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Short Communication

Effect of new post emergence herbicides on weed dynamics in wet seeded rice

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Abstract

An experiment was conducted in Kole lands of Thrissur, Kerala, India, during October 2011 to February 2012 to study the effect of various post emergent herbicides on weed flora and density in wet seeded rice. The herbicidal treatments included application of three graminicides (metamifop, fenoxaprop- p-ethyl and cyhalofop-butyl), graminicides with follow up spray of herbicides (Almix, carfentrazone and ethoxy sulfuron) to kill non grassy weeds and herbicides with broad spectrum activity (bispyribac sodium, penoxsulam and azimsulfuron). Hand weeded and unweeded controls were also included. The results showed that grasses were the dominant weed flora followed by broad leaved weeds and sedges. *Echinochloa* was the main grass weed whose density was 21 m^{-2} in unweeded control whereas the lowest density (3-5 $m^{-2)}$ was registered in graminicide applied plots. The highest broad leaved weed population was in metamifop sprayed plots. The lowest grass population was noticed in bispyribac sodium which was free of sedges also. At harvest stage of rice, in hand weeded plots the broad leaved weed *Lindernia crustacea* alone was present. The best herbicide treatment with low weed dry matter production was fenoxaprop- p- ethyl or cyhalofop-butyl with follow up spray of Almix. Bispyribac sodium registered the highest weed control efficiency next to hand weeding which was comparable to application of cyhalofop-butyl/fenoxaprop-p-ethyl/metamifop with follow up spray of Almix.

Key words: Post Emergent Herbicides, Weed spectrum, Wet seeded rice

Weed spectrum and density differ according to the method under which rice is grown as environmental requirements for weeds vary. Many weeds have a wide range of environmental tolerance and broad geographical distribution (Kim and Park, 1996). About 350 species in more than 150 genera and 60 plant families have been reported as weeds of rice (Barret and Seaman, 1980). Smith (1981) reported Poaceae as the most important weed family in rice. According to Joy et al. (1991) weed flora in rice consisted of 37% grasses 33% sedges and 30% broad leaved weeds. Chemical weed control is becoming popular and a number of post emergent herbicides differing in selectivity and mode of action are available. The choice of the right herbicide depends on major weed flora and response of weeds to various herbicides. The present study was undertaken to examine weed flora of rice in one of the major rice tracts of Kerala and weed control efficiency of various post emergent herbicides in rice.

A field experiment was conducted during *mundakan* season (October 2011 to February 2012) in farmer's field at Alappad in the Kole lands ($10^0$31' N latitude and $76^0$13' E longitude and 1m below mean sea level) of Thrissur district. The soil was clayey with pH 5.5, organic C 2.1%, available P and K 26 and

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281 kgha^{-1} respectively. The experimental site enjoys typical humid tropical climate. Mean monthly minimum and maximum temperatures were 32.5^{0}C and 22.3^{0}C, respectively during the experimental period. The herbicidal treatments included application of three graminicides (metamifop, fenoxaprop- p-ethyl and cyhalofop-butyl), graminicides with follow up spray of herbicides (Almix (metsulfuron methyl 10%+ chlorimuron ethyl 10%, carfentrazone and ethoxy sulfuron) to kill non grassy weeds and herbicides with broad spectrum activity (bispyribac sodium, penoxsulam and azimsulfuron). The experiment comprised of 13 treatments, viz., post emergent spray of metamifop (125 g ha^{-1}), metamifop (125 g ha^{-1}) with a follow up spray (fs) of carfentrazone ethyl (20 g ha^{-1}), metamifop (125 g ha^{-1}) with a follow up spray of almix (4 g ha^{-1}), cyhalofop-butyl (100 g ha^{-1}), cyhalofop-butyl (100 g ha^{-1}) with a follow up spray of almix (4 g ha^{-1}), fenoxaprop-p-ethyl (60 g ha^{-1}), fenoxaprop-p-ethyl (60 g ha^{-1}) with a follow up spray of almix (4 g ha^{-1}), fenoxaprop-p-ethyl (60 g ha^{-1}), with a follow up spray of ethoxysulfuron (15 g ha^{-1}), bispyribac sodium (30 g ha^{-1}), penoxsulam (25 g ha^{-1}), azimsulfuron (35 g ha^{-1}), unweeded control and hand weeded control. The trial was laid out in Randomized Block Design with three replications.

