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Compatibility of herbicides and insecticides for tank mix application in wet seeded rice

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Abstract

An experiment entitled “compatibility of herbicides and insecticides for tank mix application in wet seeded rice” was conducted at Alappad Kole lands of Thrissur district, from August 2016 to January 2017. The experiment aimed at studying the compatibility of two commonly used herbicides (bispyribac sodium & cyhalofop-butyl) with two new generation insecticides (flubendiamide & imidacloprid) for tank mix application in wet seeded rice and to assess the pest control efficiency of herbicides and insecticides. Efficacy of cyhalofop-butyl was not affected by mixing with the insecticides. In the case of bispyribac sodium, the insecticide imidacloprid appeared to be compatible, but efficacy of bispyribac sodium was reduced when mixed with flubendiamide. Due to low incidence and no significant difference among insect pest counts among various treatments, efficacy of insecticides when tank mixed with herbicides could not be interpreted.

Key words: Bispyribac sodium, Cyhalofop-butyl, Flubendiamide, Imidacloprid, Tank mixing.

Weeds and insect pests are the major biotic constraints in rice production. Yield as well as quality of rice is hindered by these biotic factors. Uncontrolled weed growth causes about 64 per cent yield reduction in wet- seeded rice (Rao et al*.,* 2007). Dhaliwal et al. (2004) reported a cumulative loss of 25 per cent in rice production due to insect pest attack. Hence timely control of these pests is of utmost importance to get high yields.

Time of application of herbicides and insecticides often coincides. Then farmers have a tendency to go in for mixing and application of the two types of chemicals without any knowledge of the the compatibility and effectiveness. Hence an experiment was conducted at Alappad Kole lands of Thrissur district (geographically situated at $10^0$31’ N latitude and $76^0$13’ E longitude and 1m below mean sea level), to study the efficacy of mixing some commonly used herbicides and insecticides, during August 2016 to January 2017.

The soil of the experimental site was clayey in texture with pH 5.25, organic carbon 2.75 per cent, available N 242.51 kg ha^{-1}, available P 26.51 kg ha^{-1} and available K 419.46 kg ha^{-1}. The experiment was laid out in randomized block design with 14 treatments and 3 replications, using the variety Uma. The treatments included sequential and tank mix applications of herbicides and insecticides, hand weeding with or without insecticide application, application of herbicides alone, and unweeded control.

The treatments were:

T_1: Bispyribac sodium at 25g ha^{-1} at 20 DAS and flubendiamide at 25g ha^{-1} the next day

T_2: Bispyribac sodium at 25g ha^{-1} at 20 DAS and imidacloprid at 30g ha^{-1} the next day

T_3: Bispyribac sodium at 25g ha^{-1} + flubendiamide at 25g ha^{-1} at 20 DAS

T_4: Bispyribac sodium at 25g ha^{-1} + imidacloprid at 30g ha^{-1} at 20 DAS

T_5: Cyhalofop-butyl at 80g ha^{-1} at 20 DAS and

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flubendiamide at 25g ha^{-1} the next day
T_6: Cyhalofop-butyl at 80g ha^{-1} at 20 DAS and imidacloprid at 30g ha^{-1} the next day
T_7: Cyhalofop-butyl at 80g ha^{-1} + flubendiamide at 25g ha^{-1} at 20 DAS
T_8: Cyhalofop-butyl at 80g ha^{-1} + imidacloprid at 30g ha^{-1} at 20 DAS
T_9: Hand weeding at 20 and 40 DAS + flubendiamide at 25g ha^{-1}
T_{10}: Hand weeding at 20 and 40 DAS + imidacloprid at 30g ha^{-1}
T_{11}: Bispyribac sodium at 25g ha^{-1} at 20 DAS
T_{12}: Cyhalofop-butyl at 80g ha^{-1} at 20 DAS
T_{13}: Hand weeding at 20 and 40 DAS
T_{14}: Unweeded control

