Efficacy of herbicide – urea tank mixing for weed control in wet seeded rice

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Abstract

Tank mixing of herbicides with urea is a common practice among rice farmers, done to enhance herbicidal effect and to save labour costs. Field experiments were conducted in 2019-20 and 2020-21 in Alappad Kole in Thrissur, Kerala to evaluate the effect of tank mixing of commonly used herbicides with 1% urea on weed control efficiency and yield of wet seeded rice. Six herbicides, *viz.,* cyhalofop butyl (0.08 kg/ha), cyhalofop butyl + penoxsulam (0.15 kg/ha), bispyribac sodium (0.025 kg/ha), fenoxaprop-p-ethyl (0.06 kg/ha), carfentrazone ethyl (0.02 kg/ha) and chlorimuron ethyl + metsulfuron methyl (0.004 kg/ha) were applied with and without urea mixing, in a Randomized Block Design with three replications. A hand weeded control and unweeded control were also included for comparison. The treatments were applied 15 to 20 days after sowing. At 45 to 50 days after sowing, all the herbicide applied plots were hand weeded to remove all weeds. Results indicated that mixing urea with bispyribac sodium and cyhalofop butyl + penoxsulam were superior to application of these herbicides without urea mixing in reducing weed growth and increasing rice grain yields. Pooled data on weed dry weight at 15 days after herbicide application revealed that mixing with urea could enhance weed control efficiencies of bispyribac sodium and cyhalofop butyl + penoxsulam by 17.5 per cent and 14.85 per cent respectively as compared to their application without urea. Although the highest yield was obtained with hand weeded control (5.13 t/ha), tank mixing with urea resulted in increases in grain yield to the tune of 17.52 per cent on application of bispyribac sodium (5.03 t/ha) and 18.75 per cent on application of cyhalofop butyl + penoxsulam (4.94 t/ha) as compared to their application without urea mixing.

Key words: Bispyribac sodium, Cyhalofop butyl + penoxsulam, Kole area, Synergistic effect, Weed control efficiency.

Introduction

The Kole area of Kerala is a high yielding rice tract covering almost 30000 ha. Situated below mean sea level, this area is very fertile, and bumper yields are commonly obtained. Wet seeding of rice is commonly practiced here, and a diverse array of weeds is a serious problem, necessitating enormous expenditure on labour. The farmers of the area are very progressive and frequently practice mixing of agrochemicals to reduce cultivation costs and increase yields. Mixing of herbicides with other agrochemicals like fertilizers, fungicides and pesticides is a common farmer practice, done to reduce labour costs, mechanical damage to crop foliage, and the quantities of chemicals used, as well as to enhance efficiency.

Tank mixtures of urea with herbicides are commonly adopted in the Kole fields based on the popular belief that the herbicide efficacy would be enhanced. Scientific information on the physical or chemical compatibility of urea with foliage applied herbicides, especially the newer commercial formulations currently available and popular among the rice farmers, is limited. Sankaran et al. (1974) reported that application of butachlor in a mixture

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with urea significantly increased rice crop yield, but did not increase weed control efficiency of butachlor. Moody (1981) opined that combination of herbicides with fertilizers could improve weed control and enhance crop yields either by synergism or by more efficient utilization of the fertilizer. However, this would depend on soil properties, types of weeds, nature of fertilizers and time of application. With this background, an investigation was undertaken to evaluate the efficacy of adding urea with commonly applied herbicides in wet seeded rice.

Material and methods

Field experiments were carried out in 2019-20 and 2020-21 in the Kole area in Alappad, Thrissur in Kerala. Geographically, the area is located between 10°20' and 10°40' North latitudes and 75°58' and 76°11' East longitudes, with an altitude of 0.5 to 1m below Mean Sea Level. The experiment was begun in September (late Mundakan) in both years. As is the practice in Kole areas which are located below mean sea level, the submerged fields were dewatered, ploughed and leveled. Plots of 20 sq. m area were formed by constructing bunds of 30 cm width and 15 cm height. Fourteen treatments included six commonly used herbicides, viz., cyhalofop butyl (0.08 kg/ha), cyhalofop butyl + penoxsulam (0.15 kg/ha), bispyribac sodium (0.025 kg/ha), fenoxaprop-p-ethyl (0.06 kg/ha), carfentrazone ethyl (0.02 kg/ha) and chlorimuron ethyl + metsulfuron methyl (0.004 kg/ha), applied individually and on tank mixing with 1% urea. A hand weeded control [weeding at 20 and 40 days after sowing (DAS)] and unweeded control were included for comparison. The experiment was laid out in randomized block design with three replications.

