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Tank mix application of selected herbicides and insecticides for weed and insect control in transplanted rice

S. Mohapatra* and S.K. Tripathy
Regional Research and Technology Transfer Station, Orissa University of Agriculture and Technology, Chiplima, Sambalpur, Odisha 768 025

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ABSTRACT

Post-emergence application of two insecticide molecules chloropyriphos 200 g/ha, fipronil 50 g/ha and three herbicide molecules chlorimuron-ethyl + metsulfuron-methyl at 4 g/ha, bispyribac-sodium at 25 g/ha, cyhalofop-butyl + penoxsulam at 135 g/ha were tested alone as well as in combination with an untreated control against grass, sedge, broad-leaf weed and stem borer for their compatibility during winter seasons 2015-16 and 2016-17. Tank mix application of cyhalofop-butyl + penoxsulam + fipronil (135 + 50 g/ha) recorded lowest incidence of dead heart (0.59%), white ear (3.53%), total weed density (8 no./m^2) and weed biomass (3.5 g/m^2) and enhanced weed control efficiency (84.6%), grain yield (5.23 t/ha), net returns (` 40.44 x10^3/ha) and benefit : cost ratio (2.02). Dead heart percentage was less (0.59 to 1.55%) in sole fipronil and its combination with different herbicide than that of chloropyriphos (0.92 to 1.92%). There was no difference in grain yield of rice in treatments, which received application of cyhalofop-butyl + penoxsulam alone and with fipronil indicating the compatibility of herbicide with insecticide.

Key words: Herbicide and insecticide mixture, Tank mix application, Transplanted rice, Weeds

Rice is grown primarily by manual transplanting of seedlings in puddle soil. Weed infestation along with insect pests are two major biotic stresses, which occurs simultaneously and damage rice crop under field conditions. Higher weed infestation is a major constraint in water deficient transplanted rice ecosystems. Post-emergence application of herbicide was found effective in controlling weeds in transplanted rice (Tripathy *et al*. 2016). Chlorimuron-ethyl + metsulfuron-methyl, bispyribac-sodium and cyhalofop-butyl + penoxsulam are new generation post-emergence broad spectrum herbicides introduced for control of all types of weeds in transplanted rice. Similarly chloropyriphos and fipronil are popularly used to control the incidence of major pest. Sequential application of herbicides and insecticides are labour consuming and sometimes less effective. Therefore combined application of herbicide and insecticide as tank mixture may save time and labour.

Change in physical and chemical properties in combinations could lead to enhancement or reduction in the efficacy of either of the two compounds. Knowledge of combined application of various chemicals can be helpful in the formulation and adoption of a sound and cost effective pest control. It can also help to exploit the synergistic and antagonistic interactions between various pesticides for an effective eradication of pest problems. Instead of sequential application of herbicide, insecticide, fungicide and fertilizer, it is advantageous to tank mix suitable agrochemicals to control weeds as well as other pest co-existing in the crop to save labour, time and increase input use efficiency. However, these chemicals should be compatible with each other. Individual effects of insecticides were studied widely but very little information is available for combined effects of pesticides (Singh 2000). Interactions between different group of pesticides (fungicides, insecticides and herbicides) can lead to better management of pest and diseases of rice (Prakash *et al.* 2013, Karthikeyan 2015). Keeping this in view, this trial was laid out to evaluate the compatibility of selected insecticides and herbicides as tank mix.

MATERIALS AND METHODS

Field experiment was conducted at Regional Research and Technology Transfer Station, Chiplima, Odisha, during winter seasons 2015-16 and 2016-17. The soil of the experimental field was sandy clay loam with pH 6.6, organic carbon 0.43% and available N ($KMnO_4$ method), P (Olsen) and K (NH_4OHC method) content of 268.0, 13.4 and 132.0 kg/ha,

***Corresponding author:** sanjukta.mohapatra34@gmail.com

respectively. Thirty five days old seedlings of variety '*MTU 1001*' were transplanted in plot size of 5 x 5 m with a spacing of 20 x 10 cm at the rate of two seedlings per hill. A common fertilizer dose of 80, 40 and 40 kg of N, P_2O_5 and K_2O/ha, respectively was applied to the crop. Full dose of P_2O_5 and half dose of N and K_2O were applied as basal and remaining N and K_2O were top-dressed in 2 equal splits, at maximum tillering and panicle-initiation stages of the crop. Plant protection measures and irrigation were provided as and when required. Pre-emergence application of pretilachlor 750 g/ha was given to all the treatments. The experiment consisted of 12 treatments including sole and combined application of two insecticides and three herbicide molecules along with an untreated control (**Table 1**). The sprays were made at 20 DAT with a knapsack sprayer fitted with flood jet nozzle. The observations were made a week after spraying on per cent tiller damage (dead heart) at vegetative stage and white ear at reproductive stage for yellow stem borer (*Scirpophaga incertulas* Walker) and incidence of weeds. The grain yield was recorded in t/ha and the experiments were laid out using completely randomized block design (RBD). The treatments were replicated thrice.