Pre-germinated seeds at the rate of 100 kg/ha were sown in each plot. Fertilizers were applied at the rate of 110:45:45 kg N:P_2O_5:K_2O per hectare as per the package of practice recommendations of Kerala Agricultural University (KAU, 2016). Field scouting was done at 18 DAS. Herbicides and insecticides were sprayed at 20/ 21 DAS and hand weeding was carried out at 20 and 40 DAS. Species wise weed count, weed dry matter production and weed control efficiency were studied at 30 DAS, 60 DAS and at harvest. Observations on weeds and insect pests were recorded with the help of a quadrate (0.25m x 0.25 m). The data on species wise weed counts and weed dry matter production were subjected to square root transformation (“x+0.5) to normalize their distribution. Weed control efficiency (WCE) was computed using the total dry weight of weeds. Yield attributing characters like panicles/m^2, spikelets per panicle, filled grains per panicle, filling percentage and 1000 grain weight were observed at the time of harvest. Both the grain and straw yield were also recorded after harvest. Economics of cultivation were worked out based on the minimum support price for rice (Rs.21.50/kg) given by the Government of Kerala during 2012 and prevailing market price of straw (Rs.9/kg). The data recorded at periodic intervals were subjected to Analysis of Variance techniques (ANOVA).

Weed spectrum

Weeds in the experimental field included grasses, sedges and broad leaf weeds. Important grass weeds were *Echinochloa crus-galli, Echinochloa stagnina* and *Leptochloa chinensis,* and the main sedge was *Cyperus iria*. Population of broad leaf weeds was very low. *Ludwigia parviflora* and *Limnophila heterophylla* were noted in some plots.

Species wise weed count

Effect of treatments on species wise weed count at 30 DAS, 60 DAS and at harvest are presented in Table 1. At 30 DAS, *Cyperus iria* and *Echinochloa crus-galli* were the dominant weeds. Density of broad leaf weeds and *Cyperus iria* was more in cyhalofop-butyl treated plots, as cyhalofop butyl was not effective against broad leaf weeds and sedges. Among tank mix applications of bispyribac sodium and insecticides, lowest weed count was recorded in bispyribac sodium+ imidacloprid (T_4) treatment, and among cyhalofop – butyl and insecticides, cyhalofop-butyl + flubendiamide (T_7) treatment recorded lowest weed density. Bispyribac sodium+ flubendiamide (T_3) treated plot showed highest number of *Echinochloa crus-galli* (18nos./ m^2).

At 60 DAS, *Cyperus iria* and *Leptochloa chinensis* were the major weeds. Count of *Cyperus iria* continued to be high in cyhalofop-butyl treatments whereas population of *Leptochloa chinensis* was high in bispyribac sodium sprayed treatments. Bispyribac sodium is reported to be less effective againt *Leptochloa*. *Ludwigia parviflora* was the only broad leaf weed observed and its population was negligible, except under cyhalofop – butyl and unweeded treatments. Comparing herbicide – insecticide combinations, tank mix application of bispyribac sodium and flubendiamide resulted in less control of *Echinochloa crus-galli* when compared to their sequential application.

At harvest, *Echinochloa crus-galli* and *Cyperus iria* were the major weeds. *E. stagnina* was also seen at this stage. Total weed count was high in unweeded