Manuratna, a short duration variety (100 days duration) was used in the experiment. Fertilizers were applied at 90:35:45 kg N, P and K per hectare as per the package of practice recommendations of the Kerala Agricultural University (KAU, 2016). All herbicides, with and without urea mixing, were sprayed 15 to 20 DAS (three to four leaf stage of weed) using a knapsack sprayer fitted with flat fan nozzle and a spray volume of 375 L/ha. Thrity days after herbicide application, hand weeding was done in all the herbicide treated plots. The soil pH was 4.6 and the organic carbon content was 1.3%. The soil was low in available N (184 kg/ha), medium in available P (21 kg/ha) and available K (156 kg/ha). Observations on dry matter production of weeds in g/m^2 were recorded at 15 and 30 days after treatment application using quadrate of 50×50 cm dimension, and expressed as kg/ha. Weed control efficiency (WCE) was calculated as per formula of Mani and Gautham (1973) and weed index (WI) was calculated using the formula proposed by Gill and Vijayakumar (1969), and expressed in percentage. The formulae are as follows:

$$WCE = \frac{\text{WDMP in unweeded control–WDMP in treatment}}{\text{WDMP in unweeded control}} \times 100$$

* WDMP= Weed Dry Matter Production

$$WI = \frac{\text{Grain yield in hand weeded plot – Grain yield in treatment}}{\text{Grain yield in hand weeded plot}} \times 100$$

Biometric characters of rice were measured at 30, 60 days after sowing and at harvest. Data on yield attributes, grain and straw yields were recorded at harvest.

The statistical package 'MSTAT-C' (Freed, 1986) was used for analysis of data. Square root transformation, $\sqrt{(x+0.5)}$, was used to make the analysis of variance valid when data varied widely (Gomez and Gomez, 1984). The statistical software 'WASP 2.0' was used for the analysis.

Results and discussion

Weed spectra

The weed spectra in the experimental field were similar in both years of experimentation. *Echinochloa colona*, *E. stagnina*, and *Leptochloa chinensis* were the main grasses. The sedges were mainly constituted by *Cyperus iria* and *Fimbristylis miliacea*, while *Ludwigia perennis* was the chief

broad leaf weed. *Monochoria vaginalis*, a monocot, was also present sporadically. Weedy rice (*Oryza sativa* f. *spontanea*) was ubiquitous in all the plots.

Weed dry matter

Data on dry matter production of grasses, sedges and broad leaf weeds at 15 and 30 days after treatment application as well as their pooled data are presented in Tables 1 and 2. At 15 days after herbicide application, there was no significant difference in the pooled values on dry matter production for all three individual classes of weeds, with and without urea mixing. However, a numerical decrease in weed dry weight was observed on mixing the herbicides with urea.

At 15 days after application, significant effect of mixing with urea was observed with regard to cyhalofop butyl + penoxsulam and bispyribac sodium on total dry weight of weeds. The dry weight of weeds was reduced by 22.5 per cent and 23.4 per cent respectively for these two herbicides as compared to their urea-free application. A similar synergistic effect of tank mix application of cyhalofop butyl + penoxsulam with urea in rice was reported by Singh et al. (2015), who attributed this response to the specific nature of weeds, herbicides, or environmental conditions. These two treatments (cyhalofop butyl + penoxsulam and bispyribac sodium) resulted in the lowest weed dry matter next to the hand weeded control, probably as they are broad spectrum herbicides, controlling all types of weeds. Similarly, Soliman et al. (2011) reported that application of isoproturon + diflufenican, tribenuron- methyl and clodinafop propargyl at medium rates on mixing with 1% urea increased

Table 1. Effect of herbicide-urea combinations on weed dry weight at 15 days after application (kg/ha)