All herbicides were sprayed at 20 days after sowing (DAS) with follow up spray on the next day using knapsack sprayer. Data on weed count and weed dry matter production were taken at 30 and 60 days after sowing and at harvest. The uprooted weeds were cleaned, air dried and then oven dried at 80±5^{0}C and dry weights were recorded and expressed in g/m^2. Weed control efficiency (WCE) was also calculated (Gill and Vijayakumar, 1969). Data on weed biomass that showed wide variation was subjected to square root transformation, $(x+0.5)^{1/2}$, to make the analysis of variance valid (Gomez and Gomez, 1984). Multiple comparisons among treatment means were done with Duncan's Multiple Range Test (DMRT).

Effect on weed population, density and dry matter production

Weed flora of the experimental plot is given below.
Grasses : *Echinochloa colona, Echinochloa crusgalli, Echinochloa stagnina* , *Leptochloa chinensis.*
Sedges : *Fimbristylis mileacea, Cyperus iria, Cyperus difformis*
Broad leaved weeds : *Ludwigia perennis, Lindernia crustacea, Monochoria vaginalis, Sphaeranthes indicus, Alternanthera* sp

A critical analysis of relative proportion of grasses, sedges and broad leaved weeds in unweeded control revealed that grasses are the dominant weed flora (Fig. 1) and they constituted 60% of the total

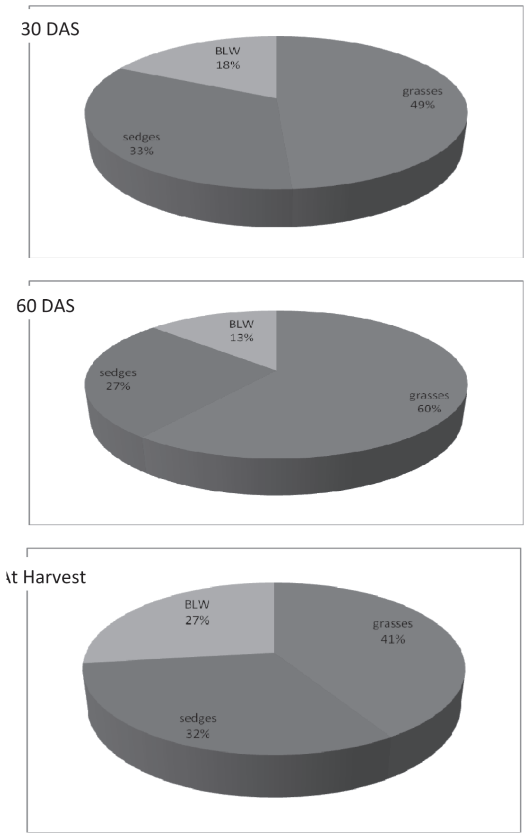

Figure 1. Dynamics of weed spectrum in the experimental plot at various stages of the crop in unweeded control

Table 1. Species wise weed count at 60 days after sowing (DAS) and at harvest stage (H) of rice

Treatments	*Echinochloa* spp.		*Cyperus* spp.		*Fimbristylis* sp.		*Ludwigia* sp.		*Lindernia* sp.	
	60DAS	H	60DAS	H	60DAS	H	60DAS	H	60DAS	H
Metamifop	5	5	4	3	10	11	2	3	5	11
Metamifop fsCarfentrazone ethyl	5	5	1	1	1	6	2	-	5	8
Metamifop fs Almix	2	7	2	1	2	9	1	2	5	4
Cyhalofop-butyl	3	7	1	1	4	9	1	1	8	5
Cyhalofop-butyl fs Almix	3	7	3	1	1	11	1	1	1	4
Fenoxaprop p-ethyl	4	6	3	1	4	11	3	2	10	11
Fenoxaprop-p-ethyl fs Almix	3	6	-	1	-	5	-	-	7	10
Fenoxaprop-p-ethyl fsethoxysulfuron	3	10	-	1	5	6	1	1	5	9
Bispyribac sodium	1	-	-	-	-	-	-	-	7	8
Penoxsulam	7	7	1	1	1	5	-	1	6	6
Azimsulfuron	4	9	3	-	5	5	-	-	10	6
Unweeded control	32	22	7	5	7	15	1	5	5	11
Handweeded control	-	-	-	-	-	-	-	-	8	8

