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INSECTICIDES INDUCED RESURGENCE OF SUCKING PESTS IN PADDY: A REVIEW

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ABSTRACT: Insecticide induced resurgence of sucking pest [planthoppers (brown Planthopper, *Nillparvata lugens* and white backed planthopper, *Sogatella furcifera* & leafhoppers(*Nephotettix virescens* and *N. nigropictus*] in paddy crop reveals that the insecticides of organochlorine, organophosphate, carbamates and synthetic pyrethroids induced resurgence in hoppers. Insecticides of neonicotinoids, IGRs and botanicals are effective and frequently used against hoppers management in paddy crop. Imidacloprid, a neonicotinoid is a key insecticide universally used for control of hoppers, but resurgence inducement is cropping up against neonicotinoid particularly imidacloprid. Reports reveals that sublethal doses along with number of spray, spray schedule, spray interval and methods of spray effects frequent outbreaks/resurgence of hoppers population in paddy crop. Insecticides effects longevity, lifecycle, reproduction, sex ratio etc. of hoppers. Insecticidal application also effects plant structure and its biochemical composition which in turn influences resurgence of hoppers.
KEYWORDS: Insecticides, Resurgence, Hoppers, Paddy

INTRODUCTION:

Rice, *Oryza sativa* L., is the staple food of more than two- third population of the world. This is a crop of hot and humid environment, grown under assured irrigation as well as high rainfall areas of the world. Likewise, it is also a staple food of Indian and grown in an area of about42.75mha with total production of 105.24 m tones during 2012-13 (*Anon.*, 2014). Paddy is grown in hot and humid climate, also suitable for breeding and multiplication of insect pests. More than 100 insect species attack paddy crop, of which 20 are major insect pests *i.e.* Leafhopper, Planthopper, Stem borer, Leaf folder, Gall midge, Hispa and Ear cutting caterpillar are common in most of the paddy growing area of the world (Atwal and Dhaliwal, 2012 and Heinrichs *et. al*., 1979). This insect pest collectively causes 0.5 to 3.0 t/ha yield losses while singh and Dhaliwal (1994)reported overall yield losses due to insect pests to the tune of 21 to 51 per cent. Litsinger *et. al*. (1987)reported that damage during vegetative stages (50 %), contributes more to yield reduction than the reproductive (30%) or ripening stage(20%).Samuales *et. al.* (1996) also reported that infestation of BPH caused 20-25 per cent reduction in grain yield than healthy grain.

Amongst of the sucking pests of paddy, the two leafhoppers i.e green leafhopper and white leafhopper and two planthoppers i.e brown planthopper and white backed planthopper are important pest of paddy crop. However, planthoppers, especially brown planthopper, *Nilaparvata lugens* (stal.) & white backed planthopper, *Sogatella furcifera* (Horvath) and leafhopper particularly the green leafhopper, *Niphotettix virescens* (Distant) & *N. nigropictus* (stal) pose threats to attain potential yield of paddy in India.

Crop protection technology has relied almost exclusively on the use of chemical insecticides to combat insect pests of paddy on account of easy availability, cheap, ease in application and quick knock down effects.

Chemical insecticides used against insect pests of paddy reveal that whale oil was used as first chemical against brown planthopper in paddy in the year 1670 in Japan (Suenaga and Nakatsuka, 1958).Application of whaleoil was replaced by kerosene oil in 1897 and further mixture of mineral oil with pyrethrum or nicotine was used from 1912 to combat insect pest of paddy

(Nagata, 1982). Although, these chemicals were partially effective to control the menace of insect pests. With the advent of insecticidal properties of DDT in 1939 and BHC in the year 1940^{s} pave the way for controlling insect pests with chemical insecticides. BHC was the first chemical insecticides found effective against planthopper in paddy in Japan in the year 1949. Organophosphates (parathion) replaced Organochlorine (BHC) against planthopper in 1952 and further parathion was replaced by more potent organophosphatic insecticides i.e diazinon and malathion. In 1960^{s}, OP insecticides were replaced by the more superior insecticides of carbamates against plant-hopper. The carbamate insecticides such as BPMC (2-sec-butyl phenyl-N-methyl carbamate), MTMC (3-methyl phenyl methyl carbamate) and propoxur were more frequently to control plant-hopper. Later on, owing to the insecticidal resistance development, mixture of OP and carbamates were used than their alone application to obviate the problem of insecticidal resistance and to effectively control hoppers (Heinrichs,1994). Compounds having high insecticidal property along with novel mode of action and relatively safer to non-target organisms are now a day recommended for the effective control of hoppers control in paddy crop. In this series, insect growth regulator such as buprofezin are found most effective and also reduces the chances of insecticidal resistance against plant-hoppers in paddy (Heinrichs *et. al*.,1984).