Table 1. Effect of treatments on weed count at 30 DAS, 60 DAS and at harvest

	At 30 DAS (no./m²)				At 60 DAS (no./ m²)				At harvest (no./m²)			
	Echinochloa crus-galli	*Limnophila heterophylla*	*Ludwigia parviflora*	*Cyperus iria*	*Echinochloa crus-galli*	*Leptochloa chinensis*	*Ludwigia parviflora*	*Cyperus iria*	*Echinochlo acrus-galli*	*Echinochloa stagnina*	*Leptochloa chinensis*	*Cyperus iria*
T_1	* 2.64^{d} (7.00)	0.71^{e} (0.00)	0.71^{e} (0.00)	2.19^{e} (4.33)	*2.99^{cd} (8.50)	4.63^{abc} (21.00)	0.71^{e} (0.00)	3.31^{bcd} (10.50)	4.26^{abc} (18.00)	3.28^{a} (10.33)	3.84^{a} (14.33)	0.71^{c} (0.00)
T_2	2.76^{cd} (7.66)	0.71^{e} (0.00)	0.71^{e} (0.00)	2.52^{d} (6.00)	2.12^{de}(4.00)	4.52^{bc} (20.00)	0.71^{e} (0.00)	2.19^{cd} (4.33)	2.12^{def} (4.00)	2.85^{bc} (7.66)	2.85^{b} (7.66)	0.71^{c} (0.00)
T_3	4.24^{b} (18.00)	0.71^{e} (0.00)	0.71^{e} (0.00)	2.91^{c} (8.00)	4.27^{ab} (18.66)	3.53^{c} (12.00)	0.71^{e} (0.00)	3.55^{bcd} (12.33)	3.57^{bcd} (12.50)	0.71^{e} (0.00)	3.67^{a} (13.00)	0.71^{c} (0.00)
T_4	2.81^{cd} (8.00)	0.71^{e} (0.00)	0.71^{e} (0.00)	2.33^{de} (5.00)	2.99^{cd} (8.50)	5.45^{ab} (35.66)	0.71^{e} (0.00)	0.71^{d} (0.00)	2.12^{def} (4.00)	3.23^{ab} (10.00)	3.76^{a} (13.66)	0.71^{c} (0.00)
T_5	2.70^{d} (7.33)	2.19^{bcd}(4.33)	2.47^{cd} (5.66)	3.43^{b} (11.33)	2.44^{de} (5.50)	0.71^{d} (0.00)	1.95^{bc} (3.33)	7.58^{a} (58.66)	3.58^{bcd} (12.33)	0.71^{e} (0.00)	0.71^{d} (0.00)	7.63^{a} (58.33)
T_6	3.10^{c} (9.66)	2.03^{d} (3.66)	2.73^{abc}(7.00)	3.48^{b} (11.66)	2.23^{de} (4.50)	0.71^{d} (0.00)	1.58^{d} (2.00)	5.42^{abc} (38.66)	3.09^{cde} (10.00)	0.71^{e} (0.00)	0.71^{d} (0.00)	8.57^{a} (73.00)
T_7	2.82^{cd} (8.00)	2.11^{cd} (4.00)	2.33^{d} (5.00)	3.43^{b} (11.33)	2.82^{cde} (7.50)	0.71^{d} (0.00)	1.72^{cd} (2.50)	6.86^{ab} (46.66)	4.80^{ab} (25.00)	2.19^{d} (4.33)	0.71^{d}(0.00)	5.28^{b} (28.00)
T_8	2.75^{cd} (7.66)	2.27^{bc} (4.66)	2.85^{ab} (7.66)	3.62^{b} (12.66)	2.19^{de} (4.33)	0.71^{d} (0.00)	2.23^{b} (4.50)	7.45^{a} (64.00)	2.91^{cde} (8.00)	0.71^{e} (0.00)	0.71^{d} (0.00)	8.61^{a} (73.66)
T_9	1.27^{e} (1.66)	0.71^{e} (0.00)	0.71^{e} (0.00)	0.71^{f} (0.00)	0.71^{f} (0.00)	0.71^{d} (0.00)	1.55^{d} (2.00)	0.71^{d} (0.00)	0.71^{f} (0.00)	0.71^{e} (0.00)	2.03^{c} (3.66)	0.71^{c} (0.00)
T_{10}	1.13^{e} (1.33)	0.71^{e} (0.00)	0.71^{e} (0.00)	0.71^{f} (0.00)	3.60^{bc} (12.50)	0.71^{d}(0.00)	0.71^{e} (0.00)	3.46^{bcd}(11.50)	1.58^{ef} (2.00)	0.71^{e} (0.00)	2.12^{c} (4.00)	0.71^{c} (0.00)
T_{11}	2.75^{cd} (7.66)	0.71^{e} (0.00)	0.71^{e} (0.00)	2.66^{cd} (6.66)	3.46^{bc} (11.50)	4.33^{bc} (18.33)	0.71^{e} (0.00)	2.23^{cd}(4.50)	2.12^{def} (4.00)	2.51^{cd} (6.00)	2.97^{b} (8.33)	0.71^{c} (0.00)
T_{12}	3.10^{c}(9.66)	2.33^{b}(5.00)	2.60^{bcd}(6.33)	3.58^{b}(12.33)	1.99^{e} (3.50)	0.71^{d} (0.00)	2.11^{b} (4.00)	6.83^{ab}(46.60)	0.71^{f} (0.00)	0.71^{e} (0.00)	0.71^{d} (0.00)	7.56^{a} (66.00)
T_{13}	1.41^{e}(2.00)	0.71^{e}(0.00)	0.71^{e}(0.00)	0.71^{f}(0.00)	2.33^{de} (5.00)	1.67^{d} (2.33)	0.71^{e} (0.00)	2.23^{cd} (4.50)	2.12^{def}(4.00)	0.71^{e}(0.00)	2.12^{c} (4.00)	0.71^{c}(0.00)
T_{14}	5.09^{a} (26.00)	3.93^{a} (15.00)	2.91^{a} (8.00)	5.24^{a} (27.00)	4.58^{a} (20.50)	6.20^{a} (38.00)	2.54^{a} (6.00)	8.15^{a} (66.00)	5.65^{a}(32.00)	3.07^{ab}(9.00)	3.48^{a}(12.00)	9.19^{a}(84.00)

