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Cost-benefit economics under evaluation of ecofriendly insecticides against major insect pests of rice in eastern Uttar Pradesh conditions

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Abstract
Present study was conducted on the cost-benefit economics under evaluation of some novel ecofriendly insecticides against major insect pests of rice in Eastern Uttar Pradesh conditions for the two consecutive years (2014 and 2015) at farmer field of district Deoria. This evaluation was observed most effective ecofriendly insecticides concerned to lowest infestation, lowest P: D ratio, highest yield, and cost: benefit ratio. There were 10 treatments (09 insecticides + 01 check) evaluated under randomized block design (RBD) by transplanting method of rice cultivation on localized popular rice cultivar Samba Mahsuri. The insecticide treatments comprise 9 insecticides (Cartap Hcl, 50 SP, Indoxacarb 14.5 SC, Imidacloprid 17.8 SL, Chlorpyriphos 20 EC, Thiamethoxam 25 WG, Chlorantraniliprole 18.5 SC, Azadirachtin (Neem Oil) 0.03 EC, *Bacillus thuringiensis kurstaki* (Btk) 3.5 WP, and combination of Neem Oil 0.03 EC + Btk 3.5 WP). The infestations of major insect pests of rice were observed for most serious insect pests, which were 1.Yellow stem borer (*Scirpophaga incertulus* Walker), 2.Common rice leaf folder (*Cnaphalocrosis medinalis* Guenee), 3.Brown plant hopper (*Nilaparvata lugens* Stal), 4.Rice hispa (*Dicladispa armigera* Oliver), and 5.Rice earhead bug (*Leptocorisa acuta* Thunberg). Though, there were observed all the insecticides varied each other for cost: benefit ratios, but Imidacloprid and Neem Oil + Btk were also inference most effective ecofriendly insecticides for major insect pests of rice based on cost: benefit ratios, since there were 2 insecticides (Imidacloprid and Neem Oil + Btk) inference most effective ecofriendly insecticides for major insect pests of rice based on lowest infestation, lowest P: D ratio, and highest yield respectively. The cost: benefit ratios for most effective ecofriendly insecticides against major insect pests of rice were observed as, Imidacloprid (1: 10.66) and Neem Oil + Btk (1: 1.28) respectively.

Keywords: Cost-benefit economics, ecofriendly insecticides, major insect pests of rice, Eastern Uttar Pradesh, India

Introduction
Rice is one of the most important staple foods of the world (70% of the population) as well as India (65% of the population). About 90% of the world's rice is produced and consumed in the Asian region and most staple food of South East Asia. More than 110 countries grow rice on one fifth of the world food grain crop area. The rice fragrance spreads to the entire world. It provides livelihood and food security to the about, 56% of the world population (7.46 billion) as well as 65% of the India population (1.32 billion). India shares 21% of the world rice production and occupies second position after China. Uttar Pradesh shares 15% of the India rice production occupies second position followed by West Bengal (17%) and first in rice production area. Despite these above proud credentials, Uttar Pradesh is not appearing leading position. The main cause of low productivity of rice is ill cultivation practices and crop losses. The crop losses share about 32.1% losses by plant ailments (pests, diseases & weeds) and among them, about 10.8% losses caused by pests globally and India have been reported about 17.5% losses caused by insect pests. Historically, insect pest outbreaks have been causing extensive losses in rice crop production ranging from 60 to 95% over world. India have been estimated rice crop losses by insect pests ranging from 21 to 51%. (Pathak and Khan, 1994; Oerke, 2006; Dhaliwal *et al*., 2015; Sharma *et al*., 2017; Heinrichs and Muniappan, 2017; Pathak *et al*., 2018; DAC&FW, 2018; FAOSTAT, 2019) [14, 12, 6, 22, 9, 13, 3, 8].
Uttar Pradesh is the fourth largest and first most populous state of the India. It has 11.56 million hectares of cultivated area, constituting 70% of the total geographical area of state. The rice production of Uttar Pradesh is mostly concentrated to the Eastern Uttar Pradesh region. But the Uttar Pradesh is under lag phase of adaptation of modern technologies of rice crop production, especially to insect pest management, which contributes valuable share in India rice production. Though, Farmers are practicing all possible available methods and techniques

