



Incidence and management of rice caseworm and whorl maggot: A critical review

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Abstract

Rice is an important cereal crop and is cultivated virtually in all agro-ecological zones in India. However, production capacity is far below national requirement. One of the major reasons for the low yields of rice in India is depredation by pests, particularly the insect pests. The rice plant is an ideal host for a large number of insect pests-root feeders, stems borers, leaf feeders and grain feeders. However minor pests such as whorl maggot, caseworm, chaffer beetle, gundi bug, rice hispa and black beetle are emerging as great concern to farmers. Yield losses associated with these insect pest categories portray the role of the insects in low rice yield in India. Proper management of rice pests therefore is a pre-requisite for enhanced and sustainable rice production amidst smallholder farmers that typify the rice production industry in India. In this review, major emphasis is given to rice caseworm and whorl maggot mainly on their pest status, distribution and control methods.

Keywords: rice, production, management

1. Introduction

Rice (*Oryza sativa* L.) is one of the world's leading sources of food among cereals and important staple food of almost half of the world population. Worldwide, rice is grown over an area of 162.31 million hectares with total production of 738.18 million tonnes. In India, area under rice is about 42.96 million ha with the total production of 158.7 million tonnes (Anonymous 2016) [5]. It is the staple food for more than 65 per cent of the people of India. In recent years, there is a need to increase food production in order to meet the demand of rapidly increasing human population from limited land resources. This has necessitated the use of intensive farming systems, with the inputs like narrow genetic base varieties, high fertilizer dose applications, irrigation, multiple cropping etc. which favour abrupt pest development. The introduction of high yielding varieties, adoption of new agronomic practices and monoculture over large area along with the humid environment is favourable for the proliferation of insect pests which have increased the population of minor pests rendering them as major pests and vice-versa (Reddy 2013) [43].

In India, paddy is attacked by a number of insect pests viz., *Scirpophaga incertulas* (Walker), *Sesamia inferens* (Walker), *Chilo suppressalis* (Walker), *Nilaparvata lugens* (Stal.), *Sogatella furcifera* (Harvath), *Nephotettix virescens* (Distant), *Cnaphalocrocis medinalis* (Guenee), *Orseola oryzae* (Wood-Mason), *Dicladispa armigera* (Oliver), *Nymphula depunctalis* (Guenee), *Hydrillia philippina* (Ferino), *Leptocorisa acuta* (Thunberg), *Hieroglyphus banian* (Fabricius). They feed on rice crop from nursery to maturity stage and also in storage. Some of them reach the status of pests causing economic losses under farmers's field conditions. Among them, whorl maggot, caseworm, chaffer beetle, gundi bug, rice hispa and black beetle are emerging as great concern to farmers.

The rice whorl maggot, *Hydrillia* spp., is a pest of rice

mainly in irrigated ecosystem. It causes 20 to 30 per cent yield loss on the first crop during April to September, but the infestation was less in the second crop (Sain and Sain 2000) [44] in Hyderabad. Dyck (1974) [16] reported the pest to cause stunting of plants and diminution in tillering. Whorl maggot also results in distorted leaves, small clear or yellow spots, transparent streaks and pinholes on the leaves.

The rice caseworm, *Nymphula depunctalis* (Gn.) occurs sporadically on rice in India and cause severe damage to young plants (Jacob *et al.* 1978) [23]. The caseworm, *N. depunctalis* is commonly found in low lands with poor drainage and flooded fields. Because of poor stagnation in fields during floods, this pest can build up and cause severe loss in early vegetative stage. The entire crop may have to be resown and replanted in case of damaged leaves. The larvae enclose themselves within the tubular leaf case by cutting the leaf blade. Enclosed within the case, the larva attaches itself to the rice plant and feed on the leaves. Feeding damage includes cutting off the leaf cases and may result in patches of severe defoliation, stunted growth and death of plants (Srivastava *et al.* 2012) [52-53]. Study on the population buildup of insect pests and their natural enemies and their relationship with weather parameters is an essential component of pest management as it generates information which can be utilized to improve cultural, mechanical, behavioural and chemical methods of insect control.

To overcome the losses and increase in yield, pesticide applications are very much important. Newer groups of insecticides play a major role in insect pest management on rice, since they impart effective control against target pests and have no longer residue persistence in plants as well as in the soil. It is very important to study the bioefficacy of insecticides against the pests of rice for effective pest management. The pest ecology and prevailing weather conditions play an important role in managing the pest effectively and well in time.