Application of insecticides not only kills target species but it also effects the non-target organisms and plants. Further, sublethal application of insecticides may leads to resurgence and secondary outbreaks of pests. It may also affect the morphology and biochemistry of the plants. So, the present review on sucking pests of paddy is dealt with the following sub-heads: -

(i) Effects of chemical insecticides on physiology of sucking pests in paddy.
(ii) Influence of chemical insecticides on structures and bio-chemical composition of host plant.

(i) Effects of chemical insecticides on physiology of sucking pests in paddy.

Application of insecticides may result into maximum killing (near to 100 %) of target species, but the residue population (survivors) get opportunity of more space and food to multiply rapidly which result into significant population increase called resurgence. Ripper (1956) recognized resurgence as a problem in plant protection for the first time and defined it as a tremendous increase in pest population brought about by an insecticide, within a relatively short time, in spite of the good initial kill at the time of treatment. Heinrichs *et. al*. (1982 a) suggested that significant increase in population of the target pest in insecticidal treated plot than untreated plot, may be called resurgence. Chelliah (1987) reported that an abnormal increase in pest population far exceeding the injury level must be evident in resurgence. Jayaraj and Raghupathi (1987) said that statistically significant increase of the population in treated plots compared to control plots, at a particular time after insecticidal application, would not be sufficient for recognizing resurgence and overall rate of increase or decrease in the population over a considerable period of time in treated and untreated plot should be taken into account. Maximum cases of resurgence have been reported in homopterans (44 %), followed by phytophagous mites (26%) and lepidopterans (24%) reported by Kareem (1998).

Recommended and higher dosages of insecticidal application result in high mortality and rapid population decrease of the target species. However, sublethal dosages of insecticides resulted in low mortality of the target species, which stimulates survivor population to rapid feeding and reproduction, high rate of nymphal development and tremendous increase in population. Insecticidal application selectively eliminates natural enemies. These resulted into resurgence of insect population and shows that insecticides either directly induce physiological effects on target species or may affects the morphology and biochemistry of host plant to the advantages or disadvantages for the pest. Application of different type of insecticides directly influences the sucking pests of paddy or indirectly influencing host plant is divided and reviewed below: -

ORGANOCHLORINES (OC):- Application of OC insecticides for the first time reported to cause resurgence of *N. lugens* in paddy. Application of BHC caused three times higher populations of *N. lugens* than the control plot of paddy crop (IRRI, 1969).In laboratory test, seven fold increase in resistance was observed in five generation in N lugens due to the topical application of HCH (Nagata and Moriya, 1969). Chelliah and Heinrichs (1980 a) reported significantly low nymphal population and feeding by N. lugens in perthane treated plots of paddy. Perthane application prevents the resurgence of *N. lugens*, even if the paddy plots treated earlier with resurgence inducing insecticides i.e deltamethrin and methyl parathion (Chelliah and Heinrichs, 1980 b).

ORGANOPHOSPHATES (OP):-Bio-efficacy of number of OP insecticides were evaluated and used for the control of planthoppers in paddy. Resurgence of planthoppers to OP insecticides was reported from application of diazinon and methyl parathion to the paddy @ 0.04 per cent each, resulted in 38.6 to 60.9 per cent and 66.0 to 75.8 per cent increase in *S. furcifera* and *N. lugens*, respectively (IRRI, 1978). When BPH reared on methyl parathion and diazinon treated paddy paddy plants from nymph to adult stage, oviposit significantly more number of eggs (Chelliah and Heinrichs, 1978). Also, hoppers burn symptoms was more in methyl parathion treated plots than hoppers burn symptoms caused by same number of hoppers on untreated paddy plots. Aquino *et. al.* (1979) also reported higher damages by *N. lugens* in fields treated thrice, at 4,7 and 10 weeks after planting with azinphos-ethyl, triazophos, methyl parathion, dimethoate, monocrotophos and fenthion. Application of azinphos-ethyl, quinalphos, monocrotophos and triazophos increased N. lugens population by 5-10 times; tetrachlorvinphos and pyridafenthion by 15 times; diazinon, isazophos and methyl parathion by 30-35 times (Reissig *et. al.*,1982 b).Application Phorate granules @ 2 kg a.i/ha resulted in a significant increase in N. virescens population (Velusamy, 1987). Resurgence has also reported in N. cincticeps following insecticide application in paddy fields (Koyayashi, 1961 and Kiritani, 1979).

