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Ecofriendly approaches of neem products as organic pesticides on rice insect pests and predatory spider

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Abstract
During the last two decades, the Neem tree spps. *Azadirachta Indica and Azadirachta juss* have come under close view of researchers around the world as the prime source of natural bioactive pesticides. About 400 insect pest species belonging to different orders are adversely effected by Neem derivatives (Jacobson, 1986). In Indian subcontinent Neem cake application in rice fields against insect pests has been in use for several workers. However, detailed studies are lacking in tropical Indian situations. Hence this field study the plant products play an important role in evolving an ecologically sound and environmentally acceptable pest management systems. Many plants including wild species have antifeedant properties *Parthenium hysterophorus* has been found to posses antifeedent and juvenomimetic principles against *S. litura*. Extracts from *Mahagom, swietema Mahogoni* seeds, reizomes of *Sanisiveria marginata*, fruits of *Solanum Species* and *Acacia dealbata*, leaves of *pogostemon Species*, whole plant of *Andragraphis Peniculata*, neem oil and antifeedant properties against *S litura*. Juvenomimetic effect of plants have been reported to a number of species viz. *Physterophorus* and *Tribules terrestries* on *Dysdercus cingulatus*, *T terrestris* on *Helothis armigera* and *Spotoptera litura.*
Neem oil 2% and Neem seed kernel extract (NSKE) 5% reduced the fecundity of female, hatchability of eggs, percent nymphal survival and growth index of brown plant hopper (Reguraman 1989). Neem oil 8% and Neem seed Kernal extract 5% spraying once, recorded less population of rice ear-head-bug on 7 and 14 days after treatment (Reguraman, 1989). Neem oil 2%, NSKE 5%, Neem oil 2%, + Activated carbon 0.1%, NSKE 5% + Activated carbon 0.1% When sprayed in the evening controlled the grass hoppers in rice field (Mohan, 1989).

Keywords: *Azadirachta indica,* rice brown plant hopper, *Nilaparvatha lugens,* neem oil, neem seed kernel extract, neem cake

Introduction
In India rice is the most important cereal crop and is cultivated over an area of 42.7 million hectare with an average productivity of about 2.9 tones/ha. The rice ecosystem receives next to cotton**,** the highest amount of insecticides in India. Rice is severely attacked by over 20 species of insect pests. Among these, rice stem borer *Scirpophaga incertulas*, leaf folder *cnaphalocrocis medinalis* (Guenee) and brown plant hopper *Nilaparvata lugens* (stal.) are quite serious problem in Tamil Nadu.
In developing countries, inadequate product knowledge, supply uncertainities and high prices cause inefficient pesticide use and also create additional socioeconomic problems between the "haves" and the "have-nots." Alternative pest control strategies, especially those that are effective and low-cost are thus needed. Crude plant extracts may play an important role here (Brady, 1982). Over the years, more than 6000 species of plants have been screened and nearly 2400 plants belonging to 285 families were found to posses significant biological activities against insect pests (Grainge and Ahmed, 1988) [5].
The latest World Health Organization figure suggests that atleast three million and perhaps 25 million agricultural workers are prone to poison each year by pesticides and some 20,000 deaths. The extensive and intensive use of inorganic fertilizers and pesticides for maximum crop production indirectly leaves residual toxic substances in food, which is taken by animals as well as human beings (Gupta and Upadhyay, 1998).
Even today some innovative farmers in Karnataka and Tamil Nadu puddling green leaves and twigs in rice nursery beds to produce robust seedlings and simultaneously ward off attack by early pests like green leaf hoppers (*Nilaparvata virescens*),

brown plant hoppers *Nilaparvata lugens* and maggots. Abdul Kareem *et al*. (1989) [1] also confirmed that rice seedlings raised from seed treated with neem kernel extract or cake were vigorously growing and were resistant to rice leaf hoppers (*Nilaparvata Virescens*) and plant hoppers. The bioefficacy of extracts and compounds from the Neem tree spps viz., *Azadirachta Indica and Azadirachta juss* against various insect pests has been well documented (Schmutterer, 1990). In order to find out the highly effective one among the different Neem products, the present work was undertaken to study the "Effect of different plants and Neem products against rice brown plant hopper (*Nilaparvata lugens*)".

Materials and methods

The effect of plant extracts was tested against brown plant hopper *(Nilaparvata lugens*) in the rice field. The site is located at Agricultural Research Station, Thirupathisaram, Kanyakumari District, Tamil Nadu, India. The soil is clay loam with P^H 7.5 and the source of irrigation is from Pechiparai Dam canal. The experiment site is situated in tropical climate with a mean annual rainfall of 745 mm. The mean annual maximum and minimum temperature was 35^0 C and 22^0 C respectively. The relative humidity ranges between 50 and 100 percent.

Field experiment was conducted at Agricultural Research Station, Thirupathisaram, Kanyakumari District, Tamil Nadu, India during June 2017 and 2018 to study the effect of plant extracts were tested against brown plant hopper *(Nilaparvata lugens*) in rice field. The experiment site is situated in tropical climate with a mean annual rainfall of 745 mm. The mean annual maximum and minimum temperature was 35^0 C and 22^0 C respectively. The relative humidity ranges between 50 and 100 percent. The soil is clay loam with P^H 7.5 and the source of irrigation is from Pechiparai Dam canal.

