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Bioefficacy of chemical herbicides in weed management of aerobic rice at Sabour region of Bihar

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ABSTRACT

A field experiment was conducted during Kharif season of 2011 and 2012 at Bihar Agricultural University, Sabour, to evaluate the bioefficacy of different herbicides on weed management of aerobic rice (Oryza sativa. L.). Among weed control combinations two hand weeding at 20 and 40 DAS, PE Pendimethalin 30EC @ 1.0 kg ha^{-1} fb POE Bispyribac10SC @ 35.0 g ha^{-1}; PE Pendimethalin 30EC @ 1.0 kg ha^{-1} fb POE Ethoxysulfuron 15%WDG @ 15g ha^{-1} were found highly effective and exhibited better weed control efficiency, economic advantage and recorded higher grain yield as well as yield attributing characters in comparison to other treatments. The maximum mean grain yield 4.72 t ha^{-1} was recorded in two hand weeding at 20 and 40 DAS and was statistically at par with PE Pendimethalin 30EC @1.0 kg ha^{-1} fb POE Bispyribac10 SC @ 35.0 g ha^{-1}(4.43 t ha^{-1}); PE Pendimethalin 30EC @1.0 Kg ha^{-1} fb POE Ethoxysulfuron 15%WDG @15 g ha^{-1}(4.34 t ha^{-1}); PE Pendimethalin 30EC @1.0 kg ha^{-1} fb POE 2,4-D Na salt 80%@ 0.06 kg ha^{-1}(4.26 t ha^{-1}) and PE Butachlor60% EC @1.5 kg ha^{-1} fb POE Bispyribac10 SC @ 35.0 g a.i. ha^{-1} (4.24 t ha^{-1}). The highest net return of Rs. 38,108 ha^{-1} with B:C ratio 1.91 was recorded in PE Pendimethalin 30 EC @ 1.0 kg ha^{-1} + POE Bispyribac sodium 10 SC @ 35 .0 g ha^{-1} closely followed by two HW at 20 & 40 DAS (net return Rs. 37,864 ha^{-1}with B:C ratio 1.57).

Keywords **:** Aerobic rice, chemical herbicide, economics, weed management

Rice is a staple food crop for more than half of the world's population and more than 90% of rice grown and consumed in Asia (Chauhan, 2012). In Bihar, total area under this crop is 33.23 lakhs ha, producing 81.87 lakh matric tons and with average productivity of 2463 kg ha^{-1} (Anon., 2012).

Aerobic rice is specifically developed rice, combining drought tolerance of upland rice. Therefore, aerobic rice is "improved upland rice" in terms of yield potential and drought tolerance. Aerobic rice can save as much as 50% of irrigation water in comparison with lowland rice (Bouman *et al*.,2002; Wang *et al*., 2002). Aerobic rice emits 80-85 % lesser methane gas into the atmosphere thus keeping the environment safe. Aerobic systems are subject to much higher weed pressure than conventionally puddle transplanted rice. Here, weeds may cause an yield loss to an extent of 50-100% (Mishra and Singh, 2009). High weed infestation in aerobic rice has threatened its sustainability, which demands an efficient and cost-effective weed management technique (Mahajan *et al*., 2009).

Therefore, timely weed control at early stage is imperative for realizing desired level of productivity from aerobic rice. The use of herbicides offers selective and economic control of weeds right from the beginning, giving crop an advantage of good start and competitive superiority. A number of pre-emergence herbicides like butachlor, pendimethalin, pretilachlor, anilophos etc. have been recommended for the control of early flushes of grassy weeds in aerobic rice field. These herbicides are specific and are effective against narrow range of weed species. The intensive use of such herbicides year after year has resulted in herbicide resistance problems and consequently, management of weeds is becoming increasingly more difficult and complex (Karim *et al*., 2004). Moreover, continuous use of these herbicides leads to a shift of weed flora from grassy to non grassy broadleaf weeds and annual sedges. Thus, it would be desirable to use alternative herbicides that may provide wide spectrum of weed control. Manual weeding is often difficult due to inadequate supply of labour in time, higher cost and non workable condition of the field. In such situation, use of herbicides is an obvious choice. Proper weed management is considered to be one of the most important prerequisites to ensure satisfactory yield of rice. High weed pressure in aerobic rice lowers the economic return. The chemical method for weed control is a cost effective, safe, and socially acceptable control tactics that reduce weed interference below the economic injury level. Jayadeva *et al*. (2011) reported that the integrated weed management has got the potential to reduce herbicide use and to provide a robust and sustainable weed management. The ultimate challenge towards developing an effective integrated weed management is to create a cropping system unfavorable for weeds and favorable for crop. The practice of integrated weed management has been also emphasized by Azmi and Baki (2002). Therefore, for designing a sustainable weed management strategy for aerobic rice, it is a