Resurgence of insect pests also influenced by different dosages of insecticides. Low or high dosages of methyl parathion applied than @ 0.04 % reduces reproduction but when applied @ 0.04 % significantly enhances reproduction in *N. lugens* (Chelliah and Heinrichs, 1978). Sub-lethal dose of methyl parathion applied as topical against fifth instar nymph of *N. lugens* resulted in maximum reproductive rate (80.5%) than lethal dose (32 %)(Chelliah*et.al*.,1980). Similar trends was also reported by Heinrichs *et. al*.,1982 b. Recommended dosages each of monocrotophos and phosphamidon @ 0.05 % effectively control *N. lugens* while sub-lethal dosage increases 2-7 fold more population (Krishnaiah and Kalode, 1987). Timing and number of insecticidal spray also enhances the degree of resurgence. Single spray of methyl parathion@ 0.75 kg a.i/ha or two spray at 20 and 35 days after transplanting showed non-significant different from control, but when two spray applied at 50 and 65 days and three at 35,50 and 65 days after transplanting showed significant increase in *N. lugens* population (Heinrichs *et. al*., 1982 a). Similar trends were also reported by Raman and Uthamasamy,1983 and Chelliah, 1979 who reported that spraying paddy crop twice or thrice with methyl parathion, quinalphos, fenthion and deltamethrin increases N. lugens as compared to paddy crop sprayed once.

Physiology of insect pests can be affected by the application of insecticides on host plant. Application of diazinon on paddy caused reduction in nymphal duration of N. lugens, which attributed to shortened life cycle and resurgence inducement (Chelliah, 1979). However, Salim and Heinrichs (1987) & Chelliahand Heinrichs (1980 a) reported non-significant effect on nymphal duration, survival and adult longevity of *S. furcifera* and *N. lugens* feeding on paddy crop treated with monocrotophos, diazinon and methyl parathion. Positive correlation of sex ratio in favour of female and resurgence of *N. lugens* was observed when nymph reared on methyl parathion, quinalphos and fenthion treated paddy plants (Chelliah and Heinrichs, 1980 a and Raman & Uthamasamy,1983). Application of insecticides also effects feeding by plant-hoppers on paddy. Application of methyl parathion and diazinon induces increased feeding resulted in increased honeydew excretion by 43 and 33 per cent, respectively (Chelliah and Heinrichs, 1980 a). Similar trends were also observed by Raman and Uthamasamy (1983) when treated with methyl parathion, quinalphos and fenthion. Wu *et. al*.(2001) reported significantly higher amounts of honeydew secreted by N. lugens fed on methamidophos @ 750 and 1500 g a.i/ha treated paddy plants. However, Salim and Heinrichs (1987) observed non-significant difference in honeydew excreted by S. furcifera feeding on monocrotophos and diazinon treated paddy plants. Wang *et.al*.(2010) that the BPH is a classical resurgent rice pest induced by insecticides and the resurgent mechanism based on stimulation of the reproduction of adult females. However, present study examined changes in protein level in both male accessory glands and females' ovaries induced by the insecticide, triazophos.

Carbamates:- Carbamate insecticides have also been extensively used for controlling insect pests of paddy. Resurgence of *N. lugens* was reported from fields treated with carbofuran which were completely hopper burnt compared to fields received no insecticides. Applications of carbosulfan and FMC 31768 induced and increased the hopper population by 28.1 and 17.9 times, respectively while, carbofuran resulted in in 20.0 to 35.2 fold increase and methomyl increased the *N. lugens* population by 9.3 folds (IRRI,1977; Heinrichs *et. al*.,1982 a and Reissig*et. al*., 1982 b). In laboratory conditions, methomyl, FMC 27289, and FMC 31768 did not increase reproduction and produced on par hoppers population with that of control. However, BPMC and carbosulfan reduced the reproduction of the hoppers (Chelliah and Heinrichs, 1979 a, b) but Raman and Uthamasamy (1983) observed lower population of *N. lugens* nymphs in paddy plants treated with BPMC or carbosulfan @ 0.04 per cent.