for rice insect pest management based on traditional knowledge, layman and salesman advice, while all the management practices are concentrated to the farmers' perception about finishing approach of insect pests ignoring the significant role of bioagents in suppression of infestation rice insect pests. No doubt, Insecticides are the most powerful tool available for use in pest management and continue to be the foreseeable future. Insecticides are most common pesticides used widely in crop production. The role of pesticides in crop production to augment output has been well perceived and these have been considered essential inputs in crop production. There have been bunch of insecticides including conventional and novel chemical insecticides, and biological insecticides trending commonly in scientific community to evaluate their efficacy regarding ecofriendly approach, while combination application of biological insecticides have been limited evaluation towards bio rational approach of pest management. Therefore, this research work selected those novel insecticides and their combinations to evaluate their efficacy regarding the ecofriendly approach, which has been commonly trending among the scientific community and as well as market availability among Eastern Uttar Pradesh conditions.

Jena and Dani (2011) [10] have been reported that, the infestation of rice hispa (*Dicladispa armigera*) was observed reduce in Imidacloprid and Thiamethoxam. Kulagod *et al.* (2011) [11] studied on evaluation of efficacy of biorationals against yellow stem borer (*Scirpophaga incertulus*) and common rice leaf folder (*Cnaphalocrocis medinalis*) of rice as Azadirachtin and *Bacillus thuringiensis* formulation lower the infestation. Rath *et al.* (2014) [19] has been reported that, plots treated with Imidacloprid recorded lowest infestation of yellow stem borer (*Scirpophaga incertulus*) and rice earhead bug (*Leptocorisa acuta*) and highest grain yield followed by Thiamethoxam. Sarao *et al.* (2015) [20] and Tigga *et al.* (2018) [24] both have been found that, the damage of yellow stem borer (*Scirpophaga incertulus*) and rice earhead bug (*Leptocorisa acuta*) were recorded lowest in Imidacloprid. Sharanappa *et al.* (2019) [21] have been found that, the application of Imidacloprid observed favour the high population of coccinellids.

Materials and Methods

A study was conducted on the cost-benefit economics under evaluation of some novel ecofriendly insecticides against major insect pests of rice in Eastern Uttar Pradesh conditions for the two consecutive years (2014 and 2015) at farmer field of district Deoria. This confined spot of study, represents the conductive environment for survival and proliferation of insect pests in rice ecosystem under Eastern Uttar Pradesh conditions. There were 10 treatments (09 insecticides + 01 check) evaluated under randomized block design (RBD) by transplanting method of rice cultivation on localized popular rice cultivar 'Samba Mahsuri'. The insecticide treatments comprise 9 insecticides (Cartap Hcl, 50 SP, Indoxacarb 14.5 SC, Imidacloprid 17.8 SL, Chlorpyriphos 20 EC, Thiamethoxam 25 WG, Chlorantraniliprole 18.5 SC, Azadirachtin (Neem Oil) 0.03 EC, *Bacillus thuringiensis kurstaki* (Btk) 3.5 WP, and combination of Neem Oil 0.03 EC + Btk 3.5 WP). The Spray formulations selected as recommended for lowland rice ecosystems to avoid leaching and toxicity to beneficial soil inhabitants of granular formulations despite affectivity. Application of insecticides spraying were taken for two times at 30 days and 45 days after transplanting (30 DAT and 45 DAT). Samples were taken 03 times at 03, 07 and 14 days after spraying per spray of insecticides and single sample before first spray of insecticides respectively. The duration of rice crops started from pre week of August to mid-week of November for about 110 days. There were 5 samples collected per plot at the size of 20 m^2. Each plot was selected 5 spots (4 in the corner and one in the center) at 01 hill/spot to observe infestation, and also at each plot, 05 net sweeps were made randomly at every 05 steps to observe abundance of insect pest species and their bioagents. The size of sweep net were 25 cm diameter and 70 cm handle and made up of nylon. The spraying of insecticides was made by manually operated knapsack sprayer with hollow cone nozzle @ 500 l/ha spray volume. The timing of sampling was 9.30 A.M. to 12.30 P.M. and timing of spraying was 2.30 P.M. to 4.30 P.M. respectively. This observation was evaluated most effective ecofriendly insecticides concerned to lowest infestation, lowest P: D ratio, and highest yield, cost: benefit ratio. P: D ratio refers the ratio between the population of insect pests and their bioagents. The cost-benefit ratios were based on input cost (Insecticides cost + Application cost) and benefit (value of additional yield). The application cost was comprised of sprayer rent cost and labour cost. The calculation of cost: benefit ratios was taken between input cost and value of additional yield.

