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Weed management efficacy of tank mix herbicides in wet-seeded rice

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ABSTRACT

Tank mixing of herbicides is commonly practiced by farmers for control of a wide spectrum of weeds to save labour and reduce cultivation costs. However, little is known of the probable effects of herbicide mixing on herbicide efficacy. Field experiments were conducted in 2019-20 and 2020-21 in the Kole area of Thrissur district, Kerala, India to assess the feasibility of tank mixing of commonly used herbicides. The treatments involved tank mixtures and sequential applications of fenoxaprop-p-ethyl, chlorimuron-ethyl + metsulfuron-methyl, carfentrazone, bispyribac-sodium, and cyhalofop-butyl + penoxsulam. Hand-weeded and unweeded controls were also included for comparison. Tank mixing of fenoxaprop-p-ethyl with broad-leaf herbicides reduced its efficacy against *Echinochloa colona*, as compared to sequential application. The mixture of cyhalofop-butyl + penoxsulam with chlorimuron-ethyl + metsulfuron-methyl was more effective against *E. colona* than the former applied alone. This mixture also caused greater biomass reduction of *Cyperus iria* as compared to the sole application of cyhalofop-butyl + penoxsulam. Tank mixing of fenoxaprop-p-ethyl with bispyribac-sodium was more effective against *Echinochloa stagnina* and *C. iria* as compared to their sequential application, but this mixture was less effective against *E. colona.* A similar trend was observed with total weed biomass production. Highest rice yield attributes and grain yield (3.97 t/ha) were recorded with tank mixed application of cyhalofop-butyl + penoxsulam and chlorimuron-ethyl + metsulfuron-methyl, followed by the mixture of fenoxaprop with bispyribac-sodium.

INTRODUCTION

The common practice among rice farmers is tank mixing of herbicides with the objectives of broader spectrum weed control, enhanced weed control efficiency and possibility of reducing herbicide quantity (Moss *et al.* 2007). Herbicide mixing may also result in additive or synergistic effects with potential savings in labour and labour charges. Antagonistic responses may also be elicited (Matzenbacher *et al.* 2015, Bhullar *et al.* 2016). The Kole area in Kerala state, India, is a major rice tract, covering an area of 13632 ha. This unique wetland ecosystem is situated 0.5 to 1.0 m below mean sea level and remains submerged for about six months in a year. The productivity of rice in this area is perhaps the highest in the state, mainly due to the inherent fertility of the soil (Johnkutty and Venugopal 1993). Weeds are a major limiting factor of Kole wetlands, and a total of 140 species of weeds belonging to 23 families of dicotyledons, 11 families of monocotyledons and 5 families of water fern have been identified (Sujara and Sivaperuman 2008).

Kole farmers use a variety of herbicides and their mixtures to obtain a broader spectrum of weed control at lesser cost as labour is scarce and expensive. However, the mixing is done without any knowledge of the synergistic or antagonistic effect of the herbicides in the mixtures, on weed flora. In an attempt to identify herbicide mixtures with scientific basis for weed control in the Kole lands, the tank mix application of cyhalofop-butyl with pyrazosulfuron-ethyl was found effective in managing weeds in wet seeded rice (Atheena *et al.* 2017). However, tank mixing of cyhalofop with (chlorimuron-ethyl + metsulfuron-methyl) reduced the graminicidal activity of cyhalofop. Sequential application of fenoxaprop or cyhalofop followed by chlorimuron-ethyl + metsulfuron-methyl was found to give effective control of a broad spectrum of weeds (Prameela *et al.* 2014). The present study was conducted to identify suitable combinations of different herbicides for tank mixing and application for broad spectrum weed control in wet seeded rice in the Kole area of Kerala, India.

MATERIALS AND METHODS

Field experiments were conducted during the first crop season (October to January) of the Kole lands during 2019-20 and 2020-21, in a farmer's field at Alappad in Thrissur district (geographically, the area is located between $10^0$20' and $10^0$43' North latitudes and $76^0$58' and $76^0$17' East longitudes) of Kerala. The soil of the area is clayey, belonging to the taxonomical order Inceptisol. The pH is 4.6 and the soil has 188.3 kg available N, 21.5 kg available P, and 152.4 kg available K/ha. The area has been under rice traditionally for several decades. After land preparation, plots of 5 m length and 4 m breadth were formed by bunds of 30 cm width and 15 cm height. A randomized block design with three replications was used.