Dosages and method of insecticide application influences feeding, biology and population buildup of sucking pests. Root zone application of carbofuran @ 0.75 and 0.50 kg a.i/ha significantly reduced feeding in N. virescens compared to its lower dosages @ 0.25 kg a.i/ha (Basilio and Heinrichs, 1981 a) Similar trends were also observed by Lie and Wilkins, 1987 & Heinrichs *et. al*., 1982b. However, Reissig *et. al*. (1982 b) reported resurgence of *N. lugens* following soil application of carbofuran only, while foliar spray controlled hoppers efficiently. Chelliah (1979) reported shortening of nymphal duration of *N.lugens* might induced resurgence due to granular application of metalkamate. Resurgence inducing carbamates such as carbofuran and aldicarb did not effects nymphal duration of hoppers.

Synthetic Pyrethroids:- This group of insecticides had been used world over to control insect pests, also caused resurgence in paddy crop. Resurgence of *N. lugens* was reported in 1976 from deltamethrin treated paddy plots by 16.4-fold increase in population of *N. lugens* (IRRI, 1977) and 28.5 to 60.9 per cent increase in *S. furcifera* due to application of deltamethrin and cypermethrin was observed (IRRI, 1978). Likewise, Chelliah and Heinrichs (1978) also reported significantly more damage by N. lugens in Paddy crop treated with deltamethrin. *N. lugens* population buildup up to five times was reported in paddy fields due to applications of deltamethrin or fenvalerate by many workers (Reissig, *et. al*., 1982 b; Raman and Uthamasamy, 1983; Krishnaiah and Kalode, 1987 & Budhasamai *et. al*., 1992) while Heinrichs *et. al*., (1982 a) reported 20 folds increase in *N. lugens* population in paddy plots received four spray of deltamethrin. Cypermethrin and alphamethrin induced resurgence in S. furcifera and *N. lugens* was observed, resulted in more hopper burn and reduction in paddy yield by 28 per cent (Vorley, 1985). Resurgence of planthoppers population was observed across the varieties/genotypes, irrespective of level of resistance. But it varied among varieties according to level of resistance. *N. lugens* population build up was maximum (74 folds) in susceptible var. (IR 29) compared to 50 folds in moderately resistant var. (IR 40) and 5 folds in resistant var. (IR 42) (Reissig *et. al*., 1982 a). Similar trend was also observed by Salim and Heinrichs (1987), screened all types of varieties against *S furcifera*, following application of deltamethrin. Wang et.al.(2010) reported that adult male also play the resurgent mechanism besides stimulation of the reproduction of adult females. The present study examined changes in protein level in both male accessory glands and female ovaries induced by the insecticide, deltamethrin.

Sub-lethal dosages of pyrethroids such as Deltamethrin, cypermethrin, fenvalerate etc. induces resurgence of hoppers in paddy crop as reported by Chelliah and Heinrichs, 1978; Chelliah *et. al*., 1980; Heinrichs *et. al*., 1982 b & Balaji *et. al*.,1987. Timing and number of sprays also effects the population dynamics and causes resurgence of hoppers. When paddy fields sprayed with Deltamethrin, cypermethrin, fenvalerate etc in less than 50 DAT showed less population build up but when sprayed at more than 50 DAT showed resurgence of hoppers population. Likewise, more number of spray of pyrethroids induced more population buildup compared to single spray (Heinrichs *et. al*.,1982 a; Heinrichs and Mochida, 1984 & Raman and Uthamasamy, 1983). Apart from reproduction, pyrethroids application in paddy crop also effects feeding, life cycle, sex ratio, honey dew excretion etc as reported by Chelliah and Heinrichs, 1980 a; Salim and Heinrichs, 1987; Chelliah, 1979; Raman and Uthamasamy, 1983; Chelliah and Heinrichs, 1978; Sogawa and Pathak,1970.