The value of yield was based on minimum support price (MSP) of rice for 2015-16 (DAC&FW, Govt. of India, 2018) [3]. Surveillance was conducted as per methodology of agro ecosystem analysis (AESA) (Pontius *et al*., 2002) modified as accessibility. Taxonomic identification was verified with texts of reference, *i.e*., Dale (1994) [4], Barrion and Litsinger (1994) [1], Pathak and Khan (1994) [14], David and Ananthakrishnan (2004) [5]; Rice knowledge management portal (RKMP); and Subject experts respectively. The statistical inferences were verified with texts of reference, *i.e*., Dhamu & Ramamoorthy (2007) [7], and Rangaswamy (2010) [17].

Results and Discussion

The cost-benefit economics was analyzed under evaluation of ecofriendly insecticides against major insect pests of rice for pooled of both the years 2014 and 2015 respectively. Of the total observed cost: benefit ratios under evaluation of ecofriendly insecticides against major insect pests of rice for pooled of both the years 2014 and 2015, there were, Cartap Hcl (1: 5.61), Indoxacarb (1:0.58), Imidacloprid (1:10.66), Chlorpyriphos (1:1.64), Thiamethoxam (1:0.99), Chlorantraniliprole (1:0.17), Neem Oil (1:0.87), Btk (1:0.07), and Neem Oil + Btk (1:1.28) respectively. The ranking of cost: benefit ratios were observed as, Imidacloprid > Cartap Hcl > Chlorpyriphos > Neem Oil + Btk > Thiamethoxam > Neem Oil > Indoxacarb > Chlorantraniliprole > Btk for cost: benefit ratio; Chlorantraniliprole > Neem Oil + Btk > Btk > Indoxacarb > Cartap Hcl > Neem Oil > Chlorpyriphos > Imidacloprid > Thiamethoxam for lowest P: D ratio respectively. There were also observed that, the cost: benefit ratios increased with the decreased input cost. Though, there were observed all the insecticides varied each other for cost: benefit ratios, but Imidacloprid and Neem Oil + Btk were also inference most effective ecofriendly insecticides for major insect pests of rice based on cost: benefit ratios, since there were 2 insecticides (Imidacloprid and Neem Oil + Btk) inference most effective ecofriendly insecticides for major insect pests of rice based on lowest infestation, lowest P: D ratio, and highest yield respectively. Therefore, the cost: benefit ratios for most effective ecofriendly insecticides against major insect pests of rice were observed as, Imidacloprid (1:10.66) and Neem Oil + Btk (1:1.28) respectively. (Table & Figure 1).

