Short communication

Efficacy of pre and post emergence herbicides on *Echinochloa* spp.

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Abstract

A pot culture experiment was conducted to evaluate the efficacy and determine the most suitable time of application of pre and post emergence herbicides on types of *Echinochloa* dominating in the rice fields of Palakkad, Kuttanadu and Kole lands during February to May 2017. *Echinochloa colona*, two types of *Echinochloa crus-galli* (type A & B) and *Echinochloa stagnina* were the four identified types. The pre emergence herbicide treatments included pretilachlor @ 0.75 kg a.i. ha^{-1}, oxyfluorfen @ 0. 15 kg a.i. ha^{-1}, pyrazosulfuron ethyl @ 1.25 kg a.i. ha^{-1}, pendimethalin @1.5 kg a.i. ha^{-1}, pretilachlor + bensulfuron methyl @ (0.06+ 0.6) kg a.i. $ha^{-1}$and oxadiargyl @ 0.10 kg a.i. ha^{-1}. All the herbicides were applied in both puddle sown and dry sown condition. Post emergence treatments were applied at four leaf and eight leaf stages of *Echinochloa* spp. and the treatments included cyhalofop butyl @ 0.08 kg a.i. ha^{-1}, bispyribac sodium @ 0.025 kg a.i. ha^{-1}, penoxsulam @ 0.025 kg a.i. ha^{-1}, fenoxaprop–p–ethyl @ 0.06 kg a.i. ha^{-1}, ethoxysulfuron @ 0.015 kg a.i. ha^{-1} and metamifop @ 0. 125 kg a.i. ha^{-1}. Among the pre emergence herbicides, all except pyrazosulfuron ethyl were completely effective against all the four types of *Echinochloa*. Bispyribac sodium and metamifop were effective against *E. colona* at both four leaf and eight leaf stages, whereas penoxsulam was effective only at four leaf stage. Bispyribac sodium was highly effective against *E. crus-galli* (type A) at eight leaf stage. *Echinochloa crus-galli* (type B) was effectively controlled by metamifop when sprayed at four leaf stage, and penoxsulam at eight leaf stage. *E. stagnina* was tolerant to all the herbicides tried. However, cyhalofop butyl and fenoxaprop-p-ethyl although effective at the four leaf stage in reducing the survival percentage, resulted in highly persistent survivors.

Keywords: *Echinochloa colona, Echinochloa crus-galli, Echinochloa stagnina,* Post emergence herbicides, Pre emergence herbicides

Echinochloa species are one of the most devastating serious weeds associated with rice crop (Shultana et al., 2013). The genus contains more than 50 species distributed throughout the world primarily in tropical and warm temperate regions (Michael, 2003). *Echinochloa* infestation is a serious problem in the rice tracts of Kerala including Palakkad, Kuttanadu and Kole lands. Recently some new morphotypes and species of *Echinochloa* are seen to occur in these rice tracts and farmers report that the plants were less sensitive to commonly used herbicides. Effective control of *Echinochloa* spp. relies on the selection of the appropriate herbicide, the optimum rate of application and the correct time of application, along with rotation of herbicides. So, a survey was conducted in 2016 in the rice tracts of Palakkad, Kuttanadu (Moncombu) and Kole lands (Alappad Kole) to identify the dominant *Echinochloa* species. From the survey, three major *Echinochloa* types; severely infesting rice fields and leading to crop-weed competition were identified from Palakkad. The three types included *E. colona* and two types of *E. crus-galli*, one with short awns designated as *Echinochloa crus-galli* (type A) and the other with longer awns named *E. crus-galli* (type B). *Echinochloa stagnina* was the dominant weed in the rice tracts of Kuttanadu and Kole lands. In this study, the efficacy of commonly used herbicides

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were tested against all the four types of *Echinochloa* to pinpoint the herbicides which can be used effectively against each type as well as the most suitable time of application.

The experiment was conducted as pot culture study during February to May 2017, at College of Horticulture, Vellanikkara, located at 13.32^{I} N latitude, 76.26^{I} E longitude and an altitude of 40 m above mean sea level. Earthen pots (50 cm diameter X 40 cm height) were used for the experiment and 3/4th of the pots were filled with soil collected from paddy field. The soil had a pH of 6.9 with medium organic carbon, N, K and low P.