*$\sqrt{x+0.5}$ transformed values, Original values in parentheses.
In a column, means followed by common letters do not differ significantly at 5% level in DMRT.

Table 2. Effect of treatments on weed dry matter production and weed control efficiency

	Weed dry matter production(kg/ha)			Weed control efficiency (%)		
	30 DAS	**60 DAS**	**Harvest**	**30 DAS**	**60 DAS**	**Harvest**
T_1	*6.18^{bcd} (38.54)	20.09^{ef} (418.33)	23.26^{b} (543.10)	87.50^{abc}	82.59^{ab}	68.46^{a}
T_2	5.34^{de} (30.26)	17.40^{fg} (344.27)	21.75^{bc} (473.38)	90.63^{ab}	85.69^{ab}	72.53^{a}
T_3	7.64^{bcd} (58.49)	37.61^{bc} (1418.54)	19.42^{c} (378.23)	80.93^{bc}	41.02^{de}	78.04^{a}
T_4	6.71^{bcd} (45.05)	24.89^{def} (630.52)	25.01^{b} (626.01)	85.20^{abc}	73.79^{abc}	63.64^{a}
T_5	8.21^{bc} (68.44)	39.18^{b} (1538.50)	23.66^{b} (568.17)	77.64^{bc}	36.03^{e}	67.01^{a}
T_6	7.74^{bcd} (60.28)	37.14^{bc} (1398.53)	23.33^{b} (544.32)	80.11^{bc}	41.83^{de}	68.40^{a}
T_7	8.41^{bc} (72.18)	32.05^{bcd} (1028.46)	23.41^{b} (550.54)	76.33^{bc}	57.24^{cde}	68.29^{a}
T_8	7.41^{bcd} (61.27)	38.59^{b} (1510.35)	25.03^{b} (632.33)	80.27^{bc}	37.19^{e}	63.33^{a}
T_9	1.83^{f} (3.44)	10.25^{g} (106.25)	10.73^{d} (115.27)	98.84^{a}	95.56^{a}	93.32^{a}
T_{10}	2.22^{f} (5.05)	17.75^{fg} (316.35)	11.41^{d} (130.39)	98.35^{a}	86.89^{ab}	92.45^{a}
T_{11}	6.01^{cd} (38.40)	28.74^{cde} (844.22)	19.24^{c} (370.32)	87.34^{abc}	64.89^{bcd}	78.51^{a}
T_{12}	8.81^{b} (78.26)	33.03^{bcd} (1106.49)	19.02^{c} (362.39)	74.36^{c}	53.99^{cde}	78.97^{a}
T_{13}	2.77^{ef} (7.76)	10.17^{g} (104.16)	12.45^{d} (156.26)	97.50^{a}	95.67^{a}	90.94^{a}
T_{14}	17.44^{a} (304.25)	49.03^{a} (2404.44)	41.49^{a} (1722.16)	-	-	-

*$\sqrt{x+0.5}$ trasformed values, original values in parentheses. In a column, means followed by common letters do not differ significantly at 5% level in DMRT.

Table 3.Effect of treatments on incidence of insect pests at 5, 7 and 11 days after spraying.