Population buildup of rice caseworm and rice whorl maggot

Litsinger *et al.* (1994) ^[25] reported that 2 to 6 weeks of transplanting as the most vulnerable stage for the survival of the caseworm larvae. Larvae survive better, grow larger, mature more rapidly and more fecund adults during vegetative stage when reared on plants. While, Tripathi and Saxena (2013) ^[56] calculated the mean number of larva per m² of rice caseworm on different rice varieties and reported the occurrence of pest 30 days after sowing growth stage and then gradually declined till 75 days after sowing. Severity of this incidence was highest on Pusa Basmati and lowest on JRH-4. Yumnam *et al.* (2016) ^[62] observed that rice plant was damaged only by the caterpillar of *N. depunctalis* that was most predominant during early vegetative stage of rice crop in flooded rice field. Bhuyan *et al.* (2008) ^[11] while working on the management practices of rice caseworm reported that mean per cent leaf infestation by caseworm larvae based on the damaged leaves at 20 DAT ranged from 2.92 to 3.25 and was found to be non-significant with each other. The incidence pattern of rice caseworm was also studied by Haq *et al.* (2004) ^[20] throughout the year at Bangladesh Rice Research Institute farm, Gazipur and observed that the light trap incidence of caseworm was higher during the month from September to November and the insect peaked in October. Garg Vidyawati (2012) ^[18] studied the monitoring of rice caseworm population and their natural enemies during *kharif* season at Raipur. She operated the light trap and sweep net method for observing seasonal abundance of caseworm and reported that adult catches in light trap started from 31st SMW and remained continue up to 51st SMW. The highest peak of caseworm was observed during 40th SMW and highest population of caseworm due to sweep net was observed in second fortnight of October with 25 adults per 5 sweeps afterwards it declined. Also, Nirala *et al.* (2013) ^[33] studied on light trap catches of rice caseworm at research farm of Indira Gandhi Krishi Vishwa Vidyalaya, Raipur and reported that maximum adult catches of rice caseworm were observed on 41th SW of October with 416.0 adults per week and then adult population gradually decreased as the crop departing towards maturity stage. The studies on the incidence of whorl maggot in Onattukara, Kerala by Sasidharan *et al.* (1979) ^[45] revealed that leaf infestation by *H. philippina* in autumn rice started in the first week of June reaching its maximum (16%) in the last week of June. Whereas, in the winter sown rice infestation began soon after transplanting and reached maximum (39%) in early November. In both the seasons the peak of infestation was recorded 50 to 60 days before harvest. Heinrichs and Viajante (1987) ^[21] studied the leaf infestation caused by rice whorl maggot and reported that infestation rate was high as 800 flies per 49 plants resulted in 82 per cent of the leaf infested. Singh and Singh (1988) ^[50] reported the occurrence of rice whorl maggot in Gurdaspur and Kapurthala (Punjab), which resulted in leaf damage varying from 12 to 71 per cent. Sharma *et al.* (2004) ^[46] studied that the population of whorl maggot that varied between 10 to 83 adults per 30-minute sweeping during the crop season. Adults of pest were not observed in the field till the transplanting of crop and also in nursery beds. The population level of 10 adults of *H. philippina* recorded through sweep net during first week of transplanting. The population of the pest was maximum during mid or late

August. The adults of whorl maggot were not observed from first week of October onwards till the harvesting of crop. There was gradual decrease in the population of whorl maggot from the booting stage onwards till harvest stage

Influence of environmental factors on population buildup of pests

Bhatnagar and Saxena (1999) ^[10] showed the effect of climate on the population buildup of rice insect pests. Rice caseworm showed a negative significant correlation with evening relative humidity and rainfall, along with a positive correlation with sunshine hours in jagdalpur, Madhya Pradesh. Garg Vidyawati (2012) ^[18] conducted a field experiment to assess the impact of different weather parameters (bright sunshine hours, rainfall, maximum and minimum temperature, maximum and minimum relative humidity and wind speed) on the population dynamics of caseworm, one of the important pests of rice. There was significant negative correlation between peak populations of caseworm with rainfall and relative humidity and significant positive correlation showed between peak population of caseworm and bright sunshine hours. Gogoi and Bora (2013) ^[19] investigated the effects of rainfall, humidity and air temperature on the population density of larvae of caseworm during tillering stage at hill density of 20 m² and water level of 10 to 15 cm in the controlled experimental field and showed the positive correlation of rainfall, air temperature, relative humidity with density of larvae of *N. depunctalis*. Nirala *et al.* (2013) ^[33] studied the correlation between caseworm and meteorological parameters and showed non-significant negative correlation with minimum temperature, relative humidity and rainfall however positive relation with maximum temperature and sunshine hours at 1 and 5% level of significance.