The treatments included various pre and post emergence herbicides. The quantity of herbicide required was calculated based on the recommendation and the diameter of the pot (Table 2). Six ml of the solution was then carefully sprayed in each pot using a hand sprayer. Efficacy of pre emergence herbicides was studied under both dry sown and puddle sown conditions. In dry sown conditions, *Echinochloa* seeds were sown in pots filled with soil and irrigated lightly without flooding simulating rainfall. Herbicides were sprayed on the day after sowing. In puddle sown conditions, soil in the pots were puddled by hand and excess water removed after settling of the clay. Seeds were sown on the top layer and after one day again flooded to a depth of three centimetres. Water was drained after one day and herbicides were sprayed on the third day after sowing. Flooding was again done after 24 hours and continued for the duration of the study. The herbicide treatments were: pretilachlor @ 0.75 kg a.i. ha^{-1}, oxyfluorfen @ 0. 15 kg a.i. ha^{-1}, pyrazosulfuron ethyl @ 1.25 kg a.i. ha^{-1}, pendimethalin @1.5 kg a.i. ha^{-1}, pretilachlor + bensulfuron methyl @ (0.06+ 0.6) kg a.i. ha^{-1}, oxadiargyl @ 0.10 kg a.i. ha^{-1} along with an untreated control. Weed control efficiency (WCE) was calculated based on the number of surviving weed seedlings in each pot.

$$WCE = \frac{x-y}{x} \times 100$$

x - No. of *Echinochloa* seedlings in unweeded control

y - No. of *Echinochloa* seedlings in treatment plot

(Mani et al., 1973)

Efficacies of post emergence herbicides were studied under puddle sown condition. The herbicides were sprayed at four and eight leaf stages of the weed. The treatments included cyhalofop butyl @ 0.08 kg a.i. ha^{-1}, bispyribac sodium @ 0.025 kg a.i. ha^{-1}, penoxsulam @ 0.025 kg a.i. ha^{-1}, fenoxaprop–p–ethyl @ 0.06 kg a.i. ha^{-1}, ethoxysulfuron @ 0.015 kg a.i. ha^{-1}, metamifop @ 0. 125 kg a.i. ha^{-1}and an untreated control. Each pot was sown with 25 seeds of *Echinochloa* spp. and on germination, five seedlings were maintained per pot. The seeds were pre-treated with 1M ethanol under darkness for three days in order to improve germination - a modification of the procedure suggested by Kovach et al. (2012). Completely randomized design was adopted for experiments and separate experiments were conducted for the four different *Echinochloa* types with three replications for each treatment. The efficacy of each herbicide was worked out based on seedling survival percentage and weed persistence index (WPI). Seedling survival was the number of seedlings in each pot which remained green (without drying) after application of herbicide, expressed as percentage of total number of seedlings before herbicide treatment. WPI was worked out using the formula:

WPI= (p/q) x (b/a)

p - Dry weight of weeds in treated plot

q - Dry weight of weeds in control plot

a - Weed count in the treated plot

b - Weed count in the control plot

(Mishra and Misra, 1987)

WPI indicates the degree of resistance of the plant that survived the herbicide and is expressed in terms of dry matter production. The data on seedling survival percentage and weed persistence index were transformed by angular transformation to

Table 1. Efficacy of pyrazosulfuron-ethyl on *Echinochloa* spp.

Species of *Echinochloa*	Treatments	Puddle sown		Dry sown	
		Germination (%)	WCE (%)	Germination (%)	WCE (%)
E. colona	Pyrazosulfuron-ethyl	36.00	14.29	4.00	87.50
	Control	42.00		32.00	
E. crus-galli (type A)	Pyrazosulfuron-ethyl	5.33	82.62	1.33	95.25
	Control	30.67		28.00	
E. crus-galli (type B)	Pyrazosulfuron-ethyl	49.33	7.50	20.00	59.46
	Control	53.33		49.33	
E. stagnina	Pyrazosulfuron-ethyl	2.67	88.00	0.00	100.00
	Control	22.67		20	

normalize their distribution. They were then analyzed following ANOVA, and the means were compared based on the least significant difference (LSD) at 0.05 level of significance. The statistical software 'WASP 2.0' was used for analysis.

There was no seed germination in pots treated with pretilachlor, oxyfluorfen, pendimethalin, pretilachlor + bensulfuron methyl, and oxadiargyl in both puddle sown and dry sown conditions. These pre-emergence herbicides were thus 100 per cent efficient in controlling all the four types of *Echinochloa*. However, in pots treated with pyrazosulfuron-ethyl, both seed germination and seedling emergence was observed in three types of *Echinochloa* whereas there was no germination of *E. stagnina.* Pyrazosulfuron-ethyl is recommended to be applied 6 – 9 days after sowing (KAU, 2016), which could be the reason for its poor performance in the present study where it was applied 3 – 6 days earlier. Plants grown in dry sown condition were more susceptible to pyrazosulfuron-ethyl than those in wet sown condition. The susceptibility to pyrazosulfuron-ethyl was in the order *E. stagnina*> *E. crus-galli* (type A) > *E. colona* > *E. crus-galli* (type B) (Table 1).