	5 days after spraying		7 days after spraying				11 days after spraying		
	Defoliators	Sucking pests	Defoliators	Sucking pests		Borers	Defoliators	Sucking pests	
	Leaf folder (*Cnaphalocrocis medinalis*)	**White backed plant hopper (*Sogatella furcifera*)**	**Leaf folder (*Cnaphalocrocis medinalis*)**	**White backed p lant hopper (*Sogatella furcifera*)**	**Red spotted earhead bug (*Menida versicolor*)**	**Yellow stem borer (*Scirpophaga incertulas*)**	**Leaf folder (*Cnaphalocro cis medinalis*)**	**White backed planthopper (*Sogatella furcifera*)**	**Red spotted earhead bug (*Menida versicolor*)**
T$_{1}$	*1.65^{a} (2.66)	0.71^{a} (0.00)	2.12^{a} (5.33)	0.71^{a} (0.00)	1.17^{a} (1.33)	0.707^{a} (0.00)	1.91^{a} (4.00)	1.91^{a} (4.00)	0.71^{a} (0.00)
T$_{2}$	1.65^{a} (2.66)	0.71^{a} (0.00)	2.85^{a} (8.00)	0.71^{a} (0.00)	0.71^{a} (0.00)	1.17^{a} (1.33)	2.59^{a} (9.33)	1.17^{a} (1.33)	0.71^{a} (0.00)
T$_{3}$	1.17^{a} (1.33)	0.71^{a} (0.00)	2.85^{a} (8.00)	1.91^{a} (4.00)	0.71^{a} (0.00)	0.71^{a} (0.00)	1.17^{a} (1.33)	1.82^{a} (5.33)	0.71^{a} (0.00)
T$_{4}$	1.65^{a} (2.66)	0.71^{a} (0.00)	3.12^{a} (9.33)	1.17^{a} (1.33)	1.17^{a} (1.33)	0.707^{a} (0.00)	2.85^{a} (8.00)	1.65^{a} (2.66)	0.71^{a} (0.00)
T$_{5}$	0.71^{a} (0.00)	0.71^{a} (0.00)	2.59^{a} (6.66)	1.17^{a} (1.33)	0.71^{a} (0.00)	1.17^{a} (1.33)	0.71^{a} (0.00)	1.65^{a} (2.66)	0.71^{a} (0.00)
T$_{6}$	0.71^{a} (0.00)	0.71^{a} (0.00)	2.85^{a} (8.00)	0.71^{a} (0.00)	0.71^{a} (0.00)	0.71^{a} (0.00)	2.38^{a} (6.66)	0.71^{a} (0.00)	0.71^{a} (0.00)
T$_{7}$	0.71^{a} (0.00)	1.17^{a} (1.33)	2.59^{a} (6.66)	1.65^{a} (2.66)	0.71^{a} (0.00)	0.71^{a} (0.00)	1.65^{a} (2.66)	0.707^{a} (0.00)	0.71^{a} (0.00)
T$_{8}$	1.17^{a} (1.33)	0.71^{a} (0.00)	2.85^{a} (8.00)	0.71^{a} (0.00)	1.17^{a} (1.33)	0.71^{a} (0.00)	3.50^{a} (12.00)	1.65^{a} (2.66)	1.17^{a} (1.33)
T$_{9}$	0.71^{a} (0.00)	0.71^{a} (0.00)	3.12^{a} (9.33)	1.17^{a} (1.33)	0.71^{a} (0.00)	1.17^{a} (1.33)	2.38^{a} (6.66)	0.71^{a} (0.00)	0.71^{a} (0.00)
T$_{10}$	1.65^{a} (2.66)	0.71^{a} (0.00)	2.59^{a} (6.66)	0.71^{a} (0.00)	1.17^{a} (1.33)	0.71^{a} (0.00)	2.85^{a} (8.00)	0.71^{a} (0.00)	0.71^{a} (0.00)
T$_{11}$	1.17^{a} (1.33)	0.71^{a} (0.00)	3.12^{a} (9.33)	0.71^{a} (0.00)	0.71^{a} (0.00)	0.71^{a} (0.00)	1.82^{a} (5.33)	1.65^{a} (2.66)	1.17^{a} (1.33)
T$_{12}$	1.17^{a} (1.33)	0.71^{a} (0.00)	3.86^{a} (16.00)	0.71^{a} (0.00)	1.17^{a} (1.33)	1.17^{a} (1.33)	2.38^{a} (6.66)	1.91^{a} (4.00)	0.71^{a} (0.00)
T$_{13}$	1.17^{a} (1.33)	0.71^{a} (0.00)	3.12^{a} (9.33)	0.71^{a} (0.00)	0.71^{a} (0.00)	1.17^{a} (1.33)	3.50^{a} (12.00)	0.71^{a} (0.00)	0.71^{a} (0.00)
T$_{14}$	1.65^{a} (2.66)	1.56^{a} (2.33)	3.56^{a} (12.33)	1.91^{a} (4.00)	1.17^{a} (1.33)	1.17^{a} (1.33)	4.37^{a} (18.66)	1.82^{a} (5.33)	1.65^{a} (2.66)

*$\sqrt{x+0.5}$ transformed values, original values in parentheses. In a column, means followed by common letters do not differ significantly at 5% level in DMRT.