fs - follow up spray

population at 60 DAS. The higher proportion of grasses compared to sedges and broad leaved weeds in rice in Kole lands was also reported by Joy et al. (1993) and Sindhu (2008). Among grasses, *Echinochloa* spp. was the predominant one. It is a crop associated weed, which thrives well in flooded situation and is a major weed of rice. Sedges constituted 33% of total weeds at 30 DAS and the population of *Fimbristylis miliacea* was higher than that of *Cyperus* spp. The broad leaved weeds constituted only 18% of total weed flora at 30 DAS whereas it increased to 27% by harvest stage of crop. John and Sadanandan (1989), Hussain et al. (2008) and Singh and Singh (2010) also reported *Echinochloa crusgalli*, *Leptochloa chinensis*, *Cyperus iria*, *Fimbristylis miliacea*, *Ludwigia parviflora*, *Lindernia crustacea* and *Monochoria vaginalis* as the major weeds of wet seeded rice. The rice plants completely covered the land area by about 45 days and further weed growth was low. *Lindernia crustacea*, a minor weed, was present even in hand weeded plot most probably because this can survive under a low level of light intensity. Although *Leptochloa chinensis* is an emerging problem weed in Kole lands, in the present study, its population was low as indicated by lower count of 4 no./m^2 at harvest stage of crop in unweeded control. However, it was seen that no *Leptochloa* was present in herbicidal treatments with the exception of one *Leptochloa*/m^2 registered in penoxsulam sprayed plot at harvest. It may be due to the application of graminicides as well as broad spectrum herbicides which probably controlled *Leptochloa*. Singh et al. (2004) and Kim et al. (2003) have earlier reported the effectiveness of fenoxaprop p-ethyl against *Leptochloa*. Saini (2003) noticed reduction of annual grasses by the application of cyhalofop-butyl in wet seeded rice. Hence the study indicates that the herbicides tested might have controlled *Leptochloa* also.

All herbicides were post emergent in action and were sprayed at 20 DAS with follow up spray (fs) on the next day. When observations on weed population were taken at 30 DAS, complete control of weeds could be observed in many treatments. Sedges and broad leaved weeds were present in graminicide (metamifop, cyhalofop-butyl and fenoxaprop p-ethyl) applied plots. The application of graminicides followed by a herbicide selective against broad leaved weeds and sedges or herbicide with broad spectrum action resulted in weed free condition in other treatments.

It was found that all the herbicides were effective against *Echinochloa,* the major weed of rice, as evidenced by a low count in the range of 2-7 m^{-2}, against 32 no.s m^{-2}, in unweeded check by 60 DAS.

Table 2. Effect of the treatments on count of grasses, sedges and broad leaved weeds (No.m $^{-2}$)

