl butoxide and TBPT (an enzyme inhibitor) produced a significant enhancement of the knockdown effect of permethrin against resistant populations of *N. lugens*.

Wang *et al.* (1988b) showed that in laboratory studies, malathion selected and carbofuran selected strains of the delphacid rice pest *N. lugens* developed 7.2- and 8- fold resistance to malathion and carbofuran, respectively, within 8 generations. The frequency of individuals with high aliesterase [carboxylesterase] activity increased gradually in each generation selected by carbofuran. In strains selected successively with carbaryl and malathion, carbofuran and malathion, carbaryl and monocrotophos and carbofuran and monocrotophos over 8 generations, the LC_{50} values were the same as that of the original susceptible strain. The LC_{50} increased by 5 and 6.5 fold after selection for 8 generations with methamidophos and buprofezin, respectively on Hybrid Shanyou 63 (Liu-Xianjin *et al.*, 1996). *Invitro* degradation activity of ^{14}C- methyl malathion was higher in malathion resistant strain as compared to susceptible strain (Miyata *et al.*, 1989).

Sun and Chen (1993) reported more than 10 molecular forms of carboxylesterases with α -naphthyl acetate as a substrate in the delphacid. It was proposed that gene encoding the enzymes was expressed to a greater extent in resistant than in susceptible planthoppers. The resistant strain had higher activity and quantity of carboxylesterases (preferably of the E1 type of active form) than the susceptible insects. The carboxylesterases of *N. lugens* being unable to hydrolyse parathion could bind strongly to the potent anti-choline esterases paraoxon and oxon of several organophosphate compounds (Chen and Sun. 1994).

b) Studies in Japan: Endo *et al.* (1988a) studied the development and mechanism of insecticide resistance in the *N. lugens*, which was collected from the field in Japan and selected with malathion or MTMC (metolcarb). The susceptibility of malathion and metolcarb selected strain to malathion decreased to 1/39 and 1/25, respectively of the initial level after 45 selections, while that to metolcarb decreased to 1/2.5 and 1/4.2. Several synergists were tested with these insecticides, and of these 2-phenyl-4 H-1, 3, 2 - benzodioxaphosphorin 2-oxide and 2-phenoxy-4 H-1, 3, 2 benzo-dioxaphosphorin 2-oxide were most effective and inhibited the decomposition of malaoxon. Malathion resistance is caused by high degradative activity to malathion and malaoxon and metolcarb resistance by low sensitivity of acetyl cholinesterase. Aliesterase activity and insensitivity to AchE were related to resistance in BPH to OP and carbamate compounds, respectively (Hama and Hosoda, 1983).

c) Studies in Korea: Kim and Hwang (1987) investigated biochemical differences between strains of *N. lugens* resistant to organophosphorus insecticides, susceptible to them or hybrids between resistant and susceptible strains in the laboratory. Esterase isoenzyme activity was much greater in the resistant than in the susceptible strain. Esterase activity in delphacids treated with diazinon, fenitrothion or BPMC [fenobucarb] was not decreased in the resistant strain or in the F_1

hybrids but was markedly decreased in the susceptible strain, as compared with untreated delphacids. The increase of esterase activity was associated with the development of resistance and was inherited through a dominant gene.

d) Studies in U.K.: Tranter and Emden (1984) compared the susceptibility of 8 populations of the rice pest, *N. lugens* in the laboratory, using five organophophate insecticides. Carbofuran resistant strain showed resistance intermediate to that of the Japanese and susceptible strains.

III Methodologies for detecting resistance

In Japan Nagata *et al.* (1979) estimated long term change of susceptibility of *N. lugens* to 8 widely used insecticides using a microtopical application technique. Four day old adult females were used. The LD_{50} values obtained in 1975-76 were compared with those obtained in 1967 to determine if insecticide resistance had developed during 9 years. Results showed that *N. lugens* had developed resistance to organophophates especially malathion (upto 10- fold) over the 9 year period and there was some slight decrease in susceptibility to carbamate compounds. Nagata (1982) developed an improved microtopical application technique to determine the insecticide susceptibilities of brown planthopper *N. lugens* and topical LD_{50} values were determined for the first time in 1967.

In Thailand, Fabellar *et al.* (1988) monitored the susceptibility of rice pests to insecticides. Twelve Asian rice growing countries formed a network to establish baseline insecticide susceptibility of major pests of rice. Susceptibility was determined by topical application with a hand operated microapplicator and a calibrated micro-syringe. Treated larvae were transferred to petri-dishes. The test usually had three replications, with atleast 15 insects per replication. Larval mortality was recorded at 24, 48 and 72 hrs. after treatment, and the LD_{50} and LD_{95} values were calculated using probit analysis. The results had shown that *N. lugens* in Indonesia may be less susceptible to insecticides than *N. lugens* from India, Sri Lanka, Thailand or Japan.