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prerequisite to assess the simultaneous effect of different herbicides application. The present study was, therefore, conducted to find out suitable herbicide combinations with comparing to mechanical weeding at 20 and 40DAS and two hand weeding to provide a comprehensive integrated weed management system for aerobic rice.

MATERIALS AND METHODS

Field experiment was conducted during *kharif* seasons of 2011 and 2012 at Bihar Agricultural University, Sabour, Bihar (25^{O} 04' N Latitude, 87^{O} 04' E Longitude and 37.19 meter above mean sea levels). The treatments were arranged in a randomized block design with three replications. The experiment was comprised of 11 weed management treatments *viz*. pendimethalin30EC @1.0 kg ha^{-1} as pre-emergence (PE) followed by (fb) bispyribac sodium10SC @ 35 g ha^{-1} as post-emergence (POE); pendimethalin30EC @1.0 kg ha^{-1} as PE fb 2,4-D,Na salt 80% @ 0.06 kg a.i ha^{-1} as POE; pendimethalin 30EC@1.0 kg ha^{-1} as PE fb ethoxysulfuron15% WDG @15g ha^{-1} as POE; pendimethalin30EC @1.0 kg ha^{-1} as PE fb chorimuron 10%+ metsulfuronmethyl 10%WP @ 40 g ha^{-1} as POE; butachlor 60EC @1.5 kg ha^{-1} as PE fb bispyribac sodium10SC @ 35g ha^{-1} as POE; butachlor 60EC @1.5 kg ha^{-1} as PE fb 2,4-D Na salt 80%@ 0.06 kg ha^{-1} as POE; butachlor 60EC @1.5 g ha^{-1} as PE fb ethoxysulfuron15% WDG @15g ha^{-1} as POE; butachlor 60EC @1.5 kg ha^{-1} as PE fb chorimuron 10% + metsulfuronmethyl 10%WP @ 40g ha^{-1} as POE; mechanical weeding at 20 and 40 DAS; hand weeding at 20 and 40 DAS and un-weeded check. Pre and post emergence herbicides were applied at 3DAS and 20 DAS, respectively.

The rice variety "Sahbhagidhan" was sown at 20 cm apart in rows in 10 cm plant to plant distance in the first fortnight of June, depending upon the onset of monsoon, during the two years. The crop was fertilized with 80, 40, 20 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. In rice, half recommended dose of N (40 kg ha^{-1}) and full dose of P_2O_5 and K_2O was applied at sowing while the remaining nitrogen (40kg ha^{-1}) was applied in two splits dose, half at active tillering and the rest half at panicle initiation stage. All the other recommended agronomic and plant protection measures were adopted to raise the crop. Pre-emergence and post-emergence herbicides were applied in saturated soil moisture by using knapsack sprayer fitted with flat fan nozzle at spray volume of 600 liters ha^{-1}. In the plots under hand weeding, weeds were removed manually by using khurpi. The experimental soil was sandy-loam in texture with pH 7.2. The organic carbon, electrical conductivity, available nitrogen, phosphorus and potash were 0.58%, 0.105ds m^{-1}, 272.6, 16.47 and 288.32 kg ha^{-1}, respectively. The rainfall received during the crop season of respective years was 1202 mm and 670 mm respectively.