Treatments		Grasses			Sedges			Broad Leaf Weeds			Total		
		1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1	Cyhalofop butyl	4.40^{ef}	4.43^{ef}	4.41^{defg}	7.07^{b}	5.73^{b}	6.41^{b}	1.20^{bcd}	1.46^{bc}	1.34^{bcd}	8.41^{bcd}	7.35^{bc}	7.90^{bcde}
	+ urea 1%	(19.37)	(19.61)	(19.49)	(51.43)	(33.34)	(42.39)	(0.95)	(1.63)	(1.29)	(71.74)	(54.79)	(63.16)
T2	(Cyhalofop butyl +	3.34^{f}	2.98^{fg}	3.20^{fg}	4.14^{cd}	4.02^{cd}	4.09^{cd}	0.78^{d}	0.94^{c}	0.87^{e}	5.36^{ef}	5.13^{de}	5.27^{f}
	penoxsulam) + urea 1%	(12.30)	(9.88)	(11.09)	(17.32)	(16.09)	(16.71)	(0.13)	(0.42)	(0.27)	(29.74)	(26.39)	(28.07)
T3	Bispyribac sodium	3.95^{ef}	3.28^{fg}	3.66^{efg}	4.03^{cd}	3.73^{cde}	3.98^{cd}	0.91^{cd}	1.15^{bc}	1.07^{cde}	5.71^{e}	5.07^{e}	5.48^{f}
	+ urea 1%	(15.66)	(11.73)	(13.70)	(16.76)	(14.95)	(15.86)	(0.34)	(1.08)	(0.71)	(32.76)	(27.76)	(30.26)
T4	Fenoxaprop-p-ethyl	4.20^{ef}	4.18^{ef}	4.24^{defg}	7.33^{b}	5.79^{b}	6.61^{b}	1.47^{b}	1.31^{bc}	1.40^{bc}	8.57^{bcd}	7.37^{bc}	7.99^{bcde}
	+ urea 1%	(17.81)	(18.81)	(18.31)	(54.53)	(34.70)	(44.62)	(1.90)	(1.31)	(1.61)	(74.25)	(54.82)	(64.54)
T5	Carfentrazone ethyl	7.55^{b}	7.10^{bc}	7.40^{b}	3.92^{cd}	2.30^{efg}	3.22^{de}	0.80^{d}	1.35^{bc}	1.12^{bcde}	8.63^{bc}	7.54^{bc}	8.15^{bcde}
	+ urea 1%	(59.33)	(5.97)	(55.25)	(16.26)	(4.97)	(10.62)	(0.15)	(1.40)	(0.78)	(75.95)	(57.33)	(66.64)
T6	(Chlorimuron ethyl	7.41^{bc}	6.93^{bc}	7.18^{b}	3.19^{de}	1.92^{fg}	2.59^{ef}	0.98^{bcd}	0.98^{c}	1.00^{de}	8.11^{bcd}	7.19^{bc}	7.67^{cde}
	+ metsulfuron methyl)	(55.01)	(48.32)	(51.67)	(10.34)	(3.23)	(6.78)	(0.50)	(0.53)	(0.51)	(65.84)	(52.08)	(58.96)
	+ urea 1%												
T7	Cyhalofop butyl	4.30^{ef}	5.10^{de}	4.72^{def}	8.21^{ab}	5.97^{b}	7.18^{b}	1.39^{bc}	1.57^{b}	1.51^{b}	9.46^{b}	8.03^{bc}	8.78^{bc}
		(20.33)	(26.98)	(23.61)	(67.75)	(35.87)	(51.81)	(1.53)	(2.05)	(1.79)	(89.52)	(64.89)	(77.21)
T8	(Cyhalofop butyl	4.36^{ef}	4.51^{ef}	4.46^{defg}	5.01^{c}	4.81^{b}	4.91^{c}	1.06^{bcd}	1.15^{bc}	1.16^{bcde}	6.92^{de}	6.65^{cd}	6.80^{c}
	+ penoxsulam)	(21.98)	(21.48)	(21.73)	(25.43)	(22.93)	(24.18)	(0.77)	(0.93)	(0.85)	(48.18)	(45.34)	(46.76)
T9	Bispyribac sodium	5.44^{cde}	4.65^{ef}	5.10^{de}	4.85^{c}	4.69^{bc}	4.76^{c}	1.18^{bcd}	1.15^{bc}	1.20^{bcde}	7.52^{cd}	6.75^{c}	7.15^{de}
		(31.79)	(23.31)	(27.55)	(24.78)	(21.67)	(22.97)	(0.96)	(0.95)	(0.96)	(57.03)	(45.93)	(51.48)
T10	Fenoxaprop-p-ethyl	5.24^{def}	5.43^{cde}	5.34^{cd}	7.86^{ab}	6.18^{bc}	7.07^{b}	1.20^{bcd}	1.39^{bc}	1.30^{bcd}	9.54^{b}	8.34^{b}	8.96^{b}
		(28.58)	(30.54)	(29.56)	(62.85)	(37.81)	(50.33)	(0.96)	(1.44)	(1.20)	(92.39)	(69.80)	(81.18)
T11	Carfentrazone ethyl	7.09^{bcd}	6.45^{bcd}	6.79^{bc}	3.64^{cd}	3.07^{def}	3.35^{de}	0.98^{bcd}	1.26^{bc}	1.14^{bcde}	8.05^{bcd}	7.20^{bc}	7.66^{cde}
		(51.25)	(41.67)	(46.46)	(13.87)	(9.10)	(11.49)	(0.54)	(1.12)	(0.83)	(65.66)	(51.89)	(58.77)
T12	(Chlorimuron ethyl	7.88^{ab}	7.65^{ab}	7.78^{b}	3.50^{cde}	2.66^{defg}	3.07^{de}	1.23^{bcd}	1.33^{bc}	1.30^{bcd}	8.68^{bc}	8.15^{bc}	8.44^{bc}
	+ metsulfuron methyl)	(62.58)	(58.68)	(60.63)	(12.36)	(6.56)	(9.46)	(1.08)	(1.37)	(1.23)	(76.02)	(66.62)	(71.32)
T13	Hand weeded control	3.25^{f}	2.32^{g}	2.85^{g}	1.93^{e}	1.35^{g}	1.58^{f}	1.40^{bc}	1.32^{bcb}	1.38^{bcd}	4.00^{f}	2.88^{f}	3.49^{g}
		(10.65)	(5.59)	(8.12)	(3.93)	(1.52)	(2.73)	(1.54)	(1.30)	(1.42)	(16.13)	(8.41)	(12.27)
T14	Unweeded control	9.66^{a}	9.25^{a}	9.47^{a}	9.35^{a}	8.19^{a}	8.81^{a}	2.03^{a}	2.60^{a}	2.33^{a}	13.61^{a}	12.^{59a}	13.14^{a}
		(93.34)	(86.37)	(89.86)	(88.68)	(67.03)	(77.86)	(3.69)	(6.28)	(4.98)	(185.72)	(159.67)	(172.70)
SEm		0.53	0.52	0.52	0.60	0.52	0.56	0.09	0.11	0.09	0.61	0.57	0.59
CD (0.05)		2.09	1.74	1.66	1.57	1.51	1.11	0.56	0.58	0.39	1.66	1.56	1.20