Treatments	30DAS			60DAS			At harvest		
	G	S	B	G	S	B	G	S	B
Metamifop	*2.1^{bc}	3.3^{ab}	3.9^{a}	2.4^{bc}	3.7^{a}	2.7^{bc}	2.4^{c}	3.9^{ab}	3.8^{ab}
	(4)	(11)	(15)	(5)	(14)	(7)	(5)	(15)	(14)
Metamifop fs carfentrazone ethyl	0.71^{d}	0.71^{c}	0.71^{c}	2.3^{bcd}	1.3^{cd}	2.6^{bc}	2.3^{c}	2.6^{cde}	2.9^{bcd}
	(0)	(0)	(0)	(5)	(2)	(7)	(5)	(7)	(8)
Metamifop fs Almix	0.71^{d}	0.71^{c}	0.71^{c}	1.5^{de}	2.1^{bc}	2.6^{bc}	2.8^{bc}	3.1^{bcd}	2.5^{cd}
	(0)	(0)	(0)	(2)	(4)	(7)	(7)	(9)	(6)
Cyhalofop-butyl	1.9^{bc}	3.3^{ab}	2.7^{b}	1.8^{cde}	2.4^{bc}	3.0^{ab}	2.8^{bc}	3.2^{bc}	2.5^{cd}
	(3)	(11)	(7)	(3)	(5)	(9)	(7)	(10)	(6)
Cyhalofop-butyl fs Almix	0.71^{d}	0.71^{c}	0.71^{c}	1.8^{cde}	1.9^{bc}	1.3^{d}	2.6^{bc}	3.5^{b}	2.2^{d}
	(0)	(0)	(0)	(3)	(3)	(1)	(7)	(12)	(5)
Fenoxaprop p-ethyl	2.2^{b}	3.1^{b}	2.9^{b}	2.1^{bcd}	2.7^{b}	3.6^{a}	2.5^{c}	3.6^{b}	3.7^{ab}
	(5)	(9)	(8)	(4)	(7)	(13)	(6)	(13)	(13)
Fenoxaprop-p-ethyl fs Almix	0.71^{d}	0.71^{c}	0.71^{c}	1.9^{bcd}	0.7^{d}	2.8^{abc}	2.5^{c}	2.4^{de}	3.2^{abc}
	(0)	(0)	(0)	(3)	(0)	(7)	(6)	(5)	(10)
Fenoxaprop-p-ethyl fs ethoxysulfuron	0.71^{d}	0.71^{c}	0.71^{c}	1.9^{bcd}	2.4^{bc}	2.3^{bc}	3.3^{b}	2.6^{cde}	3.2^{abc}
	(0)	(0)	(0)	(3)	(5)	(5)	(10)	(7)	(10)
Bispyribac sodium	0.71^{d}	0.71^{c}	0.71^{c}	0.9^{ef}	0.7^{d}	2.7^{bc}	0.7^{d}	0.7^{f}	2.9^{bcd}
	(0)	(0)	(0)	(1)	(0)	(7)	(0)	(0)	(8)
Penoxsulam	0.71^{d}	0.71^{c}	0.71^{c}	2.6^{ab}	1.4^{cd}	2.5^{bc}	2.9^{bc}	2.3^{de}	2.7^{cd}
	(0)	(0)	(0)	(7)	(3)	(6)	(8)	(5)	(7)
Azimsulfuron	0.71^{d}	0.71^{c}	0.71^{c}	2.1^{bcd}	2.7^{b}	3.2^{ab}	3.0^{bc}	2.3^{e}	2.5^{cd}
	(0)	(0)	(0)	(4)	(7)	(10)	(9)	(5)	(6)
Unweeded control	4.7^{a}	3.8^{a}	2.9^{b}	5.7^{a}	3.7^{a}	2.7^{bc}	5.1^{a}	4.5^{a}	4.1^{a}
	(22)	(15)	(8)	(32)	(14)	(7)	(26)	(20)	(17)
Handweeded control	0.71^{d}	0.71^{c}	0.71^{c}	0.7^{f}	0.7^{d}	2.9^{ab}	0.7^{d}	0.7^{f}	2.9^{bcd}
	(0)	(0)	(0)	(0)	(0)	(8)	(0)	(0)	(8)

*$(x+0.5)^{1/2}$ transformed values, Original values in parentheses. In a column, means followed by common letters do not differ significantly at 5% level by DMRT. G- Grasses, S- sedges, B- broad leaved weeds, fs - follow up spray

The trend was same at harvest stage of crop also. The population of sedges reveals that fenoxaprop fs Almix, penoxulam, metamifop fs carfentrazone ethyl and bispyribac Na could control them. This herbicide was found to be effective against *Fimbristylis* as well as *Cyperus.*

At 60 DAS, the weed population was the lowest in bispyribac sodium, cyhalofop-butyl fs Almix and in fenoxaprop p-ethyl fs Almix because of broad spectrum action. Yadav et al., (2007) also reported the broad spectrum action of bispyribac sodium. The highest weed count was registered in unweeded check. Fenoxaprop p-ethyl, penoxsulam and azimsulfuron registered higher total weed population next to unweeded control. Fenoxaprop controlled only grasses and hence the high weed count is attributed to the broad leaved weeds and sedges. Khodayari et al. (1989) had documented that the effectiveness of fenoxaprop p-ethyl was only against grasses and not to broad leaved weeds and sedges. It can also be seen that the count of sedges was high in metamifop at 60 DAS, which was comparable to unweeded control, probably because its herbicidal action is only against grasses (Kim et al., 2003). At harvest stage, the lowest weed count was reported in hand weeded control as well as in bispyribac sodium sprayed plots (8 m^{-2}) indicating that bispyribac sodium is as effective as hand weeding twice in suppressing weed population. Similar results were also reported by Yadav et al. (2009). Azimsulfuron and penoxsulam,