For weight assessment, samples were kept at low temperature to minimize loss through respiration and then put to air circulating ovens at 85 ^{0}C for 16 hours (Klingman 1971). Weeds were separated into three broad classes of grass, sedge and broad-leaf before drying.

As a lab study, emulsion stability test was conducted. Recommended spray concentration of herbicide insecticide combinations were taken in a beaker and 30 ml of hard water was added and stirred with a glass rod at the rate of 4 revolutions per second. Then transferred to a 100 ml graduated cylinder and volume was made up to the mark using standard hard water. The cylinder was kept in a thermostat at 30 ± 1 ^{0}C for 30 min. After the expiry of specified time, the volume of sediment at the bottom and creamy material at the top were noted. Creamy material should not exceed ISI limit of 2 ml (Deepa and Jayakumar 2008). The data were statistically analyzed in RBD as per Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Laboratory study

No sediment at the bottom or floating creamy material at surface was found in any of the combinations. Hence it confirms that the herbicides like chlorimuron-ethyl + metsufuron-methyl or bispyribac-sodium or cyhalofop-butyl + penoxsulam can be used in combination with insecticides like chloropyriphos or fipronil.

Effect on stem borer

Dead heart percentage was less (1.55 to 1.92%) in sole insecticide treated plot than sole herbicide treated plots. Fipronil was more effective than that of chloropyriphos for control of stem borer in rice (**Table 1**). The incidence of dead hearts and white ear

Table 1. Effect of treatments on dead heart, white ear and crop injury in rice (mean data of 2 years)

Treatment	Stem borer		Crop injury	
	(DH %) 50 DAT	(WE %) harvest	(5 DAA)	(15 DAA
Chloropyriphos (200 g/ha) 20 EC 20 DAT	1.71(1.92)	2.52 (5.37)	1.0	1.0
Fipronil (50 g/ha) 80 WG 20 DAT	1.59 (1.55)	2.16 (3.70)	1.0	1.0
Chlorimuron-ethyl + metsulfuron-methyl (Almix) ready mix (4 g/ha) 20 WP20 DAT	2.81 (6.92)	2.81 (6.92)	1.0	1.0
Bispyribac -sodium (25 g/ha) 10 SC 20 DAT	2.76 (6.67)	2.76 (6.67)	1.2	1.0
Cyhalofop-butyl + penoxsulam (Vivaya) ready mix (135 g/ha) 6.1 OD 20 DAT	2.73 (6.47)	2.73 (6.47)	1.3	1.0
Chloropyriphos + chlorimuron-ethyl + metsulfuron-methyl (200 + 4 g/ha) 20 DAT	1.48 (1.21)	2.38 (4.70)	1.2	1.0
Chloropyriphos + bispyribac-sodium (200 + 25 g/ha) 20 DAT	1.38 (0.92)	2.32 (4.40)	1.3	1.0
Chloropyriphos + cyhalofop-butyl + penoxsulam (200 + 135 g/ha) 20 DAT	1.43 (1.07)	2.39 (4.73)	1.4	1.0
Fipronil + chlorimuron-ethyl + metsulfuron-methyl (50 + 4 g/ha) 20 DAT	1.42 (1.04)	2.25 (4.07)	1.3	1.0
Fipronil + bispyribac -sodium (50 + 25 g/ha) 20 DAT	1.34 (0.82)	2.15 (3.63)	1.4	1.0
Fipronil + cyhalofop-butyl + penoxsulam (50 + 135 g/ha) 20 DAT	1.25 (0.59)	2.12 (3.53)	1.4	1.0
Control (weedy check)	2.97 (7.87)	2.97 (7.87)	1.0	1.0
LSD (P=0.05)	0.99	0.47	1.01	-

Figures in parentheses represent the original values, which were subjected to square root transformation ($\sqrt{x+1}$) before analysis, DH- dead heart, WE – white ear, DAT- days after transplanting, DAA – days after application, Crop injury is measured on a scale 1-10, 1= no crop injury and 10 = complete crop destruction were also low in all other combinations of insecticides and herbicides over sole application of either of them and over control. Among combined application, fipronil + cyhalofop-butyl + penoxsulam suffered less due to dead heart (0.59%) and white ear (3.53%) damage caused by stem borer followed by fipronil + bispyribac-sodium (0.82 and 3.53%) and fipronil + chlorimuron + metsulfuron (1.07 and 3.63%), respectively. Tank mixing of insecticides with herbicides did not reduce the efficiency of the insecticide against stem borer. Hence, they are compatible with each other for tank mix spray application to control rice pest. These are in conformity with the findings of Deepa and Jayakumar (2008).