Barwal and Rao (1986) ^[8] observed the effect of micro environment on the incidence of whorl maggot. They reported the incidence to be positively correlated with relative humidity and rainfall. They also observed the preference of early crop stage for infestation by rice whorl maggot

Population buildup of associated natural enemies

Sinu *et al.* (2007) ^[51] reported that an undescribed aquatic ichneumonid wasp species was potentially useful early stage pupal parasitoid of rice caseworm. 73 per cent of the parasitized pupae of caseworm reported under water yielded adult parasitic wasps. The adult female wasps usually dive into the water in search of the host pupae, remaining under water for a maximum of 90.2s, while searching for rice caseworm pupae. Chantaraprapha and Litsinger (1986) while studying the predators of rice caseworm observed that *Sternolophus rufipes* larvae consumed up to 6 to 7 fifth instars caseworm larvae daily, but only 2 to 3 of first or second instar larvae. Also concluded that snails kill caseworm eggs. Snails grazing on algae growing on submerged rice foliage dislodge caseworm eggs laid on the undersides of floating leaves and kill them. Litsinger *et al.* (1994) ^[25] reported that larval and adult predators comprised the largest component of the natural enemy fauna. Spiders, birds and adult dragonflies/ damselflies were the dominant predators of caseworm adults, while aquatic beetle larvae, aquatic bug nymphs and adults and ants preyed on caseworm larvae. A rice field pulmonate snail *Lymnaea quadrasi* caused limited caseworm egg mortality in a

passive and fortuitous manner. Water beetles dytiscid *Cybister tripunctatus orientalis* and hydrophilid *Sternolophus rufipes* were voracious larval predators. Garg Vidyawati (2012) [18] monitored the natural enemies of rice caseworm at Raipur and reported that spider, lady bird beetle, rove beetle, and damselfly were important predators of rice caseworm. Spider and damselfly were found to be most active during first fortnight of September with 46 and 53 adults per 5 sweeps respectively, while lady bird beetle and rove beetle were most active in month of October in Raipur with 70 and 43 adults per 5 sweeps respectively. Ferino (1968) studied the biology of rice whorl maggot and reported two hymenopterous parasitoid, *Opius* sp. and *Tetrastichus* sp., from the puparia of pest. Total parasitism of whorl maggot fluctuated between 14.4 and 71.4 per cent. Abraham and Mathew (1974) reported that *H. philippina* is a pest of rice seedlings causing considerable damage to the autumn crop (April to October). During laboratory rearing experiments with this Ephydrid, a Braconid of the genus *Chorebus* was found parasitising the pupae, with a population peak and maximum parasitism (3%) in July. Manjunath (1977) [28] observed the two parasites, both identified as species of *Gyrocampa*, had been found attacking larva of rice whorl maggot. The parasites were active in March and April in summer and September and October in *kharif*, and parasitism reached 18.5 to 27.5 per cent in the summer crop and 24.3 to 60.4 per cent in the *kharif* crop. Natarajan and Mathur (1980) [32] recorded new parasitoid of the rice whorl maggot and reported a species of *Chaenusa* from the pupae of rice whorl maggot. Reissig *et al.* (1985), Pathak and Khan (1994) while working on bioefficacy of insecticides, reported that the eggs of the *Hydrellia philippina* were parasitized by *Trichogramma* sp., and *Tetrastichus* sp., egg parasitoid. Webber (1988) [60] reported that *Opius* could parasitize up to 30 per cent of pupae of *Hydrellia philippina*. Sain *et al.* (2000) [44] while studying the damage caused by rice whorl maggot, reported that 8.3 to 26 per cent of the leaves were damaged in the vegetative stage (20–40) days after transplanting on untreated plants. Reissig *et al.* (1985), Pathak and Khan (1994) while working on bioefficacy of insecticides, reported predators such as *Lycosa pseudoannulata*, *Oxyopes javanus*, *Neoscona theisi* and *Ochther abbreviatialis* associated with rice whorl maggot. Heong *et al.* (1992) [22] found a relative abundance of *Pardosa pseudoannulata* of 25 to 54 per cent of all the spiders on rice whorl maggot in the Philippines across the season.