Data on weed density, weed dry weight and weed control efficiency were recorded at different stages after rice sowing with the help of a quadrate (0.5 × 0.5m) at 3 places and then converted into per m^2. These were subjected to squire root transformation to normalize their distribution. Weeds were cuts at ground level, washed with tap water. The biomass was determined after drying the samples in an oven at 70^{0}C for 72 hrs. Crop was manually harvested during last week of October in all two years. Weed control efficiency (WCE) was calculated as per the standard formula: WCE % = (dry weight of weeds in weedy check plots - dry weight of weeds in treated plots) / dry weight of weeds in weedy check plots ×100.

Grain yield of rice along with other yield attributing characters like effective panicles m^{-2}, grain $panicle^{-1}$ and test weight were recorded at harvest. Grain yield was converted to t ha^{-1} at 14% moisture content. Cost of cultivation and gross return were calculated on the basis of prevailing market prices of different inputs and outputs, respectively.

RESULTS AND DISCUSSION

Weed flora, weed density, weed dry weight and weed control efficiency

The most predominant weed species present in the experimental site were *Cynodon dactylon* (L) Pers**,** *Cyperus rotundus* (L)*., Cyperus iria* (L)., *Cyperus difformis* (L).*,Digitaria sanguinalis* (L)*., Fimbristylis miliacea* (L) Vaha*., Eclipta alba* (L)*., Echinochloa colona* (L).link*., Echinochloa crus-galli* (L) P. Beauv*., Eleusine indica.,* (L) *Phyllanthus niruri* (L)*., Euphorbia hirta* (L)*., Amaranthus viridis* (L)*., Oxalis acetosella* (L). and *Commelina benghalensis* (L). The combination of grasses, sedges and broad leaf weeds in weedy check plot were 18, 30, and 52% respectively. The results are in conformity with the findings of Anwar *et al*.,(2012). Emergence of broad leaf weeds was noticed earlier than of sedges and grasses. Weed community in the aerobic rice is generally dominated by broadleaf weeds followed by sedges and grasses were reported by Jayadeva *et al.,* (2011) and Sunil *et al*., (2010).

The lowest total weed density (4.6 m^2), dry matter production (2.3g m^2) and highest weed control efficiency (95.4%) irrespective of weed species were

recorded under two hand weeding followed by pendimethalin30EC @1.0 kg ha^{-1} as PE fb bispyribac10SC @ 35.0 g ha^{-1} as POE (5.7 m^2), (3.3g m^{-2}), (90.3%), pendimethalin30EC@1.0 kg ha^{-1} as PE fb ethoxysulfuron15%WDG@ 15.0 g ha^{-1} as POE (7.8 m^2), (4.5g m^2), (81.5%) at all the stages of crop growth during both the years respectively and all these treatments recorded highest values for number of tillers m^{-2}, number of panicles, number of grains $panicle^{-1}$, 1000 grain weight during both years. The effect due to different weed management practices on grain yield of rice was found to be statistically significant.

Weed density and weed dry weight were higher at 20 than 40 DAS. This was perhaps due to death by application of chemical herbicides of some of the weeds like *Cyperus difformis*, *Echinochloa crus-galli,*, *Marsilea quadrifoliata* and *Commelina benghalensis* and the shading effect of crop plant on short nature weeds. At both the stages of observation unweedy check recorded significantly higher weed population and weed dry weight than any other treatment (Table 1). Two hand weeding at 20 and 40 DAS were recorded the minimum weed population and dry weight and the highest weed control efficiency at both the stages. Among the herbicidal treatments, application of pendimethalin30EC @1.0 kg ha^{-1} as PE fb bispyribac10SC @ 35.0 g ha^{-1} as POE and pendimethalin30EC @1.0 kg ha^{-1} as pre-em fb ethoxysulfuron 15%WDC@ 15.0 g ha^{-1} as POE were recorded the highest grain yield . This might be due to the fact that rice under aerobic culture will reduce the weed competition and thereby there is improvement in yield attributes, resulting in higher grain yield. The superior performance of ethoxysulfuron could be attributed to the fact that it is a potent inhibitor of protox,

Table 1 : Effects of weed management practices on weed biomass weed density and weed control efficiency in aerobic rice (Mean data of two years)