Crop injury

The visual toxicity ratings were used to quantify the crop tolerance to the herbicide. In qualitative assessment, the plants in control (weedy check) were used as reference. Chlorimuron + metsulfuron, bispyribac-sodium, cyhalofop + penoxsulam applied alone or in combination with insecticides chloropyriphos or fipronil did not show any crop injury symptoms (**Table 1**). None of the treatments had any toxicity on the rice crop in terms of crop stand, crop growth, yellowing, necrosis, scorching, epinasty and hyponasty. Similar results were reported by Deepa and Jayakumar (2008) for control of weed and insect in rice.

Effect on weeds

The major weed flora in the experimental field comprised of grasses *Echinochloa crusgalli* (L.), *Echinochloa colona* (L.), *Digitaria sanguinalis* (L.) Scop., *Panicum repens* (L.), *Leptochloa chinensis* (L.) *Paspalum distichum* (L.); sedges *Cyperus difformis* (L.), *Fimbristylis miliacea* (L.) Vahal; Scirpus juncoides and broad-leaved weeds (BLW) *Ludwigia paraviflora* (L.), *Ammania baccifera* (L.), *Eclipta prostrata* (L.), *Eclipta alba* (L.), *Lippa nodiflora* Nich, *Marsilea quadrifolium* (L.), *Sphenoclea zeylanica* Gaertn., *Commelina benghalensis* (L.). The composition of grasses, sedges and broad-leaved weeds in weedy check plot was 25.4, 50.9 and 23.5%, respectively. Emergence of sedges and broad-leaved weeds were noticed earlier as compared to grasses.

At 50 DAT, the densities of all the weeds were influenced significantly due to various combinations of herbicides with insecticides. Compatible mixture of cyhalofop + penoxsulam with fipronil or chloropyriphos was found more effective to control the density of grass, sedges and broad-leaf weeds than chlorimuron-ethyl + metsulfuron-methyl with fipronil or chloropyriphos. All the herbicidal treatments were able to reduce the density of weed as compared to weedy check (**Table 2**).

Weed control efficiency (WCE) of herbicides and insecticides tank mixture were superior to their

Table 2. Effect of treatments on weed density, biomass and weed control efficiency (WCE) at 40 days after transplanting in rice (mean data of 2 years)