*√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 herbicide-urea combinations on weed dry weight at 30 days after application (kg/ha)

Treatments		Grasses			Sedges			Broad Leaf Weeds			Total		
		1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1	Cyhalofop butyl + urea 1%	7.38^{d} (55.46)	7.55^{de} (57.26)	7.48^{ef} (56.36)	10.19^{b} (105.60)	8.11^{b} (67.30)	9.21^{b} (86.45)	1.81^{bc} (2.80)	2.05^{b} (3.79)	1.81^{b} (3.30)	12.71^{bc} (163.85)	11.28^{bcd} (128.35)	12.02^{cd} (146.10)
T2	(Cyhalofop butyl + penoxsulam) + urea 1%	6.43^{d} (41.61)	6.33^{e} (40.27)	6.40^{f} (40.94)	5.99^{cd} (36.35)	5.69^{cd} (32.58)	5.87^{cde} (34.47)	1.22^{c} (1.16)	1.16^{c} (0.97)	1.00^{c} (1.07)	8.89^{e} (79.12)	8.59^{e} (73.82)	8.74^{f} (76.47)
T3	Bispyribac sodium + urea 1%	6.73^{d} (45.44)	6.69^{e} (44.96)	6.71^{f} (45.20)	5.68^{cd} (32.78)	5.36^{cd} (31.75)	5.66^{cdef} (32.26)	1.42^{bc} (1.52)	1.69^{b} (2.43)	1.39^{bc} (1.97)	8.92^{e} (79.73)	8.87^{e} (79.13)	8.91^{f} (79.43)
T4	Fenoxaprop-p-ethyl + urea 1%	6.87^{d} (48.68)	7.83^{de} (62.32)	7.37^{ef} (55.50)	10.90^{ab} (119.46)	8.23^{b} (68.82)	9.66^{b} (94.14)	1.63^{bc} (2.29)	1.97^{b} (3.52)	1.65^{b} (2.90)	13.04^{bc} (170.42)	11.58^{bc} (134.66)	12.33^{bcd} (152.54)
T5	Carfentrazone ethyl + urea 1%	11.65^{b} (135.97)	11.22^{b} (127.99)	11.46^{bc} (131.98)	5.18^{cd} (27.02)	4.52^{cd} (21.22)	4.87^{def} (24.12)	1.52^{bc} (2.16)	1.83^{bc} (2.93)	1.54^{bc} (2.55)	12.84^{bc} (165.15)	12.27^{b} (152.14)	12.57^{bcd} (158.64)
T6	(Chlorimuron ethyl + metsulfuron methyl) + urea 1%	11.38^{b} (132.62)	11.02^{b} (123.44)	11.22^{bc} (127.98)	4.47^{d} (20.53)	4.04^{d} (17.36)	4.34^{f} (18.95)	1.86^{bc} (3.01)	1.65^{bc} (2.75)	1.64^{b} (2.88)	12.40^{bc} (156.15)	11.91^{b} (143.45)	12.16^{cd} (149.81)
T7	Cyhalofop butyl	7.45^{d} (56.98)	7.92^{de} (64.04)	7.70^{ef} (60.51)	11.43^{ab} (132.24)	8.64^{b} (75.03)	10.17^{ab} (103.63)	2.02^{b} (3.58)	2.17^{b} (4.23)	1.97^{b} (3.90)	13.86^{b} (192.79)	11.92^{b} (143.30)	12.96^{bc} (168.05)
T8	(Cyhalofop butyl + penoxsulam)	6.96^{d} (48.39)	7.43^{de} (55.09)	7.20^{ef} (51.99)	6.63^{c} (43.90)	6.21^{c} (38.71)	6.42^{c} (41.31)	1.62^{bc} (2.18)	1.58^{bc} (2.14)	1.44^{bc} (2.16)	9.72^{de} (94.47)	9.82^{d} ^{e}(96.43)	9.77^{f} (95.45)
T9	Bispyribac sodium	7.69^{d} (60.72)	7.81^{de} (61.34)	7.80^{ef} (61.03)	6.18^{cd} (39.53)	6.16^{c} (38.60)	6.18^{cd} (39.07)	1.84^{bc} (3.06)	1.98^{b} (3.45)	1.79^{b} (3.26)	10.16^{de} (103.31)	10.13^{cde} (103.39)	10.15^{ef} (103.35)
T10	Fenoxaprop-p-ethyl	8.67^{cd} (77.35)	8.80^{cd} (77.65)	8.76^{de} (77.50)	11.29^{ab} (127.87)	9.06^{ab} (83.76)	10.27^{ab} (105.57)	1.89^{bc} (3.35)	1.89^{bc} (3.35)	1.80^{b} (3.35)	14.40^{b} (208.56)	12.81^{b} (164.26)	13.64^{b} (186.41)
T11	Carfentrazone ethyl	10.28^{bc} (106.81)	10.23^{bc} (105.43)	10.29^{cd} (106.12)	4.99^{cd} (25.28)	4.21^{d} (18.23)	4.63^{ef} (21.75)	1.80^{bc} (2.85)	1.92^{bc} (3.28)	1.72^{b} (3.07)	11.60^{cd} (134.93)	11.22^{bcd} (126.94)	11.44^{de} (130.97)
T12	(Chlorimuron ethyl + metsulfuron methyl)	12.67^{ab} (166.73)	11.76^{b} (138.69)	12.31^{b} (152.71)	4.98^{cd} (26.52)	4.33^{d} (19.87)	4.69^{ef} (23.20)	1.93^{b} (3.30)	1.99^{b} (3.70)	1.84^{b} (3.50)	13.87^{b} (196.55)	12.73^{b} (162.26)	13.37^{bc} (179.40)
T13	Hand weeded control	3.43^{e} (11.90)	3.45^{f} (12.33)	3.47^{g} (12.11)	2.21^{e} (5.02)	1.64^{e} (2.90)	1.97^{g} (3.96)	1.76^{bc} (2.61)	1.42^{bc} (1.53)	1.44^{bc} (2.07)	4.42^{f} (19.53)	4.08^{f} (16.76)	4.26^{g} (18.14)
T14	Unweeded control	14.48^{a} (209.97)	15.04^{a} (227.61)	14.77^{a} (218.79)	12.22^{a} (150.79)	10.56^{a} (112.12)	11.42^{a} (131.45)	3.20^{a} (9.76)	3.92^{a} (15.02)	3.51^{a} (12.39)	19.22^{a} (370.52)	18.79^{a} (354.75)	19.01^{a} (362.63)
SEm		0.79	0.76	0.78	0.86	0.65	0.75	0.12	0.17	0.15	0.92	0.85	0.88
CD (0.05)		2.47	1.85	1.65	1.82	1.82	1.34	0.68	0.77	0.62	2.08	1.71	1.48