The experiment was laid out in randomized block design with three replications and eleven treatments *viz*. T_1-Neem oil 3%, T_2-Neem seed kernel extracts 5%, T_3-Neem cake extracts 10%, T_4- Basal application of Neem coated urea followed by Neem oil 3%, T_5-Basal application of Neem oated urea followed by Neem seed kernel extract 5%, T_6-Basal application of Neem coated urea followed by Neem cake extract 10%, T_7-Neem oil 2% followed by monocrotophos 0.02%*, T_8-Neem seed kernel extract 3% followed by monocrotophos 0.02%*, T_9-Neem cake extract 5% followed by monocrotophos 0.02%*, T_{10}-Monocrotophos 0.04% (Recommended dose) and T_{11}-Control (No spray)

Twenty five days old seedlings were transplanted in plots of 8 x 5 m at the rate of three seedlings per hill with spacing of 12.5 x 10 cm, variety ASD 16 was selected for this trial. Plots were sprayed with the neem formulations and insecticidal treatments with one check control using a Knapsack sprayer fitted with flat fan nozzle, leaving one meter wide 'buffer zone' between plots, so as to limit 'spray drift' from entering adjoining plots. Fertilization was done as per blanket recommendation 125:50:50 kg N: P: K /ha for all treatments except T4, T5 and T6.

Spraying was done when any one of the insect pest reached the economic threshold level in any one of the plots. Spray fluids were prepared on high volume spray concentration (500 l/ha).

Assessment of pest population, damage and natural enemies

In each plot 20 hills were randomly selected and observed for the presence of pests, damage and natural enemies on 3, 5, 7, 10, and 14 days after treatment (DAT).

The percentage of leaf damage was recorded taking randomly 20 selected hills adopting "Stratified sampling" method.

$$\% \text{ of damaged leaves} = \frac{\text{Total number of affected leaves in 20 hills}}{\text{Total number of leaves (healthy+affected) in 20 hills}} \times 100$$

The number of nymph/adults of Brown Planthopper *Nilaparvata Lugens (Stal*) were counted and expressed per hill in 20 randomly selected hills. The values are transformed to square root transformation and analysed by ANOVA and DMRT.

Results

The effects of plant extracts were tested against brown plant hopper and leaf folder in the laboratory. The field experiments were conducted at the Agricultural Research Station Thirupathisaram, Kanyakumari District during Kharif season of 2017 and 2018 to evaluate the neem products as organic pesticides and its performances on rice insect pests and predatory spider for ecofriendly world. The results obtained are analyzed and presented in this chapter.

Experiment I - Laboratory Studies

Effects of plant extracts on Rice brown plant hopper (BPH)

Oviposition and hatchability of brown plant hopper

The number of eggs laid, nymphs emerged and hatchability percent of brown plant hopper in rice plants treated with plant extract were analyzed. The number of egg laid was minimum (65.00) in Neem oil 3 percent followed by Neem seed kernel extract 5 percent (93.67). The next best treatment was Neem Seed cake 10 percent (103.00) which was at par with *N. tabacum* 10 percent (103.67) treatment. Among the different treatments highest number of eggs was recorded in *A.cocculus* 10 percent (138.33) while in control 140.00 eggs was recorded. The oviposition and hatchability of brown plant hopper was given in Table 1.

Regarding inhibition of the nymphal emergence, A. indica oil 3 percent was the best and recorded a minimum of 42.33 nymphs followed by *A. indica* seed kernel 5 percent (60.33) and *N. tabacum* 10 percent (65.00).

Table 1: Effect of Plant Extract on Oviposition and hatchability of the Brown Plant Hopper

Treatment	Total number of egg laid	Number of nymphs emerged	Hatchability %
T_1 Neem seed kernel 5%	93.67 (9.68)^b	60.33 (7.77)^b	58.19 (7.63)^a
T_2 Neem seed cake 10%	103.00 (10.15)^e	61.00 (7.81)^c	59.22 (7.70)^b
T_3 Neem oil 3%	65.00 (8.06)^a	42.33 (6.51)^a	65.12 (7.49)^c
T_4 *Leucas aspera* 10%	132.67 (11.52) ^{j}	103.00 (10.15)^k	77.64 (8.61)^j
T_5 *Ocimum basilicum* 10%	128.00 (11.31)^i	91.33 (9.56)^i	71.35 (8.45)^f
T_6 *Nicotiana tabacum* 10%	103.67 (10.18)^d	65.00 (8.06)^d	69.39 (8.33)^e
T_7 *Tagetes erecta* 10%	106.67 (10.33)^e	79.00 (8.89)^e	74.06 (8.61)^h

T_8 *Acorus calamus* 10%	110.33 (10.50)^{f}	90.67 (9.52)^{h}	82.18 (9.07)^{k}
T_9 *Tephrosia purpurea* 10%	111.33 (10.55)^{g}	81.67 (9.04)^{f}	73.35 (8.56)^{g}
T_{10} *Anamirta cocculus* 10%	138.33 (11.56)^{k}	95.67 (9.78)^{j}	69.16 (8.32)^{d}
T_{11} Control	140.00 (11.83)^{l}	127.67 (11.30)^{l}	91.19 (9.54)^{l}

Figure in parenthesis are transformed square root values. In a column means followed by same letter(s) are not significantly different (p=0.05) by DMRT.

Development of brown plant hopper

The data collected on mortality of brown plant hopper on first, third, fifth and seventh day after treatment (DAT) on plants treated with plant extracts showed that there was a progressive increase in mortality from first to seventh day. The development of brown plant hopper was presented in Table 2.