The infestations and their bioagents of major insect pests of rice were observed for most serious insect pests, which were 1. Yellow stem borer (*Scirpophaga incertulus* Walker), 2. Common rice leaf folder (*Cnaphalocrosis medinalis* Guenee), 3.Brown plant hopper (*Nilaparvata lugens* Stal), 4.Rice hispa (*Dicladispa armigera* Oliver), and 5.Rice earhead bug (*Leptocorisa acuta* Thunberg). Of the total observed infestations and their bioagents of major insect pests of rice for pooled of both the years 2014 and 2015, the mean of evaluation were, 3 insecticides (Cartap Hcl, Imidacloprid, and Neem Oil + Btk) inference non-significant for lowest infestation and 2 insecticides (Imidacloprid and Neem Oil + Btk) inference non-significant for lowest P:D ratio; and along with 3 insecticides (Cartap Hcl, Imidacloprid, and Neem Oil + Btk) were also inference non-significant for highest yield respectively. The ranking of evaluation was observed as, Imidacloprid > Cartap Hcl > Neem Oil + Btk > Chlorantraniliprole > Indoxacarb > Chlorpyriphos > Thiamethoxam > Neem Oil > Btk for lowest infestation; Btk > Neem Oil + Btk > Neem Oil > Imidacloprid > Cartap Hcl > Indoxacarb > Chlorantraniliprole > Thiamethoxam > Chlorpyriphos for lowest P:D ratio; Cartap Hcl > Imidacloprid > Neem Oil + Btk > Chlorantraniliprole > Indoxacarb > Chlorpyriphos > Neem Oil > Thiamethoxam > Btk for highest yield; and Imidacloprid > Cartap Hcl > Neem Oil + Btk > Chlorantraniliprole > Indoxacarb > Neem Oil > Btk > Chlorpyriphos > Thiamethoxam for mean of infestation, P:D ratio, and yield respectively. (Table 2). Similar findings were reported by Jena and Dani (2011) [10], Kulagod *et al.* (2011) [11], CRRI (2014), Prakash *et al.* (2014), Rath *et al.* (2014) [19] Sarao *et al.* (2015) [20], Heinrichs and Muniappan (2017) [9], Tigga *et al.* (2018) [24], Sharanappa *et al.* (2019) [21], and Rao (2019) [18].

There were 3 insecticides (Imidacloprid, Cartap Hcl, and Neem Oil + Btk) inference non-significant for lowest infestation; 2 insecticides (Neem Oil + Btk and Imidacloprid) inference non-significant for lowest P:D ratio; 3 insecticides (Imidacloprid, Cartap Hcl, and Neem Oil + Btk) inference non-significant for highest yield. Present research work was adopted the lowest P: D ratio, respective to non-significant lowest infestation as scale to confined efficacy of insecticides as ecofriendly. Therefore, 2 insecticides (Imidacloprid and Neem Oil + Btk) were confined most effective ecofriendly insecticides as inference non-significantly for lowest P: D ratio for the management of major insect pests of rice. Though, there were observed all the insecticides varied each other for cost: benefit ratios, but Imidacloprid and Neem Oil + Btk were also inference most effective ecofriendly insecticides for major insect pests of rice based on cost: benefit ratios, since there were 2 insecticides (Imidacloprid and Neem Oil + Btk) inference most effective ecofriendly insecticides for major insect pests of rice based on lowest infestation, lowest P: D ratio, and highest yield respectively. Though, Cartap Hcl and Chlorpyriphos were being most effective insecticides for major insect pests of rice before combination of Neem Oil + Btk treatment, but interestingly this observation was changed in P:D ratio as it did not inference non-significantly for lowest P:D ratio with 2 insecticides (Imidacloprid and Neem Oil + Btk). (Table 2). Though, both the insecticides were being most effective ecofriendly insecticides, the Imidacloprid a chemical insecticide, while Neem Oil + Btk are the biological insecticides (biorationals). Hence, Neem Oil + Btk as biorationals primarily would be the best choice before Imidacloprid for the ecofriendly management of major insect pests of rice.

Conclusion

There were 3 insecticides (Imidacloprid, Cartap Hcl, and Neem Oil + Btk) inference non-significant for lowest infestation; 2 insecticides (Neem Oil + Btk and Imidacloprid) inference non-significant for lowest P:D ratio; 3 insecticides (Imidacloprid, Cartap Hcl, and Neem Oil + Btk) inference non-significant for highest yield. Though, there were observed all the insecticides varied each other for cost:benefit ratios, but Imidacloprid and Neem Oil + Btk were also inference most effective ecofriendly insecticides for major insect pests of rice based on cost:benefit ratios, since there were 2 insecticides (Imidacloprid and Neem Oil + Btk) inference most effective ecofriendly insecticides for major insect pests of rice based on lowest infestation, lowest P:D ratio, and highest yield respectively. The cost:benefit ratios for most effective ecofriendly insecticides against major insect pests of rice were observed as, Imidacloprid (1: 10.66) and Neem Oil + Btk (1: 1.28) respectively. Though, both the insecticides were being most effective ecofriendly insecticides, while Imidacloprid is the chemical insecticide and Neem Oil + Btk are the biological insecticides (biorationals). Hence, Neem Oil + Btk as biorationals primarily would be the best choice before Imidacloprid for the ecofriendly management of major insect pests of rice.