Table 3. Effect of treatments on weed control efficiency (WCE) and weed dry weight(WDW)

Treatments	WCE(%)	Weed dry weight (kg ha^{-1}),)		
		30 DAS	60 DAS	At harvest
Metamifop	85.4^{c}	*6.09^{b}(36.67)	17.94^{d}(321.33)	18.22^{d}(332.00)
Metamifop fs carfentrazone ethyl	79.8^{f}	0.71^{c}(0)	18.35^{cd}(336.33)	21.44^{c}(459.33)
Metamifop fs Almix	80.5^{f}	0.71^{c}(0)	18.59^{c}(345.00)	21.11^{c}(445.33)
Cyhalofop-butyl	83.8^{e}	6.25^{b}(38.67)	18.59^{c}(345.00)	19.24^{d}(370.00)
Cyhalofop-butyl fs Almix	88.0^{d}	0.71^{c}(0)	13.24^{f}(175.00)	16.5^{e}(272.00)
Fenoxaprop p-ethyl	85.4^{e}	5.81^{b}(33.33)	15.38^{e}(236.00)	18.22^{d}(332.00)
Fenoxaprop p-ethyl fs Almix	90.0^{c}	0.71^{c}(0)	12.46^{g}(155.00)	15.08^{f}(227.33)
Fenoxaprop-p-ethyl fs ethoxysulfuron	79.3^{f}	0.71^{c}(0)	19.56^{b}(382.00)	21.73^{c}(472.00)
Bispyribac sodium	93.6^{b}	0.71^{c}(0)	11.39^{h}(129.33)	12.07^{g}(146.00)
Penoxsulam	76.3^{g}	0.71^{c}(0)	19.56^{b}(382.00)	23.23^{b}(539.33)
Azimsulfuron	76.1^{g}	0.71^{c}(0)	18.31^{cd}(335.00)	23.35^{b}(544.67)
Unweeded control	-	18.71^{a}(350.00)	36.06^{a}(1300.00)	47.75^{a}(2280.00)
Handweeded control	97.7^{a}	0.71^{c}(0)	6.59^{i}(43.00)	8.11^{h}(65.33)

* $(x+0.5)^{1/2}$ transformed values, Original values in parentheses. In a column, means followed by common letters do not differ significantly at 5% level by DMRT. fs - follow up spray

though broad spectrum herbicides, was found less effective in the present study compared to bispyribac sodium. However, at the harvest stage, the number of sedges was lower in azimsulfuron compared to others showing its effectiveness in controlling sedges as reported by Yadav et al. (2010).

With respect to weed dry matter production at 30 DAS (Table 3), all treatments except unweeded control and graminicide applied plots were weed free. In graminicides applied plots, the dry matter production of weeds was statistically comparable, which indicate their comparable efficiency in controlling grass weeds under Kole land situation. Increase in dry matter production was observed with time due to the progressive growth of weeds as well as further germination and growth of weeds. By 60 DAS, weed dry weight quadrupled in unweeded control (1300 kg ha^{-1}). Lowest accumulation of dry matter (43 kg ha^{-1}) was noticed in hand weeded plots followed by bispyribac sodium (129 kg ha^{-1}). The treatments metamifop fs Almix, cyhalofop-butyl, metamifop fs carfentrazone ethyl, azimsulfuron and metamifop were at par with dry matter production ranging from 321 to 345 kg ha^{-1} (Table 3). At the time of harvest also, weed dry weight was minimum (65.33 kg ha^{-1})in hand weeded plot followed by bispyribac sodium (146 kg ha^{-1}). The treatments cyhalofop-butyl + Almix and fenoxaprop p-ethyl + Almix were the next best treatments with a lower weed dry matter production, suggesting suppression of weed growth due to the application of a graminicide followed by herbicide selective against non grass weeds as also reported by Saini (2005). The same trend as that of 60 DAS was noticed at harvest stage also, though by this time there was an increase in weed dry matter production by 32 per cent and 36 per cent in fenoxaprop p-ethyl fs Almix and cyhalofop-butyl fs Almix, respectively.