Table 2: Effect of plant extract on development of Brown Plant Hopper

Treatment	Mortality percentage (DAT)				Adult developed (%)
	1st day	3rd day	5th day	7th day	
T_1 Neem seed kernel 5%	13.33 (21.41)^{e}	19.23 (26.01)^{c}	28.57 932.31)^{c}	46.67 (43.09)^{b}	53.33 (46.89)^{d}
T_2 Neem seed cake 10%	6.67 (14.96)^{i}	14.28 (22.20)^{f}	33.33 (35.26)^{a}	25.00 (30.00)^{i}	75.00 (60.00)^{e}
T_3 Neem oil 3%	13.33 (21.41)^{b}	23.09 (28.91)^{a}	30.00 (33.23)^{b}	57.14 (49.11)^{a}	42.86 (40.86)^{a}
T_4 *Leucas aspera* 10%	6.67 (14.96)^{j}	14.28 (22.20)^{g}	16.67 (25.00)^{i}	25.00 (30.00)^{h}	75.00 (60.00)^{j}
T_5 *Ocimum basilicum* 10%	6.67 (14.96)^{g}	14.28 (22.20)^{d}	20.83 (27.15)^{f}	21.05 (27.31)^{k}	78.95 (62.65) ^{h}
T_6 *Nicotiana tabacum* 10%	3.33 (10.51)^{k}	13.79 (21.80)^{i}	16.00 (23.58)^{k}	23.80 (29.20)^{j}	76.20 (46.92)^{k}
T_7 *Tagetes erecta* 10%	6.69 (14.96)^{f}	10.71 (19.10)^{j}	20.00 (27.56)^{g}	30.00 (33.21)^{f}	53.33 (46.89)^{g}
T_8 *Acorus calamus* 10%	6.67 (25.00) ^{h}	10.71 (19.10)^{k}	16.00 (23.58)^{j}	28.57 (32.51)^{g}	71.43 (57.67)^{i}
T_9 *Tephrosia purpurea* 10%	16.67 (25.00)^{a}	20.00 (26.59)^{b}	25.00 (30.00)^{d}	46.67 (43.09)^{c}	53.33 (46.89)^{b}
T_{10} *Anamirta cocculus* 10%	10.00 (18.44)^{e}	14.81 (22.63)^{e}	17.39 (24.65)^{h}	31.57 (34.19) ^{e}	56.67 (41.17)^{f}
T_{11} Control	0.00 (0.48)^{l}	0.00 (0.48)^{l}	0.00 (0.48)^{l}	0.00 (0.48)^{l}	100.00 (90.00)^{l}

Figures in parenthesis are transformed Arcsine values. In a column means followed by same letter (s) are not significantly different (P=0.05) by DMRT

Regarding development of adults in various treatments, Neem oil 3 percent recorded minimum (42.86 percent) compared to other treatments. *T. purpurea* 10%, Neem seed kernel 5% and *T. erecta* 10% recorded 53.33% adult development. Maximum adult development was noticed in *O.basilicum* 10% (78.95%) followed by *N. tabacum* 10 percent (76.20%). the adult development was 100% in control.

Effects of plant extract on rice leaf folder

Quantity of food ingestion:

The data on the quantity of food ingestion assessed in terms of weight of the excreta for every 24 hour upto 96 hour revealed that weight of the excreta was significantly lower in plant extract treatment compared to the control. Quantity of faucal pellets excreted by fourth instars larvae of leaf folder was recorded in Table 3.

Treatment with Neem oil 3% recorded minimum (0.28 mg) dried excreta, 24 hour after feeding which was significantly superior than other treatments. Maximum (0.58 mg) excreta was recorded in *L. aspera* 10% and *N. tabacum* 10% recorded 0.55 mg. Weight of faucal pellet excreted in *L. aspera* 10% and *N. tabacum* 10 per cent with the value of (0.55mg) and these two treatments were at par with each other. Weight of faucal pellet excreted was 0.62 mg in control.

When the mean weight of faecal pellets excreted was considered, the quantity of feacal pellets excreted was less in Neem oil 3 percent (0.43 mg) followed by *T. purpurea* 10 per cent (0.53mg) and Neem seed kernel extract 5 percent (0.56 mg). Among the treatments maximum (0.80mg) faucal pellets were excreted in *L. aspera* 10 percent. In control 1.01 mg was excreted.

Table 3: Quantity of food ingested by fourth instar larvae of leaf folder on rice plants sprayed with plant extracts

Treatment	Weight of the faecal pellets (mg)				Mean	% decrease from control
	24 hour	48 hour	72 hour	96 hour		
T_1 Neem seed kernel 5%	0.30 (3.14)^{b}	0.56 (4.29)^{c}	0.59 (4.41)d	0.77 (5.03)c	0.56 (4.29)c	44.55
T_2 Neem seed cake 10%	0.54 (4.21)^{h}	0.58 (4.39)^{d}	0.76 (5.00)e	0.78 (5.07)e	0.67 (4.76)e	33.66
T_3 Neem oil 3%	0.28 (3.03)^{a}	0.33 (3.29)^{a}	0.43 (4.18)a	0.59 (4.41)a	0.43 (3.76)a	57.42
T_4 *Leucas aspera* 10%	0.58 (4.36)^{l}	0.78 (5.07)^{k}	0.90 (5.44)j	0.94 (5.56)j	0.80 (5.13)k	20.79
T_5 *Ocimum basilicum* 10%	0.37 (3.48)^{d}	0.72 (4.87)j	0.90 (5.44)k	0.93 (5.53)i	0.70 (4.90)g	30.69
T_6 *Nicotiana tabacum* 10%	0.55 (4.25)^{l}	0.58 (4.37)e	0.62 (4.52)c	0.78 (5.07)d	0.63 (4.55)d	37.62
T_7 *Tagetes erecta* 10%	0.43 (3.76)^{f}	0.66 (4.66)g	0.82 (5.20)h	0.96 (5.62)k	0.72 (4.87)h	28.71
T_8 *Acorus calamus* 10%	0.39 (3.58)^{e}	0.68 (4.73)h	0.79 (5.10)f	0.89 (5.41)f	0.69 (4.76)f	31.68
T_9 *Tephrosia purpurea* 10%	0.35 (3.39)^{c}	0.56 (4.29)b	0.57 (4.33)b	0.62 (4.51)b	0.53 (4.18)b	47.52
T_{10} *Anamirta cocculus* 10%	0.49 (4.01)^{g}	0.69 (4.76)^{l}	0.89 (5.41)^{l}	0.90 (5.44)g	0.74 (4.93)j	26.73
T_{11} Control	0.62 (4.52)^{l}	1.19 (6.26)^{l}	1.07 (5.93)^{l}	1.17 (6.21)^{l}	1.01 (5.99)^{l}	-

Figures in parentheses are transformed Arcsine values.