Direct wet-seeding of rice variety '*Manuratna*' (100-105 days duration) was done between 12th and 18th October in both years. Germinated seeds were broadcasted, adopting a seed rate of 100 kg/ha. Fertilizers were applied as per the package of practices recommendation of the Kerala Agricultural University (KAU 2016). Ninety kg N, 35 kg P and 45 kg K were applied to the rice crop. One third of N, full dose of P and half dose of K were applied one week after sowing. One third of N was applied as tillering stage, and the remaining one third N and half K were applied at panicle initiation. Fields were drained 10 days before harvest of the crop, which was done between 22nd and 31st January in the two seasons.

Commonly used herbicides in the area were applied as tank mixed treatments, as combinations or in sequence, *i.e.* fenoxaprop-p-ethyl + chlorimuron-ethyl + metsulfuron-methyl, fenoxaprop-p-ethyl + carfentrazone, fenoxaprop-p-ethyl + bispyribac-sodium, cyhalofop-butyl + penoxsulam + chlorimuron-ethyl + metsulfuron-methyl, fenoxaprop-p-ethyl followed by (*fb*) chlorimuron-ethyl + metsulfuron-methyl, fenoxaprop-p-ethyl *fb* carfentrazone, fenoxaprop-p-ethyl *fb* bispyribac-sodium, and cyhalofop-butyl + penoxsulam *fb* chlorimuron-ethyl + metsulfuron-methyl. These were compared with a popular broad-spectrum herbicide bispyribac-sodium and a pre-mix herbicide mixture cyhalofop-butyl + penoxsulam. A hand weeded control and an unweeded control were also included as treatments. Application of herbicides was done with a knapsack sprayer filled with a flat fan nozzle.

The effect of tank mixed herbicides on species-wise weed density and biomass in rice was observed at 15 days after herbicide application. For this, a sampling quadrat of 50 × 50 cm size was placed randomly at two locations in each plot. The weed samples were dried in an oven at 70°C for 48 hours and the weed biomass was measured. Plant height and number of tillers/m^2 of rice were observed at 30 and 60 days after seeding and at harvest. At physiological maturing of the crop, number of panicles per sq. m, number of grains per panicle and percentage of filled grains were recorded on ten randomly selected plants in each plot. On maturity, the crop was harvested manually and grain and straw yields from the net pot area (12 sq. m) were recorded.

Data were subjected to analysis of variance using the statistical package 'MSTAT-C' (Freed 1986). Data on density and biomass of weeds which showed wide variation, were subjected to square root transformation, $\sqrt{x+0.5}$, to make the analysis of variance valid (Gomez and Gomez 1984) and then analyzed following ANOVA, and the means were compared based on the critical differences (least significant difference) at 0.05 level of significance. The statistical software 'WASP 2.0' was used for the analysis.

RESULTS AND DISCUSSION

Weed spectra

The study area was infested with grasses, sedges and broad-leaf weeds, but grasses and sedges dominate. The main grass species were: *Echinochloa colona*, *Echinochloa stagnina*, *Oryza sativa* f. *spontanea* (weedy rice), and *Leptochloa chinensis*. *Cyperus iria* and *Fimbristylis miliacea* were the main sedges, though several other species also occurred sporadically. *Ludwigia perennis* and *Monochoria vaginalis* were the chief broad-leaf weeds, though *Sphenoclea zeylanic*a and *Limnocharis flava* were also observed in the second season of experimentation. As the density of broad-leaf weeds was relatively very low, only their total contribution to weed biomass has been discussed.

Species-wise weed biomass

The data on weed biomass at 15 days after application would correspond to the critical period of weed control in direct-seeded rice (Rao *et al.* 2007, Chauhan and Johnson 2011). Fenoxaprop when applied in sequence with other broad-leaf herbicides was found to be more effective in controlling *Echinochloa colona* in both seasons (**Table 1**). Tank mixing with chlorimuron-ethyl + metsulfuron-methyl resulted in 51 and 47% more weed biomass, in the first and second season, respectively. Corresponding increases for tank mixing with carfentrazone and bispyribac-sodium were 34 and 35%, and 63 and