*√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

the herbicides efficiency in controlling annual weeds of wheat.

There was no impact for urea mixing with herbicides at 30 days after application (Table 2). Although the trend was similar and mixing with urea resulted in numerically lower values for weed dry matter production as compared to application without urea, the effects were not significant.

Weed control efficiency and weed index

The weed control efficiency (WCE) is a measure of the control of weeds by herbicides. From the data pooled over the two years of experimentation, it could be seen that the WCE followed the same trend as dry matter production at 15 and 30 days after treatment application (Table 3). The highest efficiencies of 93 and 95 per cent were recorded for hand weeding, followed by 84 and 79 per cent for cyhalofop butyl + penoxsulam with urea, and 83 and 78 per cent for bispyribac sodium with urea at 15 and 30 days after application respectively. Pooled data on weed dry weight at 15 days after herbicide application revealed that mixing with urea could enhance weed control efficiencies of bispyribac sodium and cyhalofop butyl+ penoxsulam by 17.5 per cent and 14.85 per cent respectively as compared to application without urea. The weed index (WI) was lowest for the treatment bispyribac with urea (1.89%), followed by cyhalofop butyl + penoxsulam with urea, indicating that these treatments had the lowest negative effect on rice yields. Tank mixing with urea thus conferred higher efficiency to bispyribac sodium against grasses than grass killers like cyhalofop butyl and fenoxaprop-p-ethyl. High weed indices were recorded by the broad leaf

Table 3. Effect of herbicide-urea combinations on Weed Control Efficiency and Weed Index

Treatments		WCE (%)						WI (%)		
		1st year 15 DAS	2nd year 30 DAS	Pooled 15 DAS	1st year 30 DAS	2nd year 15 DAS	Pooled 30 DAS	1st year	2nd year	Pooled
T1	Cyhalofop butyl + urea 1%	61.37	55.78	65.81	63.82	63.43	59.71	15.69	21.61	18.99
T2	(Cyhalofop butyl + penoxsulam) + urea 1%	83.98	78.65	83.47	79.19	83.75	78.91	5.13	2.45	3.64
T3	Bispyribac sodium+ urea 1%	82.36	78.48	82.62	77.69	82.48	78.10	2.93	1.05	1.89
T4	Fenoxaprop-p-ethyl+ urea 1%	60.02	54.00	65.66	62.04	62.63	57.93	19.79	21.73	20.87
T5	Carfentrazone ethyl + urea 1%	59.11	55.43	64.09	57.11	61.41	56.25	28.15	36.57	32.83
T6	(Chlorimuron ethyl + metsulfuron methyl) + urea 1%	64.55	57.85	67.38	59.56	65.86	58.69	25.22	34.11	30.17
T7	Cyhalofop butyl	51.80	47.97	59.36	59.61	55.30	53.66	20.38	27.69	24.45
T8	(Cyhalofop butyl + penoxsulam)	74.06	74.50	71.60	72.82	72.92	73.68	18.04	19.39	18.79
T9	Bispyribac sodium	69.29	72.12	71.23	70.86	70.19	71.50	13.05	19.16	16.45
T10	Fenoxaprop-p-ethyl	50.25	43.71	56.28	53.70	53.04	48.59	20.97	26.75	24.19
T11	Carfentrazone ethyl	64.65	63.58	67.50	64.22	65.97	63.89	25.51	30.37	28.22
T12	(Chlorimuron ethyl + metsulfuron methyl)	59.07	46.95	58.28	54.26	58.70	50.53	33.43	42.06	38.23
T13	Hand weeded control	91.32	94.73	94.73	95.28	92.90	95.00	-	-	-
T14	Unweeded control	-	-	-	-	-	-	55.43	74.77	66.19

herbicides, both with and without urea mixing, while the highest value was for the weedy check.