Assessment of yield losses

Heinrichs and Viajante (1987) [21] conducted a study to know the yield loss caused by rice caseworm and reported that a grain yield loss of 500 kg per ha or 10 per cent occurred when there were approximately 10 larvae per hill, 30 per cent of the leaves were cut or 25 per cent of the leaf area was scraped during first month after transplanting. Truzillo R (1991) [57] reported that the caseworm larvae damaged the leaf epidermis of rice. A yield loss of 52 per cent due to damage by the pest was observed. Valencia and Mochida (1985) [59] reported that rice whorl maggot damage ranged from 1.8 to 6.5 per cent in the insecticide treated plots and 11.4 to 43.5 per cent in check plots. The correlation coefficient between rice whorl maggot damage and yield loss was 0.57 (n=10) and not significant, indicating that rice whorl maggot infestation at the levels in

this study did not affect yield. Shepard *et al.* (1990) [48] studied the damage caused by the rice whorl maggot in the Philippines in rice cv. IR 72. Yield components were evaluated at levels of damage from 0 to 100 per cent. There were no significant differences in any of the yield components among plants with different damage levels. At the damage levels from 60 to 100 per cent, there was a gradual but significant decline in yield with increased whorl maggot damage. The rice whorl maggot is a pest of rice mainly in irrigated ecosystem. It causes 20 to 30 per cent yield loss on the first crop during April to September, but the infestation was less in the second crop (Mangal 2000) [27].

Evaluation of insecticides

Foliar sprays and granular broadcasts are the most commonly adopted methods against rice pests in various countries. In tropical countries like India, the foliar spray offer protection for 7 to 10 days, while the granular broadcasts in paddy water remain effective for 20 to 25 days. Other methods of insecticide application like seed dressing, seed bed treatment for nursery pest control and root soaking prior to transplanting had also been found effective for brief period and need to be supplemented with other treatments for effective pest management.

Chemical insecticides

Gargav and Patel (1973) [17] conducted an experiment to monitor the toxicity of spray residues of 10 insecticides on rice plants to larvae of rice caseworm and concluded that (0.05%) fenitrothion, (0.025%) quinalphos, (0.1%) carbaryl and (0.048%) monocrotophos gave 100, 100, 97.5 and 94.5 per cent mortality, respectively, after 24 h. However, only fenitrothion and carbaryl were recommended against pest due to low mammalian toxicity. Bandong and Litsinger (1981) [7] reported that rice caseworm can be controlled effectively on rice with one application of insecticide after transplanting. Insecticides such as isoprocarb, triazophos, chloropyriphos, azinphos-ethyl, BPMC, malathion, diazinon, carbaryl, phosphamidon, endosulfan and MTMC were sprayed against the pest. Isoprocarb and triazophos were the most toxic and MTMC the least toxic. Srivastava *et al.* (2012) [52-53] tested certain new insecticides against rice caseworm on paddy. They concluded that during *kharif* season, the spinosad treatment @ 125 ml ha⁻¹, registered minimum pest incidence and it was found significantly better than other treatments after 15 days of application. The yield per hectare was also reported to be maximum in spinosad treated plots and it was at par with other treatments including flubendiamide, treated plots. Paddy yields were increased by 3.30 and 3.29 t ha⁻¹, respectively when carbofuran and cartap were applied each at the rate of 2 kg a.i. per ha by placing below the soil surface near the roots at 5 days after transplanting (Anonymous, 1973) [3]. Rice yields were higher in the root zone application of carbofuran as compared to the broadcast application (Anonymous, 1976) [4]. Ramamurth *et al.* (1976) found seed treatments with diazinon 1 per cent, monocrotophos 0.1 per cent or carbofuran 1 per cent to gave effective control of whorl maggot. Mani and Jairaj (1976) observed that foliar sprays of fenthion (0.1%), fenitrothion (0.05%), parathion (0.05%) and acephate (0.3%) gave effective control of whorl maggot. Ramamurthy *et al.* (1977) reported the application of phorate, diazinon and