Table 1: Cost-Benefit Economics under Evaluation of Ecofriendly Insecticides against Major Insect Pests of Rice (Pooled of 2014 & 15)*

S.N.	Treatments	Input Cost (Rs/ha)*	Yield (q/ha)	Additional Yield Over Check (q/ha)	Value of Additional Yield (Rs.)#	Cost-Benefit Ratio
1.	Cartap Hcl	1000	35.00	3.98	5611.80	1: 5.61
2.	Indoxacarb	1750	31.74	0.72	1015.20	1: 0.58
3.	Imidacloprid	500	34.80	3.78	5329.80	1: 10.66
4.	Chlorpyriphos	600	31.72	0.70	987.00	1: 1.64
5.	Thiamethoxam	500	31.37	0.35	493.50	1: 0.99
6.	Chlorantraniliprole	6000	31.75	0.73	1029.30	1: 0.17
7.	Neem Oil	600	31.39	0.37	521.70	1: 0.87
8.	Btk	3000	31.18	0.16	225.60	1: 0.07
9.	Neem Oil + Btk	3600	34.28	3.26	4596.60	1: 1.28
10.	Untreated Check	–	31.02	–	–	–

* Input cost = (Insecticides cost + Application cost); Application cost = (Sprayer rent cost + Labour cost) = Rs. 300/ day/ ha; Sprayer rent cost = Rs. 50/ day/ ha; Labour cost = Rs. 250/ day/ ha. # Minimum support price of rice = Rs. 1410/ quintal for 2015-16 (DAC&FW, 2018).