In a column mean followed by some letter(s) are significantly different (P=0.05) by DMRT.

Experiment II – Field Investigation

Field efficacy of Neem products on Rice Brown plant hopper (*Nilaparvata lugens*)

The brown plant hopper *(Nilaparvata lugens)* population on the Neem product treated and control plots were recorded on 3, 5, 7, 10 and 14 days after treatment. The brown plant hopper population was significantly reduced (0.57 / tiller) in basal application of Neem coated urea followed by Neem oil 3 percent treated plot (T_4) compared to control (T_{11}) (1.00/tiller) on 3rd day after treatment.

When the mean incidence of brown plant hopper *(Nilaparvata lugens)* was considered (Table.4), basal application of Neem coated urea followed by Neem oil 3% (T_4) was the best with the population of 0.27 / tiller and it was followed by basal application of Neem coated urea followed by Neem seed kernel extract 5% (T_5) with the value of 0.30/tiller. Basal application of Neem coated urea followed by Neem cake extract 10% (T_6) recorded 0.36/tiller and recommended dose of monocrotophos 0.04% (T_{10}) recorded 0.42 / tiller. In control more number of brown plant hopper *(Nilaparvata lugens)* (1.67 / tiller) were recorded.

Table 4: Field efficacy of Neem products on the incidence of Brown Plant Hopper (Two years average)

Treatment	Pre treated Count (Number/hill)	Post treatment count (Number/hill)					Mean
		3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	
T_1- NO (3%)	0.75 a	0.60 a	0.31 d	0.27 b	0.48 c	0.35 bc	0.402
T_2- NSKE (5%)	0.96 b	0.79 b	0.33 d	0.31c	0.56 d	0.33 c	0.464
T_3- NCE (10%)	1.13 d	0.92 c	0.37 de	0.39 d	0.71e	0.41 d	0.56
T_4 - Basal application of NCU + NO (3%)	0.75 a	0.57 a	0.12 a	0.19 a	0.27 a	0.22 a	0.274
T_5 - Basal application of NCU + NSKE (5%)	0.69 a	0.62 a	0.17 b	0.23 a	0.28a	0.22a	0.304
T_6 - Basal application of NCU + NCE (10%)	0.69 a	0.60a	0.20 bc	0.32 c	0.40 b	0.30 b	0.364
T_7 - NO (2%) + Monocrotophos (0.02%)	0.69 a	0.93 c	0.40 e	0.49 e	0.74 e	0. 82 e	0.676
T_8 - NSKE (3%) + Monocrotophos (0.02%)	1.05 cd	0.91 c	0.42 e	0.54 f	0.71 e	0.88 e	0.692
T_9 - NCE (5%) + Monocrotophos(0.02%)	0.96 b	0.99 c	0.50f	0.53 ef	0.76 e	0.83 e	0.722
T_{10} - Monocrotophos (0.04%)	0.76 ab	0.76 c	0.23 c	0.33 c	0.42 b	0.37 cd	0.422
T_{11} - Control	1.00 bc	1.00 d	1.54 g	1.79 g	1.90f	2.12 f	1.67
SEd	0.02	0.02	0.02	0.01	0.01	0.01	
CD (0.05)	0.04	0.04	0.05	0.03	0.04	0.03	

DAT – Day after treatment, NO – Neem oil, NCE – Neem cake extract, NCU – Neem coated urea, NSKE – Neem seed kernel extract.

Field efficacy of Neem products on rice Green Leaf Hopper (*Nephotettix virescens*)

On third day after treatment, there was a significant reduction in green leaf hopper *(N. virescens)* population in the Neem coated urea followed by Neem oil 3% (T_4) (2.01/hill) and basal application of Neem coated urea followed by Neem seed kernel extract 5% (T_5) (2.33/hill) treated plots and their efficacy was superior to Neem cake extract 5% followed by monocrotophos 0.02% (T_9) (3.99/hill). Maximum number of green leaf hopper *(N. virescens)* population was recorded in control (T_{11}) (10.73/hill). Field efficacy of Neem products on rice green leaf hopper was presented in table 5.

Table 5: Field efficacy of Neem products on the incidence of Green Leaf Hopper

Treatment	Pre treatment count (Number/hill)	Post treatment count (Number/hill)					Mean
		3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	
T_1- NO (3%)	3.51 a	3.16 cd	2.42 d	2.66 c	2.30 d	2.00 b	2.508
T_2- NSKE (5%)	4.20 b	3.26 cde	2.56 de	2.91 c	2.32 d	2.13 b	2.636
T_3- NCE (10%)	4.12 b	3.33 cde	2.69 def	2.72 c	2.69 e	2.79 cd	2.844
T_4 - Basal application of NCU + NO (3%)	5.21 c	2.01 a	0.92 a	1.20 a	0.98 a	1.23 a	1.268
T_5 - Basal application of NCU + NSKE (5%)	4.98 c	2.33 b	1.73 bc	1.33 ab	1.02 a	1.17 a	1.516
T_6 - Basal application of NCU + NCE (10%)	6.85 e	2.99 c	1.45 b	1.54 b	1.33 b	1.27 ba	1.716
T_7 - NO (2%) + Monocrotophos 0.02%)	4.91 c	3.50 d ef	2.92 ef	4.23 d	2.79 e	3.00 de	3.288
T_8 - NSKE (3%) + Monocrotophos (0.02%)	5.98 d	3.92 fg	3.00 ef	4.00 e	3.00 e	3.33 de	3.45
T_9 - NCE (5%) + Monocrotophos (0.02%)	6.69 e	3.99 g	3.11f	4.02 e	3.53 f	3.69 de	3.668
T_{10} - Monocrotophos (0.04%)	4.10 b	3.51 ef	1.82 c	1.53 b	1.65 c	2.09 bc	2.12
T_{11} - Control	8.69 f	10.73 h	16.33 g	20.00 f	23.10 g	27.33 f	19.498
SEd	0.05	0.04	0.07	0.04	0.04	0.09	
CD (0.05)	0.11	0.09	0.14	0.09	0.09	0.19	

DAT – Day after treatment, NO – Neem oil, NCE – Neem cake extract, NCU – Neem coated urea, NSKE – Neem seed kernel extract.