carbofuran on 10 and 30 days after transplanting (DAT) to reduce the incidence of whorl maggot and resulted in significantly increased yields. Ramamurthy *et al.* (1978) evaluated the efficacy of fenthion (0.05%), monocrotophos (0.05%), carbaryl (5%) with molasses (2.5 kg ha⁻¹) and BHC 10D (25 kg ha⁻¹) at 15 and 30 DAT and observed them to be the effective for the control of whorl maggot. Study of Arceo and Heinrichs (1980) [6] revealed that soil application of carbofuran (0.75 kg ha⁻¹) one day before transplanting keep the numbers of damaged leaves to a maximum of 1 per hill up to 31 days after transplanting as compared with more than half the leaves damaged by the 31st day on untreated plots. Srivastava and Philip (1980) [54] observed the metphospholan (250-750 ppm) seed treatment to have no adverse effect on germination or growth of rice seeds. Singh and Rizvi (1983) [49] compared the relative efficacy of granular formulations of chlorpyrifos (1kg a.i./ ha), carbofuran (0.5kg a.i./ ha) and liquid formulations of monocrotophos (0.5 kg a.i./ ha) when applied 10 DAT. They observed chlorpyrifos to be superior to others in checking rice whorl maggot. Rajendran and Chelliah (1983) [38] reported that broadcasting of carbofuran (0.75 kg a.i./ ha) at 20 DAT followed by foliar sprays of phosphamidon (0.1%) on 35 and 50 DAT resulted in effective suppression of whorl maggot. Basit *et al.* (1984) [9] reported that foliar sprays of chlorpyrifos 0.50 and 0.25 kg a.i. per ha and granular application of carbofuran at 1.25 kg a.i. per ha were effective for whorl maggot control. Rajamani *et al.* (1984) [37] observed that soaking of rice seedlings with chlorpyrifos (0.02%) remained effective for 30 to 40 days and reduced the infestation of whorl maggot. Studies conducted by Uthamasamy and Jayraj (1985) [58] revealed that the foliar application of methamidophos and fenvalerate at 20, 40 and 60 DAT were found to be effective for whorl maggot control. Dancel and Mutya (1986) [14] observed the soil incorporation of carbofuran (0.33 and 0.50 kg a.i./ ha) to be more effective in controlling the whorl maggot than the three times broadcast application of carbofuran and five times foliar sprays of monocrotophos (2.5 and 3.0 kg a.i./ ha), respectively. Barwal and Rao (1986) [8] found that carbofuran application enhanced tillering and controlled rice pests including the whorl maggot whereas root dipping with chlorpyrifos was effective partially. Macatula and Mochida (1987) [26] evaluated monocrotophos at 0.3 kg a.i. per ha and observed it to lower the incidence of whorl maggot by 50 per cent. Pantua and Litsinger (1987) [36] compared the ovicidal activity of eight insecticides against the whorl maggot and observed deltamethrin (0.012 kg a.i./ ha) and triazophos and azinphos-ethyl at 0.4 kg a.i. per ha were highly ovicidal, causing 98, 97 and 94 per cent mortality, respectively. Yeh (1987) [61] found Dadece (mixture of deltamethrin 0.6 per cent and buprofezin 5-10 per cent) to be effective for the suppression of whorl maggot. He also observed deltamethrin in checking the insect transmitted virus diseases. Reddy (1989) [42] compared the relative efficacy of application of insecticide, one with the help of land compression sprayer (which supplies the insecticide to root zone of wetland rice at 5-10 cm depth) and other as broadcast application. He observed that carbofuran applied as suspension with the help of hand compression sprayer was better in controlling the whorl maggot than the broadcast application. Masipiquena (1990) [29] reported that in the field use of carbofuran (15G) as a controlled release formulation reduced whorl maggot