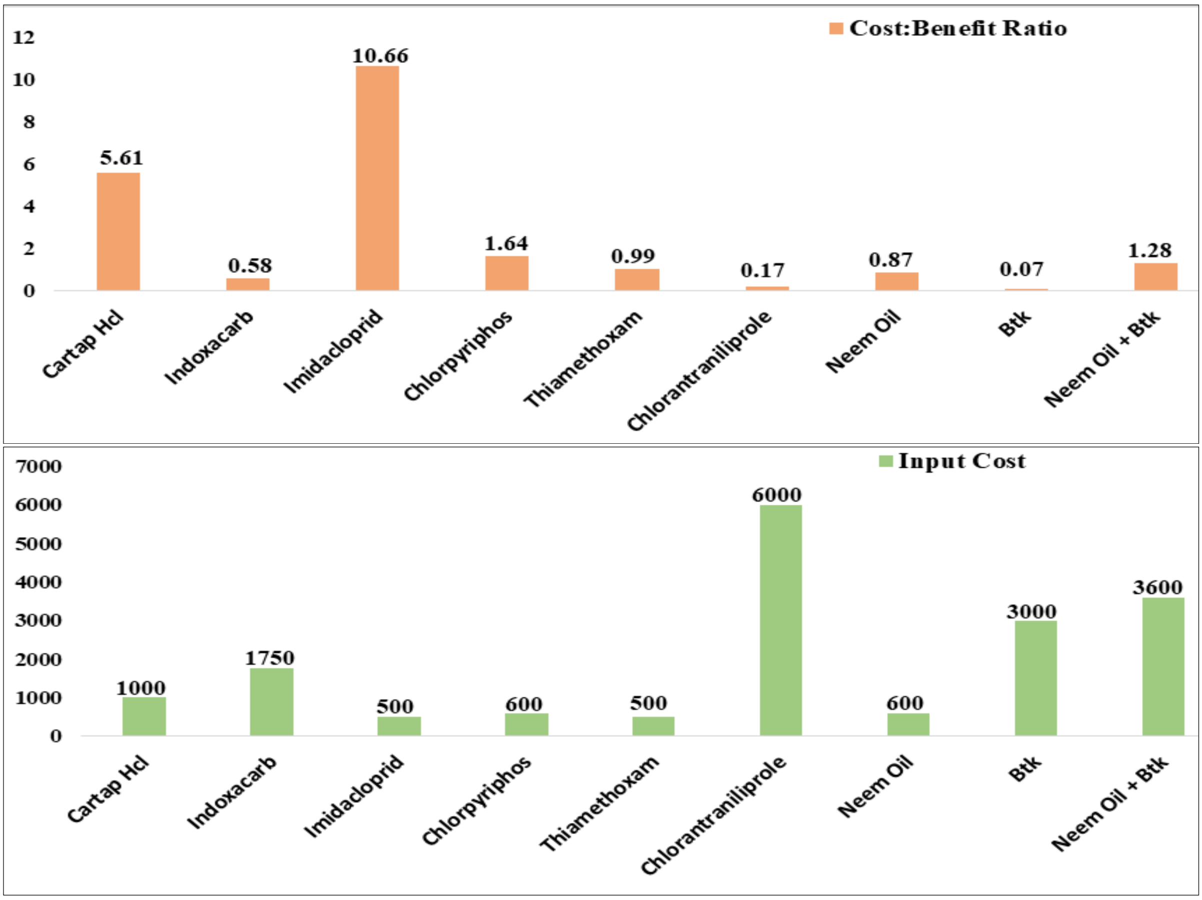

Fig 1: Cost-Benefit Economics under Evaluation of Ecofriendly Insecticides against Major Insect Pests of Rice (Pooled of 2014 & 15).

Table 2: Evaluation of Ecofriendly Insecticides against Major Insect Pests of Rice (Pooled of 2014 & 15)* (Infestation/P:D Ratio/Yield/Mean)

Rank	Infestation (%) (Lowest)	P: D (Ratio) (Lowest)	Yield (q/ ha) (Highest)	Mean Rank
1	Imidacloprid 3.38 1 NS (1.90)	Btk 3.08 (1.88)	Cartap Hcl 35.00 1 NS	Imidacloprid 2.33 1 NS
2	Cartap Hcl 3.39 2 NS (1.91)	Neem Oil + Btk 3.29 1 NS (1.94)	Imidacloprid 34.80 2 NS	Cartap Hcl 2.67 2 NS
3	Neem Oil + Btk 3.68 3 NS (1.98)	Neem Oil 3.38 (1.96)	Neem Oil + Btk 34.28 3 NS	Neem Oil + Btk 2.67 3 NS
4	Chlorantraniliprole 4.03 (2.06)	Imidacloprid 3.66 2 NS (2.03)	Chlorantraniliprole 31.75	Chlorantraniliprole 5.00
5	Indoxacarb 4.16 (2.09)	Cartap Hcl 4.36 (2.20)	Indoxacarb 31.74	Indoxacarb 5.33
6	Chlorpyriphos 4.39 (2.12)	Indoxacarb 4.72 (2.28)	Chlorpyriphos 31.72	Neem Oil 6.00
7	Thiamethoxam 4.41 (2.14)	Chlorantraniliprole 4.80 (2.29)	Neem Oil 31.39	Btk 6.33
8	Neem Oil 4.52 (2.18)	Thiamethoxam 5.50 (2.44)	Thiamethoxam 31.37	Chlorpyriphos 7.00
9	Btk 4.65 (2.21)	Chlorpyriphos 5.96 (2.54)	Btk 31.18	Thiamethoxam 7.67
$SE_{(m)}$	0.03	0.03	0.25	–
$CD_{(5\%)}$	0.08	0.10	0.72	–
$CV_{(\%)}$	1.90	2.16	1.33	–

* Values in parentheses are square root transformation ($\sqrt{(x + 0.5)}$) for uniform sample size (Steel and Torrie, 1960); 1,2,3 numerals are rank orders and NS stands for non-significant respectively; Comparison of all data respective to the non-significant lowest insect pest infestation

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