Table 4. Effect of treatments on yield, yield attributes and B: C ratio

Treatments	Panicles (No./m^{2})	Spikelets per panicle(No.)	Filling percentage(%)	1000 grain weight(g)	Grain yield (t/ha)	Straw yield(t/ha)	B:C ratio
T$_{1}$	*253.33^{ab}	103.52^{bc}	89.50^{bcde}	28.00^{a}	4.18^{b}	5.52^{a}	2.66
T$_{2}$	218.33^{bc}	89.76^{fg}	94.09^{abc}	27.00^{a}	3.75^{b}	5.24^{a}	2.47
T$_{3}$	159.66^{d}	94.50^{def}	85.86^{efg}	27.00^{a}	2.68^{c}	5.19^{a}	2.12
T$_{4}$	226.00^{b}	98.03^{cde}	88.65^{cdef}	28.00^{a}	4.25^{b}	5.70^{a}	2.82
T$_{5}$	171.33^{d}	90.19^{f}	74.65^{ij}	27.00^{a}	2.91^{c}	5.84^{a}	2.13
T$_{6}$	158.00^{d}	83.20^{gh}	79.45^{hi}	27.33^{a}	2.18^{c}	5.32^{a}	2.00
T$_{7}$	218.33^{bc}	94.48^{def}	83.65^{fgh}	27.66^{a}	4.31^{b}	5.22^{a}	2.84
T$_{8}$	175.66^{d}	77.80^{h}	81.17^{gh}	26.66^{a}	2.06^{c}	5.31^{a}	2.01
T$_{9}$	240.00^{b}	118.40^{a}	93.44^{abc}	27.33^{a}	5.75^{a}	5.96^{a}	1.99
T$_{10}$	250.33^{ab}	109.15^{b}	92.68^{abcd}	28.00^{a}	5.62^{a}	5.81^{a}	1.96
T$_{11}$	162.66^{d}	91.66^{ef}	87.87^{def}	27.33^{a}	4.00^{b}	5.19^{a}	2.66
T$_{12}$	154.00^{d}	97.46^{cde}	74.87^{ij}	27.00^{a}	2.00^{c}	5.31^{a}	2.02
T$_{13}$	290.00^{a}	100.78^{cd}	96.15^{a}	28.00^{a}	5.56^{a}	5.89^{a}	2.00
T$_{14}$	148.66^{d}	70.41^{i}	72.46^{j}	27.66^{a}	1.91^{c}	3.92^{a}	1.78

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT.

control (137 nos./m^2), followed by cyhalofop-butyl *f.b.*(followed by) imidacloprid (T_6) treatment. At the time of harvest the field was free of broad leaf weeds. This may be due to the dominating effect of *E. crus- galli* and *Leptochloa chinensis.* Weed count was low in bispyribac sodium + flubendiamide treatment at the harvest stage.

Weed dry matter production

Data on the effect of treatments on weed dry matter production are presented in Table 2. At 30 DAS, the highest weed dry matter production of 304.35 kg/ha under unweeded control was followed by 78.26 kg/ha under cyhalofop-butyl treatment (T_{12}). Weed dry matter production under tank mix treatments of bispyribac sodium with insecticides was statistically on par with their sequential application. In the case of cyhalofop-butyl and insecticides also, tank mix treatments and sequential applications were statistically on par.

At 60 DAS bispyribac sodium + flubendiamide (T_3) recorded higher weed dry matter production (1418.54 kg/ha) than its sequential application (418.33 kg/ha), and bispyribac sodium + imidacloprid (T_4) recorded a weed dry matter production which was statistically on par with sequential application. Among the sequential and tank mix applications of cyhalofop - butyl and insecticides, cyhalofop-butyl + flubendiamide (T_7) recorded a weed dry matter production significantly lower than its sequential application, and cyhalofop-butyl+ imidacloprid (T_8) resulted in a weed dry matter production which was statistically on par with its sequential application.