Treatment	Weed density (no./m^2)				Weed biomass (g/m^2)				WCE (%)
	Grass	Sedge	BLW	Total	Grass	Sedge	BLW	Total	
Chloropyriphos (200 g/ha) 20 EC 20 DAT	3.9(14)	4.8(23)	3.4(11)	7.0(48)	2.8(6.7)	3.3(9.9)	2.3(4.2)	4.7(20.7)	9.2
Fipronil (50 g/ha) 80 WG 20 DAT	3.5(11)	5.2(26)	3.4(11)	7.1(49)	2.5(5.4)	3.5(11.6)	2.2(4.1)	4.7(21.0)	7.8
Chlorimuron-ethyl + metsulfuron-methyl (Almix) ready mix (4 g/ha) 20 WP20 DAT	2.5(5)	3.2(10)	1.9(3)	4.3(18)	1.9(2.6)	2.2(4.2)	1.4(1.0)	3.0(7.8)	65.8
Bispyribac -sodium (25 g/ha) 10 SC 20 DAT	2.2(4)	2.9(8)	1.9(3)	3.9(14)	1.7(1.9)	2.1(3.4)	1.4(1.0)	2.7(6.2)	72.8
Cyhalofop-butyl + penoxsulam (Vivaya) ready mix (135 g/ha) 6.1 OD 20 DAT	1.9(3)	2.5(5)	1.8(2)	3.4(11)	1.5(1.4)	1.8(2.2)	1.4(0.9)	2.4(4.6)	79.8
Chloropyriphos + chlorimuron-ethyl + metsulfuron-methyl (200 + 4 g/ha) 20 DAT	3.5(11)	3.3(10)	1.9(3)	5.0(24)	2.5(5.4)	2.3(4.2)	1.4(1.0)	3.4(10.7)	53.1
Chloropyriphos + bispyribac-sodium (200 + 25 g/ha) 20 DAT	3.4(11)	2.9(7)	1.6(1)	4.5(19)	2.5(5.1)	2.0(3.1)	1.2(0.5)	3.1(8.8)	61.4
Chloropyriphos + cyhalofop-butyl + penoxsulam (200 + 135 g/ha) 20 DAT	2.8(9)	2.6(6)	1.8(2)	4.3(17)	2.1(4.2)	1.9(2.7)	1.4(0.9)	3.0(7.8)	65.7
Fipronil + chlorimuron-ethyl + metsulfuron-methyl (50 + 4 g/ha) 20 DAT	3.0(9)	2.4(5)	1.9(3)	4.2(17)	2.2(4.2)	1.8(2.3)	1.4(1.1)	2.9(7.6)	66.7
Fipronil + bispyribac -sodium (50 + 25 g/ha) 20 DAT	2.1(3)	2.4(5)	1.8(2)	3.4(10)	1.6(1.6)	1.7(2.1)	1.4(0.8)	2.3(4.5)	80.2
Fipronil + cyhalofop-butyl + penoxsulam (50 + 135 g/ha) 20 DAT	1.8(2)	2.3(4)	1.4(1)	3.0(8)	1.5(1.2)	1.7(1.9)	1.2(0.4)	2.1(3.5)	84.6
Control (weedy check)	3.7(13)	5.2(26)	3.5(12)	7.2(51)	2.8(6.8)	3.5(11.5)	2.3(4.5)	4.9(22.8)	0.0
LSD (p=0.05)	0.9	0.8	0.8	0.7	0.6	0.5	0.4	0.4	

Figures in parentheses represent the original values and are subjected to square root transformation ($\sqrt{x+1}$) before analysis, BLW – Broad leaf weeds, WCE – Weed control efficiency sole application. The WCE with respect to grass, sedge and broad-leaved weeds was the highest (84.6%) with application of cyhalofop-butyl + penoxsulam with fipronil followed by the same insecticide with bispyribac-sodium (80.2%). The higher WCE in these treatments might be due to better crop stand resulting in smothering of weeds leading to lower weed growth and dry matter accumulation as compared to other treatments. The results are in conformity with the findings of Singh *et al.* (2015), who observed the synergistic effect of tank mix application of penoxsulam + cyhalofop-butyl (150 g/ha) along with chloropyriphos (125 g/ha) for weed control in rice. The lowest WCE (7.8 to 9.2%) was recorded in only insecticide treated plots.

Effect on crop

Effective tillers/m^2 (442), grains/panicle (137), panicle length (23.8 cm) and test weight (23.7 g) were the highest with fipronil + cyhalofop-butyl + penoxsulam and were superior to weedy check (**Table 3**). The complex weed flora comprised of grasses, sedges and broad-leaf weeds showed reduction of 28.5% in grain yield in the weedy check compared to this treatment (5.23 t/ha). Sole application of chlorimuron + metsulfuron, bispyribac-sodium, cyhalofop + penoxsulam recorded lower grain yield as compared to their tank mix application with chloropyriphos or fipronil. The lowest yield (3.91 t/ha) was with the application of chlorimuron + metsulfuron with chloropyriphos at 4 + 200 g/ha. This differential response might be due to difference in nature of weeds, herbicides, insecticides or environmental conditions (Chhokar *et al.* 2013).

Mixed application of fipronil with chlorimuron + metsulfuron, bispyribac-sodium, cyhalofop + penoxsulam resulted in significantly higher yield than their sole application due to better control of all grasses, sedges and broad-leaf weeds. Application of chlorimuron + metsulfuron, bispyribac-sodium, cyhalofop + penoxsulam alone increased yield by 4.3, 13.0 and 19.3% and resulted in an average increase of 9.8, 24.1 and 28.4%, respectively with fipronil as compared to weedy check. Chlorimuron + metsulfuron, bispyribac-sodium, cyhalofop + penoxsulam were compatible with fipronil and chloropyriphos, as their mode of action is different in the plant. All the three herbicides inhibit the plant enzyme acetolactate synthase (ALS), which is essential for the synthesis of branched chain amino acids. Inhibition of amino acid production subsequently inhibits cell division. Insecticide chloropyriphos inhibits breakdown of acetyl choline, a neurotransmitter and fipronil block gaba-gated chloride channel of stem borer.