Post emergence herbicides had varying effects on the different types of *Echinochloa*. Although herbicides which were known to be highly effective against the weed were evaluated, they were less effective in pot culture studies. The data on seedling survival (%) and WPI are presented in Table 2.

For *Echinochloa colona*, application of both cyhalofop butyl and fenoxaprop-p-ethyl at four leaf stage was seen to be less effective, with more than 60 per cent seedling survival. Fenoxaprop-p-ethyl performed better at eight leaf stage of the weed with a seedling survival percent of 40, suggesting that application at this stage would be more effective. Bispyribac sodium and metamifop were effective at both stages of the weed, indicating their superiority in controlling *E. colona*. Chauhan and Abugho (2012) have reported that post emergence application of bispyribac sodium at four leaf stage reduced the biomass of *E. colona* up to 95 per cent. Walia et al. (2008) reported that bispyribac sodium (0.4 kg ha^{-1}) could bring about great reduction in the biomass accumulation of *E. colona* when applied at 30 DAS. There was no seedling survival when bispyribac sodium, metamifop and penoxsulam were applied at the four leaf stage. Ethoxysulfuron was seen to be least effective among the herbicides applied as the seedling survival was 100% and the surviving plants were highly persistent.

Application of bispyribac sodium at the eight leaf stage was highly effective against *E. crus-galli* (type A) as there was no seedling survival. Bispyribac sodium has also been reported to be effective in rice nursery as well as main field against *E. crusgalli* and *E. glabrescens* (Duary and Mukherjee, 2013). At the four leaf stage, although there was a 33% seedling survival, the persistence of the survived seedlings was low (0.04). Survival percentage of the weed was less when fenoxaprop-p-ethyl,

Table 2. Effect of post emergence herbicides on Seedling Survival (SS) and Weed Persistence Index (WPI) of *Echinochloa* spp.

Treatments	Dose (g or ml/pot)	*Echinochloa colona*				*Echinochloa crus-galli* (Type A)				*Echinochloa crus-galli* (Type B)				*Echinochloa stagnina*			
		Four leaf stage		Eight leaf stage		Four leaf stage		Eight leaf stage		Four leaf stage		Eight leaf stage		Four leaf stage		Eight leaf stage	
		SS (%)	WPI	SS (%)	WPI	SS (%)	WPI	SS (%)	WPI	SS (%)	WPI	SS (%)	WPI	SS (%)	WPI	SS (%)	WPI
Cyhalofop butyl	0.016 *	62.64	5.03	89.52	4.98	79.39	1.48	89.52	5.28	79.89	3.89	89.52	4.45	47.88	4.58	89.52	5.26
		(78.57)	(0.77)	(100)	(0.75)	(95)	(0.06)	(100)	(0.85)	(95.45)	(0.48)	(100)	(0.61)	(55.00)	(0.64)	(100)	(0.84)
Bispyribac sodium	0.005	0.48	0.48	31.62	3.89	34.79	1.09	0.48	0.48	43.56	3.42	67.78	3.25	61.71	3.83	61.85	4.42
		(0.00)	(0.00)	(27.84)	(0.48)	(33.33)	(0.04)	(0.00)	(0.00)	(47.62)	(0.36)	(85.70)	(0.32)	(77.50)	(0.45)	(70.00)	(0.59)
Penoxsulam	0.002	0.48	0.48	72.94	2.53	44.27	1.22	35.53	2.50	18.33	1.71	0.48	0.48	61.85	3.78	38.86	4.66
		(0.00)	(0.00)	(87.50)	(0.19)	(48.75)	(0.05)	(41.66)	(0.25)	(14.28)	(0.11)	(0.00)	(0.00)	(70.00)	(0.44)	(40.00)	(0.66)
Fenoxaprop-p-ethyl	0.017	64.84	1.51	38.97	5.56	54.06	0.92	50.38	4.55	10.61	1.34	42.12	2.59	22.09	2.18	59.84	4.22
		(75.00)	(0.08)	(39.70)	(0.94)	(65.00)	(0.02)	(59.33)	(0.63)	(5.00)	(0.08)	(45.00)	(0.21)	(20.00)	(0.19)	(66.66)	(0.54)
Ethoxysulfuron	0.002	89.52	4.74	89.52	5.68	72.46	1.61	89.52	5.30	78.11	2.97	89.52	5.35	72.94	4.20	89.52	5.63
		(100)	(0.63)	(100)	(0.99)	(86.64)	(0.08)	(100)	(0.86)	(93.75)	(0.17)	(100)	(0.87)	(87.50)	(0.54)	(100)	(0.96)
Metamifop	0.025	0.48	0.48	34.76	2.28	38.30	2.38	42.95	3.44	0.48	0.48	11.89	1.90	45.00	3.95	31.62	3.23
		(0.00)	(0.00)	(33.30)	(0.16)	(38.63)	(0.17)	(46.42)	(0.41)	(0.00)	(0.00)	(6.25)	(0.14)	(50.00)	(0.47)	(35.71)	(0.44)
LSD (0.05)		15.02	0.65	15.02	0.65	27.36	1.23	27.36	1.23	13.54	1.23	13.54	1.23	29.61	1.54	29.61	1.54