Treatment	Weed densityat 20 DAS (No. m^{-2})	Weed densityat 40 DAS (No. m^{-2})	Weed biomass at 20 DAS (g m^{-2})	Weed biomassat 40 DAS (g m^{-2})	Weed control efficiencyat 40 DAS (%)
Pendimethalin @ 1kg a.i. ha^{-1} + Bispyribac sodium @ 35 g a.i. ha^{-1}	16.33 (4.1)	35.67 (5.7)	5.43 (2.4)	10.67 (3.3)	90.3
Pendimethalin @ 1kg a.i. ha^{-1} + 2,4-D,Na salt @ 600 g a.i. ha^{-1}	19.00 (4.4)	17.67 (4.2)	6.50 (2.6)	31.00 (5.6)	71.8
Pendimethalin @ 1kg a.i. ha^{-1} + Ethoxysulfuron @ 15 g a.i. ha^{-1}	17.67 (4.2)	61.67 (7.8)	5.83 (2.5)	20.33 (4.5)	81.5
Pendimethalin @ 1kg a.i. ha^{-1} + Chorimuron and Metsulfuronmethyl premix @ 40 g a.i. ha^{-1}	19.00 (4.4)	66.33 (8.1)	6.53 (2.6)	39.33 (6.3)	64.2
Butachlor @ 1.5kg a.i. ha^{-1} + Bispyribac sodium @ 35 g a.i. ha^{-1}	20.00 (4.5)	30.67 (5.6)	6.77 (2.7)	22.67 (4.8)	79.4
Butachlor @ 1.5kg a.i. ha^{-1} + 2,4-D,Na salt @ 600 g a.i. ha^{-1}	23.00 (4.8)	74.67 (8.6)	7.03 (2.7)	40.67 (6.4)	63.0
Butachlor @ 1.5kg a.i. ha^{-1} + Ethoxysulfuron @ 15 g a.i. ha^{-1}	21.33 (4.6)	31.00 (5.6)	6.37 (2.6)	33.00 (5.8)	70.0
Butachlor @ 1.5kg a.i. ha^{-1} + Chorimuron and Metsulfuron methyl premix @ 40g a.i. ha^{-1}	25.00 (5.0)	32.67 (5.7)	7.23 (2.8)	39.67 (6.3)	62.7
Mechanical weeding at 20 and 40 DAS	27.00 (5.2)	55.00 (7.4)	8.13 (2.9)	41.00 (6.4)	62.7
Two hand weeding at 20 and 40 DAS	14.33 (3.8)	20.67 (4.6)	4.33 (2.2)	5.00 (2.3)	95.4
Un-weeded check	32.67 (5.7)	61.00 (7.8)	9.87 (3.2)	110.0 (10.5)	-
SEm±	**2.3**	**4.3**	**0.5**	**3.2**	**-**
LSD (0.05)	**6.2**	**13.1**	**1.4**	**9.1**	**-**

deregulates the porphyrin pathway. The reduction of weed density and dry weight may be attributed to broad spectrum and season long weed control properties exhibited by the herbicide mixture or sequential application. Bispyribac inhibits the enzyme acetohydroxy acid synthase, also known as acetolactate synthase (ALS), in susceptible plants. This ultimately reduces transport of photosynthate from source leaves to roots, resulting in root growth inhibition. Unweeded check plots recorded the highest weed density and dry weight and lowest weed control efficiency. Among the herbicides treatments, application of butachlor 60EC @1.5 kg ha^{-1} as PE fb 2,4-D, Na salt 80% @ 0.06 kg ha^{-1} as POE; butachlor 60EC @1.5 kg ha^{-1} as PE fb chlorimuron10% + metsulfuronmethyl 10%WP @ 40 g ha^{-1} as POE, were recorded higher weed population, dry weight and lower weed control efficiency, indicating its ineffectiveness. This was mainly due to better control of weeds growth even upto harvest resulting in lower dry weight of weeds. The results are in conformity with the findings of Singh *et al.* (2005).