Table 3. Effect of treatments on yield attributes, yield and economics of rice (mean data of 2 years)

Treatment	Tillers/m^2	Panicle length (cm)	Grains/panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Gross returns (x10^3 `/ha)	Cost of cultivation (x10^3 `/ha)	Net return (x10^3 `/ha)	Benefit: cost ratio
Chloropyriphos (200 g/ha) 20 EC 20 DAT	351	22.6	99	22.8	3.94	5.1	59.63	35.77	23.86	1.67
Fipronil (50 g/ha) 80 WG 20 DAT	372	22.9	102	23.2	3.95	5.5	60.09	36.74	23.35	1.64
Chlorimuron-ethyl + metsulfuron-methyl (Almix) ready mix (4 g/ha) 20 WP20 DAT	380	23.4	104	23.5	3.91	6.1	60.01	36.02	23.99	1.66
Bispyribac -sodium (25 g/ha) 10 SC 20 DAT	405	23.5	106	23.6	4.30	6.1	65.51	37.16	28.35	1.76
Cyhalofop-butyl + penoxsulam (Vivaya) ready mix (135 g/ha) 6.1 OD 20 DAT	408	23.6	112	23.5	4.64	6.3	70.46	37.90	32.56	1.86
Chloropyriphos + chlorimuron-ethyl + metsulfuron-methyl (200 + 4 g/ha) 20 DAT	388	23.7	110	23.6	3.97	5.8	60.62	36.69	23.93	1.65
Chloropyriphos + bispyribac-sodium (200 + 25 g/ha) 20 DAT	418	23.7	129	23.6	4.80	6.6	72.96	37.66	35.30	1.94
Chloropyriphos + cyhalofop-butyl + penoxsulam (200 + 135 g/ha) 20 DAT	438	22.5	131	23.4	4.84	7.0	73.84	37.83	36.01	1.95
Fipronil + chlorimuron-ethyl + metsulfuron-methyl (50 + 4 g/ha) 20 DAT	390	23.3	110	23.5	4.15	6.4	63.63	38.80	24.84	1.64
Fipronil + bispyribac -sodium (50 + 25 g/ha) 20 DAT	440	23.8	137	23.6	4.93	7.2	75.27	38.57	36.70	1.95
Fipronil + cyhalofop-butyl + penoxsulam (50 + 135 g/ha) 20 DAT	442	23.8	137	23.7	5.23	7.8	79.98	39.54	40.44	2.02
Control (weedy check)	349	20.8	93	23.2	3.74	5.0	56.73	35.10	21.63	1.61
LSD (p=0.05)	106.58	NS	48.75	NS	0.66	1.85				

Input price (`/kg): Rice seed, 14.10; straw, 8; urea, 5.52; di-ammonium phosphate, 24.45; muriate of potash, 17.44; chloropyriphos 20 EC, ` 270/L; fipronil 80 WG, ` 40/2 g; chlorimuron + metsulfuron 20 WP, ` 207/8 g, bispyribac-sodium 10 EC ` 660/100 ml, cyhalofop-butyl + penoxsulam, ` 1200/L.

Rice yield was 4.64 t/ha following application with cyhalofop + penoxsulam applied alone and a similar yield of 5.23 t/ha when tank-mixed with fipronil (**Table 3**). No significant difference in yield between herbicide + insecticide mixtures and herbicide alone indicate compatibility of insecticide with herbicide. Miller *et al*. (2010) reported no reduction in seed cotton yield following post-emergence application of insecticides with glyphosate.

Economics

All the herbicides and insecticides alone or in tank mix application recorded higher monetary returns than their sole application and weedy check (**Table 3**). Among the chemical weed control treatments, cyhalofop-butyl + penoxsulam + fipronil gave the maximum net returns (40.44 x 10^3 `/ha) and benefit: cost ratio (2.02) followed by same insecticide with bispyribac-sodium (36.70 x $10^3$ `/ha and 1.95, respectively) owing to low cost and high grain yield as compared to other post-emergence herbicides and insecticides.

It can be concluded that fipronil or chloropyriphos can be safely tank mixed with chlorimuron + metsulfuron or bispyribac-sodium or cyhalofop + penoxsulam, as no crop injury has been observed. Fipronil and cyhalofop + penoxsulam mixtures offer farmers the ability to integrate pest management strategies and limit application costs without sacrificing crop yield.

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