52%, respectively in 2019-20 and 2020-21. A definite decrease in effectiveness of fenoxaprop on tank mixing with broad-leaf weedkillers on *E. colona* was seen. Fenoxaprop is a very effective graminicide, used widely in the Kole area for the control of *Echinochloa* spp. and *L. chinensis*. As it controls only grasses, it is tank mixed with broad-leaf herbicides like chlorimuron-ethyl + metsulfuron-methyl and carfentrazone, and also with broad spectrum herbicides like bispyribac-sodium to get a wider swath of control. Tank mixing of these herbicides were seen to reduce the effectiveness of fenoxaprop against *E. colona*. The reduction of the efficacy of the mixture fenoxaprop with bispyribac was reported by Blouin *et al.* (2010). The antagonistic effect of the mixture of bispyribac with fenoxaprop on *Dactyloctenium aegyptium*, *Achrachne racemosa* and *L. chinensis* (Bhullar *et al*. 2016), and fenoxaprop with halosulfuron on *E. crus-galli* (Zhang *et al*. 2005) were reported earlier. The reduced efficacy of the herbicide mixture fenoxaprop and carfentrazone against *E. crus-galli*, when compared to single application of fenoxaprop, was also documented. The tank mixture of fenoxaprop and carfentrazone was however, reported to be effective in controlling *Phalaris mino*r in wheat (Singh and Singh 2005, Yadav *et al.* 2009). In the present study, fenoxaprop applied in sequence with the broad-leaf herbicides, chlorimuron-ethyl + metsulfuron-methyl and bispyribac was more effective in controlling *E. colona*, but was less effective against *L. chinensis* and broad-leaf weeds. *Echinochloa stagnina*, however, was better controlled by the tank mixture of fenoxaprop and carfentrazone than by sequential application, indicating variation in effectiveness against different species of *Echinochloa*. This mixture was also seen to be more effective against *C. iria* than sequential application of the herbicides. However, tank mixing of the pre-mix herbicide cyhalofop-butyl + penoxsulam with chlorimuron-ethyl + metsulfuron-methyl resulted in significantly lower biomass of 0.97 and 1.89 kg/ha of *E. colona* as compared to the pre-mix herbicide used alone in both seasons (2.31 and 2.24 kg/ha).

Cyperus iria was the predominant and most vigorously growing sedge in the area in both years of experimentation. Though there was not much significant difference in the effect of herbicides applied after tank mixing or in sequence on *Cyperus iria*, it was observed that tank mixing of cyhalofop-butyl + penoxsulam with chlorimuron-ethyl + metsulfuron-methyl reduced sedge biomass in

Table 1. Effect of different treatments on species-wise weed biomass (kg/ha) at 15 days after application

Treatment	*Echinochloa colona*		*Echinochloa stagnina*		*Leptochloa chinensis*		*Cyperus iria*	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Fenoxaprop-p-ethyl + chlorimuron-ethyl + metsulfuron-methyl	2.67 (6.99)	3.01 (8.74)	1.95 (4.06)	2.33 (5.43)	1.28 (1.14)	0.71 (0.00)	3.54 (12.56)	3.85 (14.92)
Fenoxaprop-p-ethyl + carfentrazone	1.75 (3.11)	2.77 (7.84)	0.71 (0.00)	1.16 (1.27)	1.28 (1.17)	1.77 (2.62)	4.01 (16.15)	4.77 (22.44)
Fenoxaprop-p-ethyl + bispyribac-sodium	1.92 (4.19)	3.09 (9.22)	1.77 (2.69)	1.28 (1.29)	1.06 (0.63)	2.30 (5.08)	3.24 (10.67)	3.06 (9.15)
Cyhalofop butyl + penoxsulam + chlorimuron-ethyl + metsulfuron-methyl	0.97 (0.58)	1.89 (3.18)	0.71 (0.00)	1.06 (0.87)	0.89 (0.37)	1.10 (1.00)	2.52 (6.39)	2.79 (9.52)
Fenoxaprop-p-ethyl *fb* chlorimuron-ethyl + metsulfuron-methyl	1.29 (1.85)	1.60 (3.65)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.50 (2.07)	3.57 (12.79)	4.04 (16.02)
Fenoxaprop-p-ethyl *fb* carfentrazone	1.15 (1.21)	1.81 (3.53)	2.08 (4.75)	1.66 (2.77)	0.71 (0.00)	0.71 (0.00)	4.97 (25.23)	4.47 (19.84)
Fenoxaprop-p-ethyl *fb* bispyribac-sodium	0.71 (0.00)	1.48 (1.99)	2.12 (4.65)	2.48 (6.16)	1.16 (1.25)	1.47 (2.83)	4.16 (17.56)	3.95 (20.41)
Cyhalofop butyl + penoxsulam *fb* chlorimuron-ethyl + metsulfuron-methyl	1.68 (2.93)	1.91 (4.03)	0.71 (0.00)	1.02 (0.73)	1.02 (0.56)	1.68 (2.88)	2.93 (8.62)	3.67 (13.62)
Bispyribac-sodium	2.98 (9.04)	3.05 (9.06)	2.67 (7.05)	2.08 (3.91)	1.42 (1.56)	2.37 (5.43)	5.52 (30.83)	5.80 (33.63)
Cyhalofop-butyl + penoxsulam	2.31 (5.01)	2.24 (4.60)	3.13 (9.97)	2.68 (6.97)	0.71 (0.00)	1.13 (1.15)	4.40 (19.42)	5.49 (30.31)
Hand weeding	1.22 (1.12)	1.98 (4.76)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.53 (2.60)	1.53 (2.39)
Unweeded control	2.84 (8.03)	4.03 (15.81)	1.49 (2.97)	2.52 (6.25)	2.54 (6.22)	2.78 (8.06)	9.89 (100.82)	9.42 (88.52)
LSD (p=0.05)	1.39	1.50	1.11	1.14	0.53	1.28	1.31	2.10