damage up to 36 days as compared to 28 days by conventional granular formulation. Pamplona *et al.* (1990) [34] found that efficacy of deltamethrin at 3.13 to 6.25 g a.i. per ha against the rice whorl maggot control. Panda *et al.* (1999) [35] found triazophos (250 g a.i./ ha), quinalphos (750 g a.i./ ha) and profenphos (1 kg a.i./ ha) to be effective for the suppression of whorl maggot in Orissa. Among the various insecticides evaluated as nursery application, cartap (1.5 kg a.i./ ha) and carbofuran (1.0 kg a.i./ ha) were found to reduce the damaged leaves by whorl maggot to 1.7 to 2.3 per cent as compared to 6.5 to 8.8 per cent observed in untreated check (Dash *et al.* 2001). Sharma *et al.* (2003) conducted a study during *kharif* to evaluate the effect of various insecticides on the damage caused by the rice whorl maggot. Carbofuran, chlorpyrifos and monocrotophos were found most effective against whorl maggot of rice. Application of insecticides in the nursery 5 days prior to transplanting was found better and resulted in higher yield as compared to insecticide application at 44 days after transplanting. Benefit cost ratio was highest *i.e.* 2.62 in nursery application of carbofuran. Seven insecticides *viz.*, ethiprole, 10 SC, clothianidin 50 WDG, cartap hydrochloride 50 SP, phosphamidon 40 SL, triazophos 40 EC, diazinon 20 EC and α -cypermethrin 10 EC were evaluated in the field against rice whorl maggot. The results revealed that per cent whorl maggot damaged leaves remained significantly lower in cartap and triazophos treated plots compared to other insecticides and control (Misra and Sahithi 2005) [31]. A study was conducted to evaluate the effect of various insecticides on the damage caused by the rice whorl maggot (*H. philippina*) and benefit cost ratio in rice under mid hill conditions of Himachal Pradesh, India. Carbofuran, chlorpyrifos and monocrotophos were the most effective treatments against rice whorl maggot. Grain yield and value of produce were highest in carbofuran treated plants, followed by chlorpyrifos and monocrotophos treated plants. The application of insecticides in the nursery 5 days prior to transplanting was better and resulted in higher yields compared to insecticide application at 44 days after transplanting. The benefit: cost ratio was highest in the nursery application of carbofuran (Sharma *et al.* 2007) [47]. A study was conducted on the efficacy of different insecticides during the boro season against whorl maggot in West Bengal, India. There were 5 treatments, *i.e.* monocrotophos 36 WSC (0.036%), imidacloprid 17.80 SL (0.0178%), endosulfan 35 EC (0.07%), clothianidin 50 WDG (50 g a.i./ ha) and untreated control. Amongst the treatments, imidacloprid proved the most effective against the whorl maggot infestation by increasing the number of tillers as well as yield over the other insecticides (Biswas and Hath 2008) [12].

Botanical insecticides

Mayabini (2005) [30] conducted extensive research on the use of botanicals in pest management system in rice, with special reference on the efficacy of neem seed kernel extract, neem oil, neem bark decoction, and several neem-based formulations for the control of insect pest of rice. The leaf extract of water pepper has shown significant repellent action against rice caseworm. Ahirwar *et al.* (2011) [2] studied insecticidal activity of fresh leaf juice, decoction and alcoholic extract of *Cleistanthus collinus* in different concentrations against rice caseworm. Leaf decoction (50%) was found to be most effective, where single application

was able to kill all the insects within 12 h and control the rice caseworm in Chhattisgarh region of India. Gogoi and Bora (2013) ^[19] reported that plant material used by farmers of Dhemaji district, Assam against rice caseworm larva. He studied the efficacy of thirteen ethnically important plants against caseworm larva out of which *Zanthoxy lumnitidum*, *Zanthoxy lumnrehta*, *Croton tiglium*, *Crataeva nurvala*, *Premna latifolia*, *Chromolaena odorata* and *Calotropis procera* were considered to be most effective.

Krishnaiah and Kalode (1984) ^[24] studied the effectiveness of neem oil against whorl maggot in Greenhouse. In the field neem oil did not reduce damage done by whorl maggot. However, relatively higher populations of a predacious mirid bugs were observed in plots treated with neem oil as compared with the other treatments. Sudhakar (1994) ^[55] studied the efficacy of neem products viz., neemorate and neemax, applied alone or in combination with chlorpyrifos 20 EC against the whorl maggot of rice. Neemorate at 20 kg ha⁻¹ was more effective in controlling whorl maggot compared to the lower dose of 15 kg ha⁻¹. Higher grain yield (4.7 t ha⁻¹) was also obtained with the application of neemorate (20 kg ha⁻¹) compared to the untreated control which only yielded 3.3 t ha⁻¹ due to damage by different pests. Spray formulations were slightly superior in minimizing pests when sprayed alone compared to the control. The effectiveness of the spray formulations increased when applied in combination with chlorpyrifos.

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