Effect on rice growth parameters

Plant height of rice was not affected significantly by tank mixing of herbicides with urea at the three stages of observation. Tiller number was also not significantly influenced by mixing herbicides with urea at 30 DAS (Table 4). At 60 DAS, bispyribac sodium and cyhalofop butyl + penoxsulam mixed with urea produced higher tiller number per unit area, on par with hand weeding, which was the best treatment. However, other herbicide treatments, with and without urea mixing, were also statistically on par, though numerically lower in tiller production. At harvest, as per pooled data, tiller number was again highest in the hand weeded plot (404), with the treatment bispyribac sodium combined with urea being on par (386). Application of bispyribac sodium alone also produced comparable tiller number (365). In general, tank mixing of herbicides with urea had a positive effect on tiller number of rice.

Effect on yield attributes and yields of rice

Significant positive effect of urea mixing was observed on rice yield attributes only with the herbicides cyhalofop butyl + penoxsulam and bispyribac sodium, which could be directly related to the higher weed control efficiency in these two treatments. Significantly higher number of panicles per unit area was observed in the treatments

Table 4. Effect of herbicide-urea combinations on tiller number of rice at different stages of growth

Treatments		No. of tillers / m^2								
		1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1	Cyhalofop butyl + urea 1%	504.67^{abcd}	406.13^{abc}	455.40^{abc}	555.87^{abcd}	494.93^{bc}	525.40^{bcd}	328.00^{cd}	341.33^{abcde}	334.67^{cde}
T2	(Cyhalofop butyl + penoxsulam) + urea 1%	529.87^{abc}	429.60^{abc}	479.73^{ab}	610.13^{abc}	533.60^{abc}	571.87^{abc}	359.33^{abc}	362.27^{abc}	360.80^{bcd}
T3	Bispyribac sodium+ urea 1%	608.53^{a}	445.33^{ab}	526.93^{a}	684.93^{ab}	565.60^{ab}	625.27^{ab}	397.33^{ab}	373.73^{ab}	385.53^{ab}
T4	Fenoxaprop-p-ethyl+ urea 1%	450.53^{bcde}	366.40^{abc}	408.47^{bcd}	527.47^{abcde}	455.73^{bc}	491.60^{cde}	293.33^{def}	330.40^{bcde}	311.87^{efg}
T5	Carfentrazone ethyl + urea 1%	365.60^{def}	307.07^{cd}	336.33^{de}	419.20^{def}	444.27^{bc}	431.73^{de}	254.00^{ef}	290.13^{e}	272.07^{gh}
T6	(Chlorimuron ethyl + metsulfuron methyl) + urea 1%	402.80^{cdef}	317.73^{bcd}	360.27^{cd}	518.00^{bcde}	440.80^{bc}	479.40^{cde}	273.33^{def}	303.73^{cde}	288.53^{fgh}
T7	Cyhalofop butyl	481.60^{abcde}	403.20^{abc}	442.40^{abc}	556.93^{abcd}	489.60^{bc}	523.27^{bcd}	310.67^{cde}	334.27^{bcde}	322.47^{def}
T8	(Cyhalofop butyl + penoxsulam)	501.87^{abcd}	428.40^{abc}	465.13^{ab}	538.00^{abcde}	512.00^{bc}	525.00^{bcd}	334.00^{bcd}	343.87^{abcde}	338.93^{cde}
T9	Bispyribac sodium	506.67^{abcd}	420.27^{abc}	463.47^{ab}	$610.40a^{bc}$	525.07^{bc}	567.73^{bc}	372.00^{abc}	357.87^{abcd}	364.93^{abc}
T10	Fenoxaprop-p-ethyl	453.73^{abcde}	345.33^{bcd}	399.53^{bcd}	521.33^{abcde}	446.93^{bc}	484.13^{cde}	273.33^{def}	304.80^{cde}	289.07^{fgh}
T11	Carfentrazone ethyl	429.60^{bcdef}	343.20^{bcd}	386.40^{bcd}	479.47^{cde}	442.40^{bc}	460.93^{de}	269.33^{def}	300.53^{de}	284.93^{fgh}
T12	(Chlorimuron ethyl + metsulfuron methyl)	329.47^{ef}	314.40^{bcd}	321.93^{de}	375.73^{ef}	432.80^{c}	404.27^{e}	243.33^{f}	282.40^{e}	262.87^{h}
T13	Hand weeded control	568.93^{ab}	489.87^{a}	529.40^{a}	688.27^{a}	653.87^{a}	671.07^{a}	406.67^{a}	401.47^{a}	404.07^{a}
T14	Unweeded control	283.20^{f}	219.20^{d}	251.20^{e}	302.67^{f}	249.73^{d}	276.20^{f}	152.00^{g}	176.80^{f}	164.40^{i}
SEm		24.21	18.98	21.33	29.08	24.01	25.95	18.30	14.40	16.24
CD (0.05)		157.40	134.83	96.56	169.93	126.97	103.00	64.71	61.62	40.19