In India, Sarupa (1997) studied the insecticide resistance in *N. lugens* prevalent in Godavari delta of Andhra Pradesh. The insects were brought to Directorate of Rice Research, Hyderabad, reared for three generations and compared with a susceptible strain maintained in DRR greenhouse without any exposure to insecticides for 30 generations. Test insecticide solutions were prepared in acetone and further dilutions were made with 2.5% Teepol in water at 1 : 10 ratio. The insects were immobilised by exposing them for 100 seconds to diethyl ether vapour. Three to four day adult females were treated topically on dorsal side with 0.5 ml drop of insecticide emulsions. Insect mortalities were observed at 4, 24 and 48 hours after insecticide application. In further studies at DRR, Krishnaiah *et al.* (2001) exposed *Nilaparvata lugens* to monocrotophos and an effective neem formulation Neem gold 4 (NG4) at LC_{70} to LC_{80} concentrations once in each generation for 26 generations under greenhouse conditions. The base line toxicity data were determined and the extent of resistance development was assessed by spraying water emulsions of test insecticides and NG 4 upto run-off stage with fine atomizer on 40 day old potted rice plants of susceptible TN1 variety. After spray deposits dried up, six day old nymphs of BPH and GLH were confined to treated plants and observations were recorded at 24, 48 and 72 hrs after confinement in case of insecticides and 3 and 6 days of confinement in case of NG 4.

IV. Present status in India and future considerations

Sarupa *et al.* (1998) assessed the

insecticide resistance in field populations of *N. lugens* prevalent in Godavari delta of Andhra Pradesh. This is the first ever report on insecticide resistance in BPH in India. The field strain was compared with susceptible greenhouse strain for the toxicity of eight test insecticides commonly used in the area. At 4 hours exposure period, Godavari strain recorded moderate resistance ratio to BPMC (2.30) followed by chlorpyriphos (2.20), phosphamidon (1.89), phorate (1.54), carbaryl (1.50), monocrotophos (1.35), carbofuran (1.247) and quinalphos (1.244). This suggested that insecticide resistance in BPH was in incipient stage to the above insecticides in Godavari delta. Krishnaiah *et al.* (2001) studied the resistance development in *N. lugens* under greenhouse conditions by continuously exposing the insects to LC_{70} to LC_{80} concentrations of a recommended insecticide monocrotophos and the most effective neem formulation NG 4 once in each generation continuously for 26 generations. The results on resistance development and cross resistance pattern revealed that NG4 strain developed 1.98 to 2.15 times resistance to NG4 and low cross resistance (1.11 to 1.96 times) to monocrotophos, ethofenprox, BPMC, cartap and imidacloprid. However, monocrotophos selected strain of *N. lugens* showed slight resistance (1.16 to 2.41) to monocrotophos, BPMC and cartap but moderate cross resistance to ethofenprox (2.04 to 3.97), NG 4 (3.0 to 3.97) and imidacloprid (2.76 to 5.38 times). These observations indicated the potential for cross resistance of the insect to more recent insecticides like ethofenprox and imidacloprid with prior exposure to monocrotophos. As the original population used in the above studies is a greenhouse strain continuously undergoing inbreeding, the potential for wild field populations of BPH to develop resistance and cross resistance can be expected to be high.

In India, nearly 18% of the total insecticides used in agriculture are utilised for protecting rice crop from ravages of insect pests mainly in double cropped deltaic areas. As BPH is the most threatening and conspicuous insect pest in these areas and a major quantum of the insecticide is aimed against this pest, we should initiate studies on determination of base-line data for all the currently used insecticides. Simultaneously, continuous monitoring of insecticide resistance development in different regions of the country shall be initiated as was done in Japan. The problem becomes more complicated as BPH is spreading to new areas like Uttar Pradesh and Bihar and became very important pest in recent years (DRR, 2001).

In Japan, rice is grown only in one season and it is well established that BPH migrates each year from mainland China and after the crop season is over, the population wipes out in winter. The extent of resistance thereby depends on insecticide usage in the origin (China) and intensity of insecticide application in Japan. In India, *N. lugens* is the most important pest in both *kharif* and *rabi* seasons there by the chances of developing insecticide resistance are more with increased usage in both the seasons. Further, the migration pattern of BPH in India is not studied so far. BPH attacking rice in single cropped areas of the Northern parts of the country may be having their origin in Eastern or Southern areas, because this insect cannot survive low winter temperatures in the North. This adds new dimension for the insecticide resistance in this insect in India.

Currently monocrotophos, carbaryl, acephate and BPMC among sprays; carbofuran and phorate among granules are the most important traditional insecticides used against BPH in India. However, of late, ether derivatives like ethofenprox and neo-nicotinoids like imidacloprid and thiamethoxam are gaining popularity as they are safer to the environment and can be used at 25-100 g a.i./ ha as compared to 500-1000 g a.i./ha of traditional insecticides. Therefore, we need to prolong the usage life of these newer insecticides and to achieve this, the monitoring of insecticide resistance in BPH needs to be initiated early.

It is well known that in cotton the insecticide resistance in gram pod borer, *Helicoverpa armigera* particularly against synthetic pyrethroids (Mehrotra, 1990) was the single most important factor responsible for complete failure of the crop in some areas and there by leading to suicide of cotton farmers. Therefore, drawing analogy, the newer insecticides like imidacloprid and thiamethoxam which are extremely effective against BPH are likely to be over used by rice farmers in Delta areas, which may hasten the resistance development.

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