$\sqrt{x+0.5}$ transformed values, original values in parentheses comparison to application of cyhalofop-butyl + penoxsulam alone 2.52 and 2.93 kg/ha in 2019-20 and 2.79 and 3.67 kg/ha in 2020-21, respectively. A clear synergism was noticed between these two herbicides which was reflected in the total weed biomass at 15 days after application. A similar effect was observed for tank mixing of fenoxaprop with bispyribac-sodium as comparison to their sequential application 3.24 and 4.16 kg/ha in 2019-20 and 3.06 and 3.95 in 2020-21, respectively. A synergistic effect of the tank mixture of fenoxaprop and ethoxysulfuron for the control of *E. crus-galli* and *E. colona* (Bhullar *et al*. 2016), *D. aegyptium* (Chauhan 2011) and of complex weed flora (Ramachandran and Balasubramanian 2012) was documented earlier.

Echinochloa stagnina, a species as important as *E. colona* in the Kole lands did not respond as clearly as the latter to tank mixing of fenoxaprop. A significant response was seen in both years of study with regard to tank mixing of fenoxaprop with chlorimuron-ethyl + metsulfuron-methyl. In 2019-20, dry weight of *E. stagnina* was increased by 63% due to tank mixing of these two herbicides while in 2020-21, the increase was 70%. Mixing of fenoxaprop with bispyribac-sodium, was found to increase the herbicidal efficacy against *E. stagnina* as compared to their sequential application with the weed biomass reduced by 20 and 94% in the two seasons, respectively. Tank mixing with carfentrazone did not elicit a specific trend.

Leptochloa chinensis is a grass weed which had become problematic in the last two decades in the Kole area, probably due to the sole indiscriminate use of bispyribac-sodium which was reported to be ineffective in controlling the weed (Jacob *et al*. 2017). Mixing of fenoxaprop with carfentrazone was seen to reduce the efficacy of fenoxaprop against *L. chinensis* as compared to the sequential application of the herbicides. Tank mixed application resulted in 1.28 and 1.77 kg/ha of *L. chinensis* biomass in 2019-21 and 2020-21 respectively, as compared to 0.71 kg/ha for sequential application in both seasons.

Weed biomass

Grasses and sedges were the main contributors to weed biomass at 15 days after application. Mixing of fenoxaprop with chlorimuron-ethyl + metsulfuron-methyl and bispyribac-sodium increased the grass weed biomass as compared to their application in sequence in both seasons (**Table 2**). Pooled analysis of the data showed that tank mixed application of fenoxaprop with chlorimuron-ethyl + metsulfuron-methyl and bispyribac produced 60 and 8% more biomass than their application in sequence, indicating some degree of antagonism. However, tank mixing of cyhalofop-butyl + penoxsulam with chlorimuron-ethyl + metsulfuron-methyl reduced the grass biomass from 2.84 to 2.41 kg/ha. This effect was seen in the pooled data on sedges also, wherein the biomass was reduced by 20%. There was no significant difference in the response of broad-leaf weeds to tank mixing or sequential application of herbicides.