Among the treatments, when the mean incidence of green leafhopper was considered, basal application of neem coated urea followed by neem oil 3% (T_4) was the best with population of 1.26/hill and it was comparable with basal application of neem coated urea followed by neem seed kernel extract 5% (T_5) 1.51/hill. Maximum green leaf hopper population was recorded in neem cake extract 5% followed by monocrotophos (0.02%) (T_9) (3.66 /hill). In control 19.49/hill green leafhopper population was recorded.

Field efficacy of neem products on Rice leaf folder

The leaf folder incidence on the neem products treated and control plots were recorded on 3rd, 5th, 7th, 10th and 14th day after treatment Table 6.

When the mean incidence of rice leaf folder was considered, basal application of neem coated urea followed by neem oil 3% (T_4) was the best with 2.64% damage. The next best treatment was basal application of neem coated urea followed by neem seed kernel extract 5% (T_5) with a value of 2.77%.

Basal application of neem coated urea followed by neem cake extract 10% (T_6) stands next with a value of 2.81%. Maximum damage (5.37%) was noticed in neem cake extract 5% followed by monocrotophos 0.02% (T_9). Neem seed kernel extract 3% followed by monocrotophos 0.02% (T8) recorded 5.10% damage. In control 17.02% damage was recorded.

Table 6: Field efficacy of Neem products on the incidence of Rice leaf folder

Treatment	Pre treatment count (%)	Post treatment count (%)					Mean
		3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	
T_1- NO (3%)	7.67^{b}	6.61^{c}	3.17^{c}	2.67^{b}	3.00^{b}	3.17^{b}	3.72
T_2- NSKE (5%)	6.89^{bc}	6.60^{cd}	3.50^{d}	2.99^{b}	3.21^{b}	3.50^{bc}	3.96
T_3- NCE (10%)	7.91^{c}	7.29^{cd}	4.33^{d}	3.33^{bc}	3.50^{bc}	3.97^{bc}	4.48
T_4 - Basal application of NCU+ NO (3%)	10.09^{a}	4.33^{a}	2.03^{a}	1.80^{a}	2.33^{a}	2.73^{a}	2.64
T_5 - Basal application of NCU + NSKE (5%)	9.10^{a}	4.50^{a}	2.11^{a}	2.00^{a}	2.50^{a}	2.78^{a}	2.77
T_6 - Basal application of NCU + NCE (10%)	8.76^{ab}	4.91^{b}	2.10^{a}	2.06^{a}	2.60^{a}	2.98^{a}	2.81
T_7 - NO (2%) + Monocrotophos (0.02%)	9.01^{cd}	7.53^{d}	4.97^{de}	3.67^{c}	3.76^{c}	4.10^{d}	4.80
T_8 - NSKE (3%) + Monocrotophos (0.02%)	10.00^{cde}	8.00^{de}	5.26^{e}	4.01^{de}	3.97^{d}	4.27^{de}	5.10
T_9 - NCE (5%) + Monocrotophos (0.02%)	11.13^{de}	8.11^{e}	6.00^{e}	4.20^{de}	4.01^{de}	4.53^{e}	5.37
T_{10} - Monocrotophos (0.04%)	9.88^{a}	4.53^{a}	2.30^{b}	2.06^{a}	2.67^{ab}	3.00a^{b}	2.91
T_{11} - Control	9.63^{e}	13.60^{f}	15.01^{f}	17.67^{f}	18.70^{f}	20.12^{f}	17.02
SEd	0. 69	0.41	0.48	0.31	0.44	0.38	
CD (0.05)	1.46	0.87	0.98	0.63	0.90	0.79	

DAT – Day after treatment, NO – Neem oil, NCE – Neem cake extract, NCU – Neem coated urea, NSKE – Neem seed kernel extract.

Field efficacy of Neem products on Rice Stem borer

Neem products could not effectively control rice yellow stem borer incidence. Yellow stem borer incidence / damage were recorded on 7th, 14th, 21st day after treatment. Field efficacy of neem products on Stem borer was presented in Table 7.

Based on mean values, recommended dose of monocrotophos 0.04% (T_{10}) recorded lower incidence of yellow stem borer (4.43%) and it was found to be the best treatment compared to others. Basal application of neem coated urea followed by neem oil 3% (T_4) and basal application of neem coated urea followed by neem seed kernel extract 5% (T_5) recorded with the values of 7.55 and 7.61% respectively. In control the value was 13.28%.