Yield and yield attributes

All the weed control treatment combinations significantly reduced the weeds flora as compared to unweedy check and recorded higher grain yield of rice. Pendimethalin30EC @1.0 kg ha^{-1} as PE fb bispyribac10SC @ 35.0 g ha^{-1} as POE; pendimethalin30EC @1.0 kg ha^{-1} as PE fb ethoxysulfuron15%WDG@ 15.0 g ha^{-1} as POE recorded the highest grain yield which was *on par* with application of pendimethalin 30EC @1.0 kg ha^{-1} as PE fb 2,4-D Na salt 80%@ 0.06 kg ha^{-1} as POE and butachlor 60EC @1.5 kg ha^{-1} as PE fb bispyribac10SC @ 35.0 g ha^{-1} as POE recorded higher grain yield as well as recorded higher yield attributing characters like productive tillers per m^2, panicle length, weight of panicle, filled grain per panicle and 1000-grain weight (25.13 g). Better weed control facilitated the crop for better absorption of nutrients, more sun light, less weeds-crop competition, space and air in weed free plots. The increased grain yield (Table 3) in these

Table 2 : Effect of weed management practices on growth, yield attributes of aerobic rice (Mean data of two years)

Treatment	Plant height (cm)	Panicle (No. m^{-2})	Panicle length (cm)	Grain panicle^{-1}	Test weight(g)
Pendimethalin @ 1kg a.i. ha^{-1} + Bispyribac sodium @ 35 g a.i. ha^{-1}	116.8	264.99	22.1	101	25.13
Pendimethalin @ 1kg a.i. ha^{-1} + 2,4-D,Na salt @ 600 g a.i. ha^{-1}	114.2	256.73	21.5	98	24.50
Pendimethalin @ 1kg a.i. ha^{-1} + Ethoxysulfuron @ 15 g a.i. ha^{-1}	115.6	258.79	21.8	99	24.57
Pendimethalin @ 1kg a.i. ha^{-1} + Chorimuron and Metsulfuronmethyl premix @ 40 g a.i. ha^{-1}	112.3	234.74	22.7	97	24.47
Butachlor @ 1.5kg a.i. ha^{-1} + Bispyribac sodium @ 35 g a.i. ha^{-1}	113.5	249.26	21.1	96	24.37
Butachlor @ 1.5kg a.i. ha^{-1} + 2,4-D,Na salt @ 600 g a.i. ha^{-1}	113.4	233.53	21.3	96	24.10
Butachlor @ 1.5kg a.i. ha^{-1} + Ethoxysulfuron @ 15 g a.i. ha^{-1}	113.9	248.05	21.5	96	24.20
Butachlor @ 1.5kg a.i. ha^{-1} + Chorimuron and Metsulfuron methyl premix @ 40g a.i. ha^{-1}	112.1	231.11	21.2	95	24.00
Mechanical weeding at 20 and 40 DAS	112.0	228.69	21.0	95	23.93
Two hand weeding at 20 and 40 DAS	117.4	266.42	22.3	103	25.60
Un-weeded check	106.3	186.34	20.2	61	22.50
Sem±	**3.40**	**15.20**	**0.73**	**1.19**	**1.29**
LSD (0.05)	**11.34**	**46.61**	**2.32**	**6.51**	**NS**

treatments were owing to reduced weed density, weed dry weight and better weed control efficiency and higher panicles/unit area conformity with Singh *et al*. (2005). Rao and Singh (1997) also reported that increased grain yield by herbicide mixture and sequential herbicide application respectively. Almix (Chorimuron10% + Metsulfuronmethyl 10%WP) was least efficient in weed control than bispyribac sodium or ethoxysulfuron in our experiment, it might be due to lack of broad spectrum weed control ability of combination. The minimum yield and yield attributes were in unweeded check plots, the result of severe weed competition by the uncontrolled weed growth.