Pooled data on total weed biomass revealed that tank mixing of cyhalofop-butyl + penoxsulam and chlorimuron-ethyl + metsulfuron-methyl significantly reduced weed biomass and was at par with hand weeding. Sequential application of fenoxaprop and carfentrazone and also of fenoxaprop and bispyribac, were found to give significantly better control of weeds than their tank mixed application. Application of bispyribac-sodium or cyhalofop-butyl + penoxsulam individually was less efficacious in controlling weed growth. In spite of antagonistic effect of tank mixtures of fenoxaprop with broad-leaf herbicides against grasses, total weed biomass in the tank mixture of fenoxaprop with bispyribac was at par with the above treatment, probably due to good control of specific grasses and sedges.

Rice yield attributes and grain yield

Significantly higher number of panicles per sq.m (287), number of grains per panicle (102), percentage of filled grains per panicle (91.6) and grain yield (3.97 t/ha) were recorded with cyhalofop-butyl + penoxsulam tank mixed with chlorimuron-ethyl + metsulfuron-methyl (**Table 3**). The hand weeded control treatment was on par with this (250, 100, 89.6 and 3.95, respectively). Tank mixing of fenoxaprop with bispyribac was also at par with this treatment with regard to number of grains per panicle and percentage of filled grains per panicle.

Effective weed control by the tank mixture of cyhalofop-butyl + penoxsulam and chlorimuron-ethyl + metsulfuron-methyl was reflected in the high grain yield in this treatment, which was more than 100% greater than that in the unweeded control, while that in the tank mixture of fenoxaprop with bispyribac was 85% higher.

Tank mixing of fenoxaprop with chlorimuron-ethyl + metsulfuron-methyl, carfentrazone and bispyribac-sodium caused a decrease in the activity of fenoxaprop against grasses, probably due to

Table 2. Effect of different treatments on grass, sedge and total weed biomass (kg/ha) at 15 days after application

Treatment	Grasses			Sedges			Total		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Fenoxaprop-p-ethyl + chlorimuron-ethyl + metsulfuron-methyl	3.53 (12.90)	4.74 (22.47)	4.20 (17.69)	3.84 (14.74)	3.93 (15.49)	3.99 (16.08)	5.26 (27.90)	6.42 (41.59)	5.89 (34.74)
Fenoxaprop-p-ethyl + carfentrazone	2.77 (7.24)	3.85 (15.46)	3.33 (11.35)	4.01 (16.15)	4.71 (22.44)	4.45 (19.87)	4.83 (23.39)	6.14 (37.90)	5.53 (30.65)
Fenoxaprop-p-ethyl + bispyribac-sodium	2.95 (8.40)	4.43 (19.87)	3.73 (14.14)	3.60 (12.99)	3.11 (9.50)	3.53 (12.46)	4.61 (21.39)	5.42 (29.49)	5.04 (25.44)
Cyhalofop butyl + penoxsulam + chlorimuron-ethyl + metsulfuron-methyl	1.52 (2.13)	3.09 (9.58)	2.41 (5.85)	2.80 (7.87)	2.81 (9.63)	3.00 (9.14)	3.17 (10.07)	4.31 (19.30)	3.80 (14.68)
Fenoxaprop-p-ethyl *fb* chlorimuron-ethyl + metsulfuron-methyl	1.78 (3.64)	3.24 (12.06)	2.62 (7.85)	4.05 (16.49)	4.13 (16.69)	4.20 (17.73)	4.48 (20.13)	5.61 (31.51)	5.08 (25.82)
Fenoxaprop-p-ethyl *fb* carfentrazone	2.77 (7.50)	3.97 (16.48)	3.39 (11.99)	4.97 (25.23)	4.47 (19.84)	4.92 (24.77)	5.71 (32.92)	6.17 (38.26)	5.95 (35.59)
Fenoxaprop-p-ethyl *fb* bispyribac-sodium	2.73 (8.11)	3.89 (15.72)	3.45 (11.92)	4.31 (18.89)	4.05 (20.67)	4.43 (20.95)	5.12 (27.01)	5.89 (36.49)	5.54 (31.75)
Cyhalofop butyl + penoxsulam *fb* chlorimuron-ethyl + metsulfuron-methyl	2.53 (6.58)	3.11 (11.02)	2.84 (8.80)	3.59 (12.94)	3.70 (13.82)	3.75 (14.21)	4.40 (19.52)	5.21 (27.53)	4.83 (23.53)
Bispyribac-sodium	4.35 (20.12)	5.19 (27.54)	4.85 (23.83)	6.04 (37.14)	5.83 (34.03)	6.16 (38.45)	7.56 (57.69)	7.83 (61.57)	7.70 (59.63)
Cyhalofop-butyl + penoxsulam	4.27 (18.20)	4.71 (22.43)	4.51 (20.31)	4.49 (20.24)	5.50 (30.48)	5.07 (25.87)	6.19 (38.43)	7.95 (63.53)	7.14 (50.98)
Hand weeding	1.59 (2.20)	2.92 (9.50)	2.35 (5.73)	2.07 (4.37)	1.62 (2.69)	1.98 (3.98)	2.56 (6.74)	3.69 (14.10)	3.22 (10.42)
Unweeded control	5.63 (31.59)	9.11 (82.99)	7.56 (57.29)	9.93 (101.70)	9.48 (89.54)	10.10 (103.80)	11.55 (134.86)	13.68 (187.24)	12.68 (161.05)
LSD (p=0.05)	1.18	1.63	1.04	1.29	2.05	1.29	1.27	1.28	0.94