Table 7: Field efficacy of Neem products on the incidence of Rice stem borer (%)

Treatment	Pre Treated Count (No/hill)	Post treatment count (%) Damage			Mean
		7 DAT	14 DAT	21 DAT	
T_1- NO (3%)	8.00 ^{a}	5.00 ^{bc}	8.00 ^{bc}	10.33 ^{cd}	7.777
T_2- NSKE (5%)	8.51 ^{ab}	5.33 ^{cd}	8.33 ^{cd}	10.00 ^{bcd}	7.887
T_3- NCE (10%)	10.00 ^{d}	6.17 ^{e}	9.01 ^{de}	11.13 ^{de}	8.77
T_4 - Basal application of NCU + NO (3%)	9.58 ^{cd}	5.67 ^{de}	7.33 ^{b}	9.67 ^{bc}	7.557
T_5 - Basal application of NCU + NSKE (5%)	8.80 ^{abc}	5.13 ^{bcd}	7.67 ^{bc}	10.03 ^{bcd}	7.61
T_6 - Basal application of NCU + NCE (10%)	9.54^{cd}	5.63 ^{de}	7.13 ^{b}	9.13 ^{b}	7.297
T_7 - NO (2%) + Monocrotophos (0.02%)	10.00 ^{d}	4.73 ^{b}	8.33 ^{cd}	12.33 ^{f}	8.463
T_8 - NSKE (3%) + Monocrotophos (0.02%)	9.93^{d}	4.91 ^{bc}	9.31 ^{e}	12.03 ^{ef}	8.75
T_9 - NCE (5%) + Monocrotophos (0.02%)	8.84 ^{abc}	5.63 ^{de}	9.00 ^{de}	13.07 ^{f}	9.233
T_{10} - Monocrotophos (0.04%)	8.87 ^{abc}	3.00 ^{a}	4.33 ^{a}	5.97 ^{a}	4.433
T_{11} - Control	9.33 ^{bcd}	11.67 ^{f}	11.49 ^{f}	16.69 ^{g}	13.28
SEd	0.43	0.32	0.45	0.49	
CD (0.05)	0.91	0.67	0.95	1.03	

DAT – Day after treatment, NO – Neem oil, NCE – Neem cake extract, NCU – Neem coated urea, NSKE – Neem seed kernel extract.

Field efficacy of Neem products on rice ear head bug (*Leptocorisa oratorius*)

The ear head bug incidence on the Neem products treated and control plots were recorded on 3rd, 5th, 7th, 10th and 14th day after treatment. Field efficacy of Neem products on rice ear head bug was presented in Table 8.

When the mean incidence of bug was considered, basal application of Neem coated urea followed by Neem oil 3% (T_4) was the best with 2.24 bugs/m^2 and it was closely followed by basal application of Neem coated urea followed by Neem seed kernel extract 5%(T_5) 2.34 bugs/m^2. Monocrotophos 0.04% (T_{10}) registered 2.86 bugs/ m^2; it was followed by basal application of Neem coated urea followed by Neem cake extract 10% (T_6) with a value of 3.07bugs/m^2.

Maximum number of bugs were noticed in reduced dose of Neem cake extract 5% followed by monocrotophos 0.02% (T_9) 4.22 bugs/m^2. In control (T_{11}) 16.76 bugs/m^2 were recorded.

Table 8: Field efficacy of Neem products on the incidence of Ear head bug

Treatment	Pre Treated Count	Post treatment count (Number /m^2)					Mean
		3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	
T_1- NO (3%)	10.13^{cde}	3.10 ^{a}	2.33 ^{c}	2.93 ^{c}	3.00 ^{c}	2.67 ^{cd}	2.806
T_2- NSKE (5%)	9.33^{abc}	2.97^{a}	2.67 ^{d}	3.60 ^{d}	3.93 ^{d}	2.33 ^{b}	3.1
T_3- NCE (10%)	10.67 ^{de}	3.63 ^{b}	2.97 ^{d}	3.03 ^{c}	4.00 ^{d}	3.00 ^{de}	3.326
T_4 - Basal application of NCU+ NO (3%)	11.09 ^{e}	4.17 ^{c}	1.33 ^{a}	1.73 ^{a}	2.13 ^{a}	1.87 ^{a}	2.246
T_5 - Basal application of NCU + NSKE (5%)	8.97 ^{ab}	3.6 7 ^{b}	1.67 ^{b}	1.97 ^{ab}	2.39 ^{ab}	2.00^{a}	2.34
T_6 - Basal application of NCU + NCE (10%)	9.00 ^{ab}	4.00 ^{bc}	1.70 ^{b}	4.03 ^{e}	3.67 ^{bc}	1.99^{a}	3.078
T_7 - NO (2%) + Monocrotophos (0.02%)	8.87 ^{a}	4.33 ^{cd}	3.67 ^{e}	4.33 ^{ef}	4.17 ^{d}	3.13 ^{e}	3.926
T_8 - NSKE (3%) + Monocrotophos (0.02%)	10.00 ^{cd}	4.67 ^{d}	3.97 ^{e}	4.77 ^{e}	4.33 ^{efd}	3.67 ^{f}	4.222
T_9 - NCE (5%) + Monocrotophos (0.02%)	11.00 ^{ce}	4.67 ^{d}	3.97 ^{e}	4.70 ^{f}	4.97 ^{e}	4.00 ^{f}	4.462
T_{10} - Monocrotophos (0.04%)	9.87 ^{bcd}	4.00 ^{bc}	1.67 ^{b}	2.17 ^{b}	3.83 ^{d}	2.67 ^{bc}	2.868
T_{11} - Control	10.17 ^{cde}	12.33 ^{e}	13.97 ^{f}	15.33 ^{g}	19.00 ^{f}	23.17 ^{g}	16.76
SEd	0.07	0.05	0.04	0.05	0.08	0.04	
CD (0.05)	0.15	0.10	0.09	0.10	0.17	0.10	

DAT – Day after treatment, NO – Neem oil, NCE – Neem cake extract, NCU – Neem coated urea, NSKE – Neem seed kernel extract.

Predator population

Among the neem products and chemical pesticides, higher predator population was recorded in basal application of neem coated urea followed by neem oil 3% sprayed plot (T_4). The predator populations were recorded on 3rd, 5th, 7th, 10th and 14th day after treatment. Field efficacy of neem products on predator was presented in Table 9.