*Angular transformed values. Original values in parentheses

metamifop and penoxsulam were applied at the four leaf stage. Ntanos et al. (2000) reported that early post-emergence application of cyhalofop butyl at a rate of 0.15 – 2 kg ha^{-1} effectively controlled *E. crus-galli*. However in the present experiment, the survival per cent and WPI was high, indicating their inadequacy to completely control *Echinochloa crus-galli* (type A) at four leaf stage. At eight leaf stage, these herbicides performed still more poorly, resulting in high dry matter production by the surviving seedlings. At the eight leaf stage, both survival (100%) and persistence (0.85) were higher when cyhalofop butyl was applied. So though an earlier application produced better results, the effect was seen to be inadequate, pointing to a probable need for either a higher dose of application or a still earlier application. Sharma et al. (2004) recommended a dose of 0.09 kg ha^{-1} as optimum for controlling *Echinochloa* in the nursery. It follows that a higher dose is required for killing *Echinochloa* of advanced age. The time of application also has to be precise as a slight variation in age of the weed seedlings can render a herbicide ineffective. Ntanos et al. (2000) observed that weed control with cyhalofop butyl (0.2 kg ha^{-1}) was reduced when applied at four leaf stage compared to the two leaf stage.

E. crus-galli (type B) was seen to be totally killed off by the application of metamifop at the four leaf stage, or penoxsulam at the eight leaf stage. However, Ottis et al. (2003) have reported that penoxsulam provided 99 per cent control of *Echinochloa crus-galli* at 21 DAT. Contrary to its effect on *E. colona* and *E. crus-galli* (type A), bispyribac sodium was seen to be ineffective against *E. crus-galli* (type B) at both stages of application. Earlier application of bispyribac sodium was ineffective in killing majority of the seedlings, while at the later stage, the persistence of the surviving seedlings was high. Fenoxaprop-p-ethyl was a good herbicide for *E. crus-galli* (type B) at the four leaf stage as the seedling survival per cent was only 5. Similar results have been reported by Singh et al. (2004). Chauhan and Abugho (2012) have also observed poor control of *E. crus-galli* when fenoxaprop + ethoxy sulfuron (150 + 18 g ha^{-1}) was sprayed at the eight leaf stage, whereas at the four leaf stage the weed control efficiency was 68 per cent. In the present experiment, at the eight leaf stage, the surviving seedlings showed high persistence.

E. stagnina, present in Kuttanad and the Kole lands, was significantly different from the other species of *Echinochloa* studied in its response to herbicides. Bispyribac sodium was found to be less effective against this species both at the four leaf and eight leaf stages and the surviving seedlings were highly persistent. Fenoxaprop-p-ethyl was effective at the

four leaf stage in reducing the survival (20%), but resulted in comparatively highly persistent survivors (WPI of 0.19). These herbicides were less effective at the eight leaf stage also. Metamifop, penoxsulam and ethoxysulfuron were seen to be ineffective at both stages.

It is a known fact that to be effective, the dose and time of application of herbicides are most important. The development of tolerance to herbicides is also a factor to be considered. Azmi (2002) has observed that certain weed species may establish when a particular herbicide is continuously used either due to inherent properties or due to application of sub-lethal concentrations, leading to resistance. Changes in anatomical characteristics or in biochemical or physiological properties can help in making weeds best adapted to applied herbicides. This can lead to changes in the weed spectrum and in composition and distribution. Continuous monitoring and continuous modification in the management strategies adopted are required for dealing with the ever changing weed population.

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