$\sqrt{x+0.5}$ transformed values, original values in parentheses

Table 3. Effect of different treatments on yield attributes and yield of wet-seeded rice

Treatment	Yield attributes of rice									Grain yield (t/ha)		
	No. of panicles per m^2			No. of grains per panicle			% Filled grains per panicle					
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Fenoxaprop-p-ethyl + chlorimuron-ethyl + metsulfuron-methyl	205.3	208.0	206.7	84.2	91.8	88.0	86.0	87.8	86.9	2.94	3.71	3.32
Fenoxaprop-p-ethyl + carfentrazone	192.7	188.0	190.3	83.7	77.6	80.7	83.6	79.3	81.4	2.56	3.15	2.85
Fenoxaprop-p-ethyl + bispyribac-sodium	226.7	228.0	227.3	93.3	96.0	94.7	86.8	88.5	87.7	3.28	4.03	3.65
Cyhalofop butyl + penoxsulam + chlorimuron-ethyl + metsulfuron-methyl	300.7	274.7	287.7	97.0	108.2	102.6	89.7	93.5	91.6	3.71	4.23	3.97
Fenoxaprop-p-ethyl *fb* chlorimuron-ethyl + metsulfuron-methyl	197.3	201.3	199.3	82.8	91.2	87.0	86.7	87.5	87.1	2.88	3.61	3.25
Fenoxaprop-p-ethyl *fb* carfentrazone	174.7	152.0	163.3	84.7	83.6	84.1	83.8	79.9	81.9	2.14	2.61	2.38
Fenoxaprop-p-ethyl *fb* bispyribac-sodium	195.3	196.0	195.7	87.9	78.4	83.1	83.2	81.1	82.2	2.65	3.20	2.93
Cyhalofop butyl + penoxsulam *fb* chlorimuron-ethyl + metsulfuron-methyl	208.0	226.7	217.3	90.4	93.4	91.9	86.9	88.0	87.4	3.07	3.93	3.50
Bispyribac-sodium	179.3	153.3	166.3	82.9	86.2	84.5	79.3	80.9	80.1	2.43	2.85	2.64
Cyhalofop-butyl + penoxsulam	180.7	182.7	181.7	81.6	89.6	85.6	79.1	81.9	80.5	2.50	2.91	2.70
Hand weeding	261.3	238.7	250.0	96.8	103.8	100.3	88.8	90.4	89.6	3.54	4.36	3.95
Unweeded control	157.3	102.7	130.0	75.9	81.0	78.5	77.6	78.4	78.0	1.91	2.04	1.97
LSD (p=0.05)	53.1	52.4	39.3	12.1	14.2	10.0	6.9	8.8	5.8	0.74	0.65	0.46

antagonism. Such mixtures are therefore to be avoided in areas infested chiefly with grass weeds. The tank mixture of cyhalofop-butyl + penoxsulam with chlorimuron-ethyl + metsulfuron-methyl however, registered synergism and a more effective control of grasses, sedges and broad-leaf weeds. However, the dosages of the herbicides in the mixtures have to be further investigated to arrive at conclusive results.

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