On 5th, 7th, 10th and 14th day after treatment, basal application of neem coated urea followed by neem oil 3% (T_4) registered 7.33, 8.67, 12.6 and 20.63/20 hills respectively. It was at par with basal application of neem coated urea followed by neem seed kernel extract 5% (T_5) and their values were 7.2, 8.33, 12.69, 21/20 hills respectively. In control the values are 15.03, 17.17, 19.33, 23.79/20 hills respectively. Lower predator population was seen in monocrotophos 0.04% (T_{10}) with the values of 5.00, 6.00, 7.97, 9.07/20 hills.

When considering the mean value, basal application of neem coated urea followed by neem seed kernel extract 5% (T_5) showed higher number of predators with a value of 11.178/ 20 hills and it was closely followed by basal application of neem coated urea followed by neem oil 3% (T_4) with a value of 11.11/20 hills. Lower population was seen in monocrotophos 0.04% (T_{10}) treatment and the value was 6.40/20 hills. In control 17.40/20 hills predator population was noticed.

Table 9: Field efficacy of Neem products on the incidence of predator population

Treatment	Pre Treated Count (Number / 20 hills)	Post treatment count (Number /20 hills)					Mean
		3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	
T_1- NO (3%)	4.00 ^{abc}	6.33 ^{def}	7.00 ^{c}	8.67 ^{d}	11.67^{b}	19.69^{cd}	10.672
T_2- NSKE (5%)	5.67 ^{d}	6.00 ^{de}	6.97 ^{bc}	7.33 ^{b}	11.79^{b}	18.33^{cd}	10.084
T_3- NCE (10%)	3.80 ^{bc}	5.67 ^{cd}	6.53 ^{bc}	7.00 ^{b}	11.33^{b}	16.96^{c}	9.498
T_4 - Basal application of NCU + NO (3%)	5.67 ^{d}	6.33 ^{ef}	7.33 ^{bc}	8.67 ^{d}	12.60^{c}	20.63^{d}	11.112
T_5 - Basal application of NCU + NSKE (5%)	5.33 ^{d}	6.67 ^{f}	7.20 ^{c}	8.33 ^{d}	12.69^{c}	21.00^{e}	11.178
T_6 - Basal application of NCU + NCE (10%)	5.33^{d}	6.33 ^{ef}	7.13 ^{c}	8.00 ^{cd}	12.33^{c}	20.33^{d}	10.824
T_7 - NO (2%) + Monocrotophos (0.02%)	3.33 ^{a}	6.00 ^{de}	7.00 ^{c}	7.33 ^{bc}	10.33^{b}	17.00^{bc}	9.532
T_8 - NSKE (3%) + Monocrotophos (0.02%)	3.89 ^{bc}	5.33 ^{c}	6.67 ^{bc}	7.00 ^{b}	10.17^{b}	18.60^{bc}	9.554
T_9 - NCE (5%) + Monocrotophos (0.02%)	4.00 ^{c}	4.33 ^{b}	5.79 ^{b}	6.67 ^{ab}	10.33^{b}	17.33^{bc}	8.89
T_{10} - Monocrotophos (0.04%)	3.69 ^{ab}	4.00 ^{a}	5.00 ^{a}	6.00 ^{a}	7.97^{a}	9.07^{a}	6.408
T_{11} - Control	8.87 ^{e}	11.69 ^{g}	15.03 ^{d}	17.17^{e}	19.33^{c}	23.79^{f}	17.402
SEd	0.05	0.06	0.09	0.07	0.10	0.09	
CD (0.05)	0.12	0.13	0.20	0.15	0.20	0.18	

DAT – Day after treatment, NO – Neem oil, NCE – Neem cake extract, NCU – Neem coated urea, NSKE – Neem seed kernel extract.

Grain Yield

Among the yield data, the effect of neem products and chemical pesticides were not significantly different in first and second year. Grain Yield during 2004 was presented in Table 10. In this experiment, higher yield of 6050 kg/ha recorded in basal application of neem coated urea followed by neem oil 3% (T_4) and it was at par with monocrotophos 0.04% (T_{10}) (6025kg/ha) basal application of neem coated urea followed by neem seed kernel extract 5% (T_5) (6000 kg/ha) and basal application of neem coated urea followed by neem cake extract 10% (T_6) (5917 kg/ha). The control (T_{11}) recorded lower yield of 3725 kg/ha. Without application, neem cake treated plots registered lower yield compared to other neem cake applied plots. The neem oil 3% sprayed (T_1) plot recorded lower grain yield, (5150 kg/ha) compared to others.

Table 10: Effect of Neem products on Rice grain yield for the two Years

Treatment	Yield (Kg/ha) 2004	% Yield over control 2004	Yield (Kg/ha) 2005	% Yield over control 2005	Mean (Kg/ha)
T_1- NO (3%)	5150 [b]	159	5650 [bc]	148	5400
T_2- NSKE (5%)	5000 [bc]	155	5475 [cd]	143	5237
T_3- NCE (10%)	4817 [bcd]	149	5400 [cde]	141	5108
T_4 - Basal application of NCU+ NO (3%)	6050 [a]	188	6325 [a]	166	6187
T_5 - Basal application of NCU + NSKE (5%)	6000 [a]	186	6170 [a]	162	6085
T_6 - Basal application of NCU + NCE (10%)	5917[a]	183	6025 [ab]	157	5971
T_7 - NO (2%) + Monocrotophos (0.02%)	4710[cd]	146	5100 [def]	134	4905
T_8 - NSKE (3%) + Monocrotophos (0.02%)	4515[de]	139	4945 [ef]	130	4730
T_9 - NCE (5%) + Monocrotophos (0.02%)	4275[e]	132	4820 [f]	128	4547
T_{10} - Monocrotophos (0.04%)	6025[a]	187	6175 [a]	162	6100
T_{11} - Control	3525[f]	100	3515 [g]	100	3520
SEd CD (0.05)	200 419	-	213 445	-	-

DAT – Day after treatment, NO – Neem oil, NCE – Neem cake extract, NCU – Neem coated urea, NSKE – Neem seed kernel extract.