Neonicotinoids: Neonicotinoids, also known as chloronicotinyl insecticides is a new class of insecticides. Insecticides of this nitroguanidine and cyanoguanidine groups are very effective at low dosages (25-50 g a.i./ha) and relatively safe to non-target organisms including mammals than the OP and carbamates, which are effective at higher dosages (500-1000 g a.i./ha) and highly toxic to non-target organisms including mammals. These insecticides act as agonist of acetyl chaoline (ACH) receptors interact with post-synaptic nicotinyl ACH receptors of central and peripheral nervous system and leads to over stimulation, stoppage of feeding, tremors, paralysis and the death of insects (Ishaaya,2001 and Nauen *et. al*.,2003).

The application of imidacloprid was found highly effective which caused 100 per cent mortality of brown planthopper, *N. lugens*(Jena *et. al*., 2000). Thiamethoxam and imidacloprid were found highly effective against *N. lugens* and *S. furcifera* in glass house (Anon., 2001). Similar trends were also reported by Krishnaiah *et. al*., 2003 and Verma *et. al*., 2003 that application of thiamethoxam and imidacloprid @ 25 g a.i./ha effectively control *N. lugens* and *S. furcifera* under field condition. Application of synthetic pyrethroids are well known to induce resurgence of sucking pests under such as leafhoppers and planthoppers. Deltamethrin applied alone caused resurgence of *N. lugens* but when applied in combination with thiamethoxam or imidacloprid effectively reduced planthopper population without induction of resurgence. Premix combination products of imidacloprid + B-cyfluthrin @ 30 g a.i./ha was effective against planthoppers(Verma *et. al*.,2003). Krishnaiah *et. al*. (2004) reported higher toxicity of imidacloprid and thiamethoxam when applied alone @ 25 PPM each and combination product of imidacloprid @ 15 ppm + B-cyfluthrin @ 15 ppm against *N. lugens*, *S. furcifera* and *N. virescence* in glass house condition.

Studies on resistance and cross resistance of imidacloprid under laboratory condition against *N. lugens* showed 11.35-foldincreasesin resistance in 25 generation with resistance ratio of 72.83 as against susceptible strain reared in laboratory (Zewen *et. al*., 2003). Further, selected resistance strain showed cross resistance to all insecticides having mode of action atacetylchaoline receptors such as acetamiprid etc. Matssumura *et. al*. (2008) reported development of resistance against neonicotinoids in brown planthopper from Thialand in 2003 and further from Vietnam, China and Japan. Species specific changes in insecticide susceptibility were found in Asian rice planthopper(i.e. BPH for imidacloprid from East Asia and Indonesia and WBPH for fipronil from East and South West Asia). Gorman *et. al*. (2008) tested the samples of BPH collected from China, India, Indonesia, Malaysia, Thailand and Vietnam at two doses of imidacloprid i.e. LC 50 and five times dose of LC50 and result showed reduced mortality and 100 fold resistance in two late season field collected samples from India at both doses. It clearly indicated development and spread of resistance in imidacloprid against *N. lugens* in Asia. Yucong *et. al*.(2009) observed moderate to high level of resistance to imidacloprid against brown planthopper under field condition and resistance mechanism attributed by enhanced P450 monooxygenases detoxification.

Insect Growth Regulators/ Bio-rational Insecticides: It represents third generation insecticides i.e. a class of chemical that interferes normal growth and development of insects. IGRs can be classified in two categories i.e.(i) Juvenile hormone analogues (JHAs)- effects endocrine system, which produces the hormones needed for growth and development into an adult form. Application of JHAs influences morphogenesis and embryogenesis in immature and adult stages, respectively. Insect poisoned with IGRs cannot moult, reproduce, and eventually they die, (ii) chitin synthesis inhibitors (CSI) – which inhibits the synthesis of chitin in insects by inhibiting the enzyme, chitin synthetase required for biosynthesis of chitin during moulting. An insect poisoned with CSI cannot produce chitin and so cannot moult, adult cannot reproduce and eventually die.