Economics

Among weed control measures, hand weeding twice were recorded the higher gross income, net income and B:C ratio (Rs. 61832, 37864 and 1.57 respectively), followed by pendimethalin30EC @1.0 kg ha^{-1} as PE fb bispyribac10SC @ 35.0 g ha^{-1} as POE (Rs.58033, 38108 and 1.91, respectively), pendimethalin 30EC@1.0 kg ha^{-1} as PE fb ethoxysulfuron 15%WDG @ 15.0 g ha^{-1} as POE (Rs. 56854, 36994 and 1.86 respectively), and butachlor 60EC @1.5 kg ha^{-1} as PE fb bispyribac10Sc @ 35.0 g ha^{-1} as POE (Rs. 55544, 35650 and 1.79 respectively), (Table 3). This could be due to high weed control efficiency and higher grain yield obtained owing to application of effective herbicide dose and combinations. Thus application of pendimethalin 30EC@1.0 kg ha^{-1} as PE fb bispyribac10SC @ 35.0 g ha^{-1} as POE, pendimethalin 30EC @1.0 kg ha^{-1} as PE fb ethoxysulfuron 15%WDG@ 15.0 g ha^{-1} as POE and butachlor 60EC @1.5 kg ha^{-1} as PE fb bispyribac10SC @ 35.0 g ha^{-1} as POE proved more effective in checking the weed population and their growth and increasing the grain yield in aerobic rice. When herbicides were replaced by manual weeding, gross income increased but net benefit decreased because of high cost involvement in manual weeding. Even a combined early

Table 3 : Effect of weed management practices on grain yield and economics of aerobic rice (Mean data of two years)

Treatment	Grain yield (t ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit : cost ratio (Rs)
Pendimethalin @ 1kg a.i. ha^{-1} + Bispyribac sodium @ 35 g a.i. ha^{-1}	4.43	19925	58033	38108	1.91
Pendimethalin @ 1kg a.i. ha^{-1} + 2,4-D,Na salt @ 600 g a.i. ha^{-1}	4.26	19295	55806	36511	1.89
Pendimethalin @ 1kg a.i. ha^{-1} + Ethoxysulfuron @ 15 g a.i. ha^{-1}	4.34	19860	56854	36994	1.86
Pendimethalin @ 1kg a.i. ha^{-1} + Chorimuron and Metsulfuronmethyl premix @ 40 g a.i. ha^{-1}	3.98	19688	52138	32450	1.64
Butachlor @ 1.5kg a.i. ha^{-1} + Bispyribac sodium @ 35 g a.i. ha^{-1}	4.24	19894	55544	35650	1.79
Butachlor @ 1.5kg a.i. ha^{-1} + 2,4-D,Na salt @ 600 g a.i. ha^{-1}	4.14	19221	54234	35013	1.82
Butachlor @ 1.5kg a.i. ha^{-1} + Ethoxysulfuron @ 15 g a.i. ha^{-1}	4.21	19762	55151	35389	1.79
Butachlor @ 1.5kg a.i. ha^{-1} + Chorimuron and Metsulfuron methyl premix @ 40g a.i. ha^{-1}	3.64	19612	47684	28072	1.43
Mechanical weeding at 20 and 40 DAS	3.59	20654	47029	26375	1.27
Two hand weeding at 20 and 40 DAS	4.72	23968	61832	37864	1.57
Un-weeded check	2.12	16255	27772	11517	0.70
SEm±	**??**	**-**	**603.3**	**476.7**	**0.042**
LSD (0.05)	**0.71**	**-**	**1762.1**	**1445.1**	**0.130**

and post emergence application generated more net benefit as compared to manual weeding. Consequently, manual weeding is less remunerative compared to herbicidal control and practicing manual weeding throughout the season is a losing concern, confirming the view by Mahajan *et al.* (2009). All the weed control methods resulted significant increase in grain and biological yield over un-weedy check (Table 3). These weed management methods were found to be promising to control weeds in aerobic rice and would play an important role in areas where labour is too expensive and time is a constraint.

It is concluded that HW at 20 and 40 DAS; Pendimethalin 30EC @1.0 kg ha^{-1} as PE fb Bispyribac10SC @ 35.0 g ha^{-1} as POE; Pendimethalin 30EC @1.0 kg ha^{-1} as PE fb Ethoxysulfuron 15% WDG @ 15.0 g ha^{-1} as POE; Pendimethalin 30EC@1.0 kg ha^{-1} as PE fb 2,4-D Na salt 80% @ 0.06 kg ha^{-1} as POE and Butachlor 60EC @1.5 kg ha^{-1} as PE fb Bispyribac 10SC @ 35.0 g ha^{-1} as POE were better among the treatments and it may effective control a broad spectrum of weeds in aerobic rice.

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