At the time of harvest weed dry matter production in all plots decreased, with highest production of 1722.16 kg/ha recorded in unweeded control. At this stage, bispyribac sodium + flubendiamide (T_3) recorded a lower weed dry matter production than its sequential application, and bispyribac sodium + imidacloprid was statistically on par to its sequential application. All treatments of sequential and tank mix applications of cyhalofop-butyl with insecticides were on par.

Weed control efficiency

Highest weed control efficiency was recorded in hand weeded treatments. Comparing the sequential and tank mix applications of bispyribac sodium and insecticides, bispyribac sodium + flubendiamide recorded lowest weed control efficiency. It might be due to the poor performance of bispyribac sodium when mixed with flubendiamide. Similar cases of efficiency impairment of herbicides due to mixing with other chemicals were reported by Atheena (2016) and Busi et al. (2017). Bispyribac sodium + imidacloprid treatment was statistically on par with its sequential application. Tank mix application of cyhalofop-butyl and flubendiamide resulted in significantly higher weed control efficiency than its sequential application, whereas performance of cyhalofop-butyl + imidacloprid was on par with its sequential application.

Insect pest population

In general, insect pest population was low in the experimental field. The pests included defoliators, sucking pests and shoot borers. *Cnaphalocrocis medinalis* (leaf folder) was the only defoliator, and sucking pests comprised *Sogatella furcifera* (WBPH) and *Menida versicolor* (red spotted earhead bug). *Scirpophaga incertulas* (yellow stem borer) was the plant borer observed during the season.

Insecticide spray was given 20/21 DAS, 20 in the case of tank mix application and 21 for sequential application, given the next day after herbicide spray. Pesticide spray had an immediate effect on control of insect pests. Insects reappeared in the field after 3-4 days. Counts of insect pests were taken at 5, 7, and 11 days after spraying and the data are furnished in Table 3.

Five days after spraying, leaf folder and WBPH were the only insect pests found in the field. At 7 days after spraying, leaf folder, WBPH and red spotted earhead bug were observed. At 11 days after spraying, yellow stem borer, leaf folder, red spotted earhead bug and WBPH were present. At all stages of observation, treatments were on par with regard to counts of individual insect pests. Since insect infestation was low, conclusive results on efficacy of insecticides on mixing with herbicides could not be obtained.

Yield and yield attributes

Effect of treatments on yield, yield attributes and B:C ratio are presented in Table 4. Out of the 14 treatments, highest grain yield of 5.75 t/ha was recorded under hand weeding + flubendiamide treatment, which was on par with hand weeding+ imidacloprid and twice hand weeded plots. Unweeded control with highest weed infestation registered lowest yield. Comparing the sequential and tank mix applications of bispyribac sodium and insecticides, bispyribac sodium + flubendiamide recorded significantly lower yield than its sequential application, and bispyribac sodium + imidacloprid recorded yield statistically on par with its sequential application. Simultaneous application of cyhalofop-butyl and flubendiamide recorded significantly higher yield than its sequential application, and cyhalofop-butyl + imidacloprid recorded yield comparable to sequential application. Yield reduction in bispyribac sodium + flubendiamide might be due to high weed density and weed dry matter production at 60 DAS. This means that efficacy of bispyribac sodium is reduced when mixed with flubendiamide.

Yield parameters were highly correlated to weed count and weed dry matter production at all stages of observation except panicles per m^2 at harvest. Test grain weight had no significant correlation with weed count and dry matter production. Highest value for number of panicles per m^2 was recorded in hand weeded plot which was on par with hand weeding + imidacloprid treatment and bispyribac sodium *f.b.* flubendiamide treatment. In the case of herbicide-insecticide combination treatments, bispyribac sodium + imidacloprid showed highest panicle number which was statistically on par with its sequential application. All the treatments were on par with respect to 1000 grain weight (test weight). Hand weeded treatments registered higher number of filled grains per panicle, with highest in hand weeding + flubendiamide treatment.

Benefit - cost analysis

Benefit - cost analysis of the data indicated that application of cyhalofop-butyl + flubendiamide and bispyribac sodium + imidacloprid recorded higher B:C ratios of 2.84 and 2.82 (Table 4) with net returns of Rs. 92808 and Rs. 94052 respectively.

Best treatments with respect to weed control efficiency, yield and B:C ratio were bispyribac sodium+ imidacloprid and bispyribac sodium *f.b.* flubendiamide.

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