Discussion

In this study, different neem products were tested in laboratory conditions as well as in the field. In filed evaluation, different neem products were tested against rice pests in field condtion.

Experiment: I - Laboratory Studies

The results obtained from the laboratory studies revealed that *A. indica* oil 3% and neem seed kernel extract 5 percent acted as best ovipositional deterrent in which only 65 eggs were laid compared to 140 eggs in control. In other treatments, eggs laid by the females ranged from 93.67 (*A. indica* seed kernel 5%) to 138.33 (*A. cocculus* 10 percent). Hatchability of egg was minimum (58.19 percent) in *A. indica* oil 3 percent compared to control (91.19 percent). Hatchability ranged between 59.22 (*A. indica* cake 10%) and 82.18 (*A. calamus* 10%) percent in other treatments. The present finding is in consonance with the findings of Islam (1983), who reported that hexane extract of neem seed reduced the egg deposition by brown planthopper. Contrary to this Saxena *et al.* (1983) [11] found that neem cake application had not adversely affected adult longevity, fecundity, oviposition and hatchability of brown planthopper. From the present in field investigations and laboratory studies, it may be concluded that besides extracts of *A. indica* plant products (oil, seed kernel and cake); extract of *T. purpurea* may also be included for further studies as one of the components of integrated pest management programme.

Experiment II –Field evaluation

The results obtained from the field studies revealed that neem products acted as best organic pesticide against brown planthopper (*N. lugens*), and green leafhopper *(N.virescens)* in rice crop. Basal application of neem coated urea followed by neem oil 3% registered lower population of brown planthopper (*N. lugens*), 0.274 in 1st year and 0.236 in 2nd year. In green leafhopper basal application of neem coated urea followed by spraying of neem oil 3% registered lower population 1.268 in 1st year and 1.508 in 2nd year. It was comparable with basal application of neem coated urea followed by spraying of NSKE (neem seed kernel extract) 5% and monocrotophos 0.04% treatments. This was due to the fact that basal application of neem coated urea followed by spraying of neem products at economic threshold levels was effective against brown planthopper (*N. lugens*), and green leafhopper *(N. virescens)* population in rice crop.

Efficacy of neem products against rice leaf folder incidence

The basal application of neem cake at the rate of 150 kg/ha with urea followed by neem oil 3% sprayed treatment recorded lowest incidence of leaf folder than that of other treatments. The neem products were superior to monocrotophos. The basal application of neem coated urea followed by the neem oil 3% sprayed plot registered 2.64% and 3.17% of leaf damage in 1st and 2nd year respectively, which was followed by basal application of neem coated urea followed by neem seed kernel extract 5% in both the years with values of 2.71% and 3.28% respectively. The higher leaf damage was recorded in control with values of 17.02% and 18.56%.

Efficacy of Neem products against Ear head bug population

The results obtained from the field studies revealed that basal application of Neem coated urea followed by spraying of neem oil 3% acted as best treatment in 1st and 2nd year with the ear head bug (*L. oratorius*) population of 2.24 bugs/m^2 and 1.79 bugs/m^2 during 1st and 2nd years respectively compared to control with the value of 16.76 bugs/m^2 during 1st year and 15.18 bugs/m^2 during 2nd year. In other treatments the ear head bug (*L. oratorius*) populations ranged from 2.24 bugs /m^2 to 2.86 bugs/m^2 in 1st year and 1.79 bugs/m^2 to 4.1 bugs/m^2 in 2nd year. This might be due to reduction in nymphal emergence, ovipositional deterrent and growth disruption effects of these neem botanicals.

Effect of Neem products on predatory spider population

Neem product was found to have a positive effect on predator population. Higher predator population of 11.11/20 hills was recorded in basal application of neem coated urea followed by spraying of neem oil 3% treated plot during 1st year. It was comparable with basal application of neem coated urea followed by neem seed kernel extract 5% and neem cake extract 10% sprayed treatments. This might be due to the soil application of neem cake worked primarily by increasing the humus content of the soil. It acted as organic soil conditions and its taste, odor, organic composition retards, repells (or) inhibits the growth and development of plant insects and parasitic nematodes.

Efficacy of neem products on crop yield

Higher yields were obtained in 2004 and 2005 when the incidences of pests were reduced due to the application of

neem products and it was comparable with monocrotophos applied plot.

Among the yield parameters basal application of neem coated urea followed by spraying of neem oil 3 percent recorded high yield compared to other treatments and it was closely followed by basal application of neem cake with neem seed kernel extract 5 percent sprayed plots during both the years. Lowest yield was recorded in control with the value of 3525 kg/ha during 1st year and where as during 2nd year the value was 3515 kg/ha. This was due to the fact that the basal application of neem cake protected the young seedling from pest and disease incidence and it improved the soil organic matter content significantly and the neem cake improved abundantly soil micro flora, greatly improved soil health and thus yield was increased significantly. From the experiment it was inferred that the neem products are highly effective against the pests of rice like Brown Planthopper (*N. lugens),* green leafhopper (*N. virescens*), leaf folder (*C. medinalis*) and earhead bug, *L. oratorius* in a cumulative way such as physiological and behavioural disturbances and it was moderately efficient against rice stem borer *S. incertulas*. Hence it may be concluded that the basal application of neem coated urea followed by neem oil 3 percent and neem seed kernel extract 5 percent can be successfully practiced for controlling insect pests in rice, obtaining additional revenue and sustained healthy soil ecosystems.

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