Economics of cultivation and Weed control efficiency

An analysis of the economics of rice cultivation shows that for high returns (Rs.67,090) and B:C ratio (1.8), spraying cyhalofop-butyl followed by Almix is the best. The treatments fenoxaprop p-ethyl fs Almix and bispyribac sodium also gave a B:C ratio of 1.8. Although the yield was a little lower in bispyribac sodium, as the cost of cultivation was low due to one time application of herbicide, it could maintain high B:C ratio of 1.8. However, the grain yield of 5.73 Mg ha^{-1}, obtained with bispyribac sodium was statistically on par with cyhalofop-butyl fs Almix and fenoxaprop p-ethyl fs Almix (5.8 Mg ha^{-1}),). Hence, it can be inferred that these three can be recommended for maximum net profit as well

Table 4. Economics of cultivation under various treatments

Treatments	Total cost(Rs. ha^{-1})	Total income(Rs. ha^{-1})	Net profit(Rs. ha^{-1})	B:C ratio
Metamifop	36,150	93,300	57,150	1.6
Metamifop fs carfentrazone ethyl	37,894	94,200	56,306	1.5
Metamifop fs Almix	37,475	98,100	60,625	1.6
Cyhalofop-butyl	35,685	97,500	61,815	1.7
Cyhalofop-butyl fs Almix	37,010	1,04,100	67,090	1.8
Fenoxaprop p-ethyl	35,349	99,600	64,251	1.8
Fenoxaprop p-ethyl fs Almix	36,674	1,02,300	65,626	1.8
Fenoxaprop-p-ethyl fs ethoxysulfuron	36,909	93,900	56,991	1.5
Bispyribac sodium	36,143	1,01,700	65,557	1.8
Penoxsulam	36,129	96,000	59,871	1.7
Azimsulfuron	36,280	90,000	53,720	1.5
Unweeded control	32,825	73,200	40,375	1.2
Handweeded control	45,825	1,08,900	63,075	1.4

fs - follow up spray

as B:C ratio (Table 4). Although hand weeded treatment produced net profit of Rs.63,075 ha^{-1}, due to high cost of cultivation (Rs.45,825 ha^{-1}) the B:C ratio was low (1.4) .

The highest WCE (97%) as well as grain yield (6.13 Mg ha $^{-1}$), (Fig 2) was recorded in hand weeded control (Table 3). However, this yield was statistically on par with cyhalofop-butyl fs Almix and fenoxaprop p-ethyl fs Almix (5.8 Mg ha^{-1}), , which recorded a WCE of 88 and 90 percentage respectively. This indicates that a WCE of 88 - 90 per cent is enough to achieve good yield.

Three herbicidal treatments which show promise in terms of WCE, grain yield and B-C ratio are cyhalofop-butyl fs Almix and fenoxaprop p-ethyl fs Almix and bispyribac sodium. It can also be inferred that if grasses are the dominant weed flora, cyhalofop-butyl or fenoxaprop-p-ethyl without follow up spray of Almix can be recommended for effective weed control.

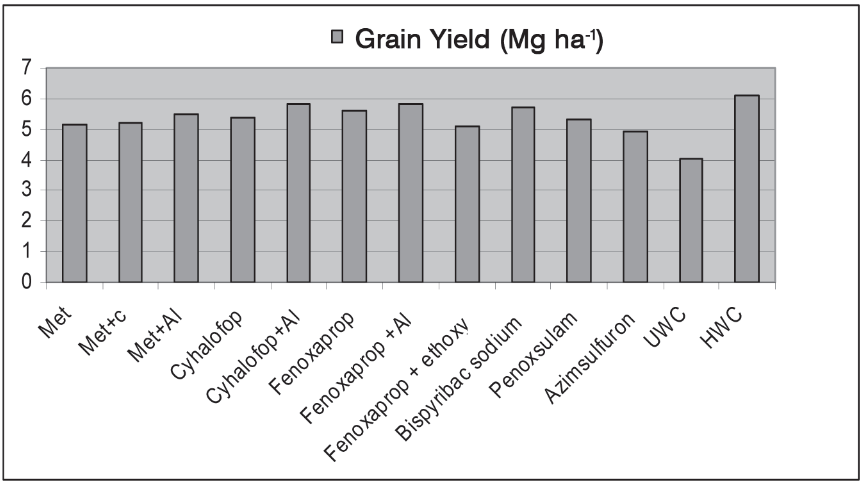

Figure 2. Grain yield of rice as influenced by the post emergence herbicides

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