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

Table 5. Effect of herbicide-urea combinations on yield attributes of rice

Treatments		Yield attributes of rice								
		No. of panicles per m^2			No. of grains per panicle			% filled grains per panicle		
		1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1	Cyhalofop butyl + urea 1%	262.00^{c}	263.67^{abc}	262.83^{bc}	89.00^{a}	106.00^{a}	97.50^{abc}	91.47^{abcd}	77.20^{cde}	84.33^{cde}
T2	(Cyhalofop butyl + penoxsulam) + urea 1%	337.33^{ab}	318.33^{ab}	327.83^{a}	93.67^{a}	112.20^{a}	102.93^{ab}	93.62^{abc}	80.06^{abcd}	86.84^{abc}
T3	Bispyribac sodium+ urea 1%	343.33^{a}	319.00^{ab}	331.17^{a}	94.53^{a}	110.20^{a}	102.37^{abc}	94.14^{ab}	83.27^{ab}	88.71^{ab}
T4	Fenoxaprop-p-ethyl+ urea 1%	260.67^{c}	254.33^{bc}	257.50^{bc}	87.20^{a}	105.80^{a}	96.50^{abc}	91.43^{abcd}	75.78^{defg}	83.60^{cde}
T5	Carfentrazone ethyl + urea 1%	221.33^{c}	220.33^{c}	220.83^{cd}	85.87^{a}	103.40^{a}	94.63^{bc}	86.47^{e}	70.83^{fg}	78.65^{fg}
T6	(Chlorimuron ethyl + metsulfuron methyl) + urea 1%	224.00^{c}	227.67^{c}	225.83^{cd}	83.73^{ab}	104.00^{a}	93.87^{c}	89.91^{cde}	74.50^{defg}	82.20^{def}
T7	Cyhalofop butyl	255.33^{c}	250.33^{bc}	252.83^{bc}	88.87^{a}	104.60^{a}	96.74^{abc}	91.06^{abcd}	76.38^{cdef}	83.72^{cde}
T8	(Cyhalofop butyl + penoxsulam)	269.33^{bc}	275.00^{abc}	272.17^{b}	93.47^{a}	107.00^{a}	100.23^{abc}	92.68^{abc}	78.72^{bcde}	85.70^{bcd}
T9	Bispyribac sodium	270.67^{bc}	278.33^{abc}	274.50^{b}	93.07^{a}	110.00^{a}	101.54^{abc}	93.94^{ab}	81.97^{abc}	87.95^{ab}
T10	Fenoxaprop-p-ethyl	252.67^{c}	243.67^{c}	248.17^{bc}	86.40^{a}	104.80^{a}	95.60^{bc}	90.83^{bcd}	75.07^{defg}	82.95^{de}
T11	Carfentrazone ethyl	230.67^{c}	239.67^{c}	235.17^{bc}	88.80^{a}	104.40^{a}	96.60^{abc}	87.75^{de}	74.21^{efg}	80.98^{efg}
T12	(Chlorimuron ethyl + metsulfuron methyl)	210.00^{c}	206.33^{c}	208.17^{d}	86.73^{a}	106.00^{a}	96.37^{abc}	86.51^{e}	70.10^{g}	78.30^{g}
T13	Hand weeded control	345.67^{a}	333.67^{a}	339.67^{a}	94.80^{a}	114.00^{a}	104.40^{a}	94.80^{a}	84.61^{a}	89.71^{a}
T14	Unweeded control	118.00^{d}	115.67^{d}	116.83^{e}	72.47^{b}	83.33^{b}	77.90^{d}	77.39^{f}	54.86^{h}	66.13^{h}
SEm		16.03	14.71	15.33	1.56	1.91	1.71	1.22	1.96	1.58
CD (0.05)		69.74	73.38	44.30	11.52	12.99	8.57	3.96	5.84	3.61

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

cyhalofop butyl + penoxsulam mixed with urea (327) and bispyribac sodium mixed urea (331). These two treatments were at par with each other and with the hand weeded control (340). All other treatments were inferior and at par with each other (Table 5). Number of grains per panicle was highest in the hand weeded treatment (104.4), but all other treatments except unweeded control (77.9) had comparable values. The percentage of filled grains was also observed to be highest in the treatments hand weeded control (89.7%), bispyribac sodium mixed with urea (88.7%), and cyhalofop butyl + penoxsulam mixed with urea (86.8%). Lowest values for grain filling percentage were recorded for unweeded control (66%), carfentrazone with and without urea mixing (78.6 and 80.9%), and chlorimuron ethyl + metsulfuron methyl without and with urea mixing (78.3 and 82.2%). Grasses being dominant in the Kole area, the ineffectiveness of these broad leaf herbicides, especially in the critical period of crop-weed competition, may be the reason for this.