Buprofezin was found effective against *N. lugens*, *S. furcifra* and *Nephotettix* spp. upon treatment as it caused series of deformities from nymph to adult stages and finally, they die (Kajihara*et. al*.,1982; Asai*et. al*., 1983 and Valencia *et. al*., 1983). Combination of buprofezin + other insecticides (especially resurgence inducing insecticides) effectively control without causing resurgence of planthopper. Formulation of buprofezin (1 %) + BPMC (2 %) dust was effective against BPH for extended period (Hirao et. al., 1983).Combination of buprofezin + deltamethrin effectively control without causing resurgence of BPH and WBPH (Panda and shi, 1988). Resurgence ratio of 0.46 was observed combination product (buprofezin + deltamethrin) as compared to 1.5 for alone application of deltamethrin (Bhudhasamai *et. al*., 1992). Combinations of buprofezin + synthetic pyrethroids (Cypermethrin or deltamethrin) were highly effective against BPH, WBPH and GLH (*N. virescens*). Combinations of buprofezin(100 g a.i./ha) + synthetic pyrethroids (Cypermethrin @ 50 g a.i./ha or deltamethrin @ 25 g a.i./ha) showed effective control of planthoppers as compared to alone application of synthetic pyrethroids (Cypermethrin @ 50 g a.i./ha or deltamethrin @ 25 g a.i./ha) which caused resurgence of planthoppers in rice fields (Krishnaiah *et. al*.,1996).

Botanical insecticides: Insecticides of plant origin were evaluated and found effective against sucking pests of paddy crop. Green leafhopper, *Nephotettix* spp. Was effectively controlled by the application of neem seed kernel extract @ 2 %, neem cake extract @ 5 % and neem leaf extract @ 5 % (Saroja, 1986). Krishnaiah and Kalode, 1993 reported that application of neem formulations, viz. Neemark, Nimbosol, Nimba, Neemta 2100 and Repelin effectively controlled N.lugens under greenhouse conditions.

Jena and Dani (1997) evaluated Neem based products and Neem oil i.e. Neemazole, Nenthrine and Neem oil and found to reduced oviposition by 50 per cent in brown planthopper.

Velusamy *et. al*., 1987 observed significant reduction in oviposition by N. lugens due to application of neem oil @ 1-2 %, neem seed kernel extract @ 5 % and neem cake extract @ 5 %. Plant derivatives, neem oil, pinnai oil, pungam oil & illupai oil @1%each and neem seed kernel extract, pinnai seed kernel extract, pungam seed kernel extract & illupai seed kernel extract @2%each as well as neem seed cake extract @ 5 % were found effective in reducing BPH and WBPH (Ramaraju and Sundara Babu, 1989). Das *et. al*.(1996) showed that Neem derivatives alone and in combination with Monocrotophos and Chlorpyriphos were highly effective against brown planthopper, *N. lugens*.

Krishnaiah *et. al*.(2000) reported that Oil based neem formulatins of azadirachtin (300 ppm) i.e. Neemgold and Nimbecidine@ 4 per cent when applied by tank mix with deltamethrin prevented resurgence 0f BPH or when applied alternatively with deltamethrin.

(ii) Influence of chemical insecticides on structures and bio-chemical composition of host plant:

Insecticides have primary effects on insects and it also exerts secondary effects on treated plants as well (Lloyd and Krieg, 1987). The effects of chemicals on growth and development of crop plants were reported by many workers (Hutt *et.al*., 2000). Foliar applications of methyl parathion, diazinon, carbosulfan and perthane increased the number of tillers and height of rice plants (Chelliah and Heinrichs, 1978). Similar trends were also observed by Venugopal and Litsinger (1984) that the application of carbofuran to rice crop showed significant increase in the root growth, plant height and rapid maturation. Qiu *et. al*.(2004) found that low dose (15 g a.i./ha) of imidacloprid significantly promoted the uptake of P and K by the root. Field experiment during rice grain filling stages showed that both low and high doses of imidacloprid reduced active growth stage and maximum of grain growth of superior grain significantly and a high dose reduced K and growth rate of inferior grain significantly.

Application of insecticides not only control insect pests but it’s under dosages causes physiological changes both in insect and treated host plants. Biochemical composition of host plants gets effected by the application of insecticides. Chelliah and Heinrichs (1978) and Raman (1981) reported that seed or seedling root dip treatments with phosphamidon, monocrotophos, dicrotophos and diamethoate did not caused significant changes in Calcium, Magnesium, Zinc and magnese contents of rice treated plants. However, it causes significant changes in copper and iron content in treated plants compared to untreated plants. Application of deltamethrin increased free amino acids and total nitrogen in leaf sheaths of treated rice plants. However, deltamethrin treated rice plants recorded lower carbohydrate: Nitrogen ratio than untreated or perthane treated rice plants and it caused BPH resurgence (Buenaflor *et. al*., 1981).

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