Data on rice grain yield pooled over the two years showed that the treatment hand weeded control (5.13 t/ha), bispyribac sodium with urea (5.03 t/ha) and cyhalofop butyl + penoxsulam with urea (4.94 t/ha) produced highest yields (Table 6). Tank mixing with urea resulted in increases of grain yield to the tune of 17.52 per cent in bispyribac sodium and 18.75 per cent in cyhalofop butyl + penoxsulam as compared to their application without urea mixing. This is commensurate with the trend in weed dry matter production and yield attributes. Bispyribac sodium and cyhalofop butyl + penoxsulam applied without urea mixing also produced high grain yields (4.28 and 4.16 t/ha), in keeping with their broad spectrum action, but urea mixing undoubtedly imparted an added advantage to these two herbicides in increasing yields. In the same line, increased grain yield in wheat due to mixing herbicides with 1% urea was also reported by Pandey and Singh (1994) and Soliman et al. (2011), which was attributed to the higher weed control efficiencies in these treatments.

Straw yields followed the same trend as grain yields, in the order hand weeded control > bispyribac sodium with urea > cyhalofop butyl + penoxsulam with urea > bispyribac sodium > cyhalofop butyl + penoxsulam (Table 6).

Tank mixing of cyhalofop butyl + penoxsulam and bispyribac sodium with urea resulted in significant reduction in weed dry matter production in wet seeded rice 15 days after application, and was on par with hand weeded control. The synergistic effect of the tank mixed application was also reflected in

Table 6. Effect of herbicide-urea combinations on grain and straw yields of rice

Treatments		Grain yield(t/ha)			Straw yield(t/ha)		
		1st year	2nd year	Pooled	1st year	2nd year	Pooled
T1	Cyhalofop butyl + urea 1%	3.83^{abcd}	4.47^{bc}	4.15^{cd}	4.67^{abcd}	5.15^{bcd}	4.91^{bcdef}
T2	(Cyhalofop butyl + penoxsulam) + urea 1%	4.31^{ab}	5.57^{a}	4.94^{ab}	4.81^{abc}	5.89^{abc}	5.35^{abc}
T3	Bispyribac sodium+ urea 1%	4.41^{ab}	5.65^{a}	5.03^{a}	5.01^{a}	6.04^{ab}	5.53^{ab}
T4	Fenoxaprop-p-ethyl+ urea 1%	3.65^{bcd}	4.47^{bc}	4.06^{cde}	4.48^{abcde}	5.23^{abcd}	4.85^{cdefg}
T5	Carfentrazone ethyl + urea 1%	3.27^{cd}	3.62^{cd}	3.44^{ef}	4.10^{cde}	4.28^{de}	4.19^{hi}
T6	(Chlorimuron ethyl + Metsulfuron methyl) + urea 1%	3.40^{cd}	3.76b^{cd}	3.58^{def}	3.90^{de}	4.58^{de}	4.24^{ghi}
T7	Cyhalofop butyl	3.62^{bcd}	4.13^{bc}d	3.87^{cde}	4.45^{abcde}	5.00^{cde}	4.73^{defgh}
T8	(Cyhalofop butyl + penoxsulam)	3.73^{abcd}	4.60^{b}	4.16^{cd}	4.69^{abc}	5.60^{abc}	5.15^{abcde}
T9	Bispyribac sodium	3.95^{abc}	4.61^{b}	4.28^{bc}	4.95^{ab}	5.60^{abc}	5.28^{abcd}
T10	Fenoxaprop-p-ethyl	3.59^{bcd}	4.18^{bcd}	3.89^{cde}	4.09^{cde}	5.04^{bcd}	4.57^{efgh}
T11	Carfentrazone ethyl	3.39^{cd}	3.97^{bcd}	3.68^{cdef}	4.22^{bcde}	4.55^{de}	4.39^{fghi}
T12	(Chlorimuron ethyl + Metsulfuron methyl)	3.03^{d}	3.31^{d}	3.17^{f}	3.86^{e}	4.03^{e}	3.94^{i}
T13	Hand weeded control	4.55^{a}	5.71^{a}	5.13^{a}	5.18^{a}	6.16^{a}	5.67^{a}
T14	Unweeded control	2.03^{e}	1.44^{e}	1.73^{g}	3.03^{f}	2.23^{f}	2.63^{j}
S.Em		0.17	0.29	0.23	0.15	0.27	0.21
C.D. (0.05)		0.87	0.93	0.70	0.78	1.01	0.62

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

higher tiller number of rice per unit area at all stages of observation. Yield attributes and grain yield were also higher in these treatments. Thus urea was seen to synergistically interact with specific herbicides. In such situations a decrease in the dose of herbicide could be contemplated. Variations in the doses of herbicides and the concentration of urea to be mixed need to be tested to arrive at the best combination.

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