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Comparative efficacy and economics of weed management treatments in upland rice at western mid hill of Nepal

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ABSTRACT

Weeds cause drastic reduction of rice yield and quality. The weeds problem is more severe in upland rice system. The efficiency and economics of different weed management treatments on weed dynamics, yield and economics of upland rice were evaluated by carrying out field experiment during rainy season of 2017 at NARC research station, Dasarathpur, Surkhet, Nepal. The experiment consisted of six treatments, *viz*: control, farmers' practice of hand weeding (HW) twice at15 and 30 days after seeding (DAS), manually running dry land weeder twice 15 and 30 DAS, one HW at 15 DAS *fb* bispyribac-sodium post-emergence application (PoE) at 0.4 g/ha 30 DAS, pre-emergence application (PE) of pendimethalin 1.5 g/ha *fb* 1 HW 15 DAS and pendimethalin PE at 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS, were tested in one factor RCBD design with four replications. Pendimethalin PE 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS was found to be most efficient and economical weed management option in upland rice with the highest rice grain yield (2.63 t/ha), net returns and B:C ratio.

Upland rice is grown in rainfed, fields and grown as dry direct-seeded rice, much like wheat or maize cultivation. The ecosystem is extremely diverse, including fields that are levelled, gently rolling or steep, at altitudes up to 2,000 meters and with rainfall ranging from 1,000 to 4,500 mm annually. Soils range from highly fertile to highly weathered, infertile and acidic, but only 15 percent of total upland rice grows where soils are fertile, and the growing season is long. Many upland farmers plant local rice that do not respond well to improved management practices—but these are well adapted to their environments and produce grains that meet local needs (Joshi *et al.* 2001).

The productivity of upland rice continues to remain low about 0.8 t ha^{-1}(MOALD 2019) Climatic and soil conditions are the major physical constraints of the upland rice productivity (Gupta and O'Toole 1986). The upland soil is acidic in nature and deficient in nitrogen, phosphorus with aluminum and manganese toxicity. Weeds and drought in upland rice are also the severe problems. Upland rice environments vary widely among the locations (Tommar 2001). Cultivar improvement, use of farmer participatory methods to reduce erosion, and weed management are areas where research advances are needed and being made.

Though the upland rice has lots of prospective for food security especially in remote area but at the same time it suffers from different problem like disease, pest, climatic adversity, lower fertility and weed infestation. Among these, weed menace is the main problem as it causes losses from 10-90% (Ehsanullah *et al.* 2014). Direct-seeded rice is likely to have high level of weed infestation than transplanted rice and with greater difficulty to manage (Begum *et al.* 2006, Rao *et al.* 2007, Chauhan and Johnson 2009). Traditionally, weeds are being controlled through manual weeding. Manual weeding, though effective, is getting increasingly difficult and costly due to labor scarcity and rising wages rates. With the availability of herbicides and associated weed management technology, it is possible to improve the yield of dry direct-seeded upland rice using herbicides (Mishra and Singh 2008, Khaliq *et al.* 2011). Thus, this study was conducted to evaluate different weeds management treatments, understand the weed dynamics and identify effective and economical weed management methods in the upland rice.

This study was conducted in mid-western Nepal in Surkhet district, Lakhbesi municipality at the experimental field of Agriculture Research Station field in collaboration with CIMMYT, Nepal. The experiment was laid out in randomized complete block design (RCBD) with six weed management treatments: Weedy check (no weeding)/ control, manually running dry land weeder twice (15 and 30 days after seeding [DAS]), farmers' practice of hand weeding (HW) twice (15 and 30 DAS), one HW at 15 DAS followed by (*fb*) bispyribac-sodium post-emergence application (PoE) at 0.4 g/ha 30 DAS, pendimethalin pre-emergence application (PE) at 1.5 g/ha *fb* one HW 15 DAS, pendimethalin PE at 1.5 g/ha *fb* bispyribac-sodium PoE at 0.4 g/ha15 DAS, replicated four times. The size of individual plot was 16.2 m^2 (4.5 m x 3.6 m) with the total experimental area of 388.8 m^2 (18 x 21.6 m).

Local upland rice variety Kalanathre (locally known as Gajale) was selected because of its adaptive nature and popularity among the farmers of this area. Seed rate used was 100 kg/ha. Seeds were sown continuously in line manually with row spacing of 20 cm on June 12, 2017. The pre-emergence herbicides were sprayed uniformly in the field at 3 DAS. Recommended dose of inorganic fertilizers *i.e.* nitrogen, phosphorus, and potash 60:30:20 kg/ha were applied using Urea (46%N), DAP (18% N, 46% P) and MOP (60% K). In the weedy check plot, throughout the crop duration weed growth was allowed along with the rice, whereas the respective methods of weed control treatments were implemented in other treatments as described. From the net plot, the weed biomass, weed species and grain yield were recorded and economic efficiency was calculated. The recorded data on various observed parameters were compiled and arranged treatment wise systematically in four replications. MS Excel was used for simple statistical analysis. Compiled data related to weed species density and biomass was transformed by square root transformation before analysis of variance. GenStat and R package were used for data analysis. ANOVA was constructed and significant data were subjected to DMRT for mean separation with reference to Gomez and Gomez (1984).

Effect on weeds

During harvesting of crop, weed density was more in control plot (2.646) which was statistically at par with density in dry land weeder plot (2.654) and farmer practice HW (2.699) which was followed by pendimethalin *fb* HW (2.521) and HW *fb* bispyribac-sodium (2.31) respectively with lowest density in pendimethalin *fb* bispyribac-sodium (1.92) treated plot (**Table 1**). Weed density at different time interval was also found significant to different weed management practices.

Weed biomass at 1st weeding was found to vary significantly amongst different weed management practices. The highest weed biomass was found in farmer's practices (108 g/m^2) followed by HW *fb* bispyribac-sodium (85.7 g/m^2). Similarly, the weed biomass in dry weeder used plot was 48.8 g/m^2, 50.8 g/m^2 in control plot and lowest with pendimethalin *fb* HW (7.6 g/m^2) and in pendimethalin *fb* bispyribac-

Table 1. Effect of different weed management treatments on weed control efficiency, total weed density and weed biomass at different growth stages in upland rice

Treatment	Weed control efficiency (%)			Weed density (no./m^2)			Weed biomass (g/m^2)		
	15 DAS	30 DAS	99 DAS	15 DAS	30 DAS	99 DAS	15 DAS	30 DAS	99 DAS
Weedy check (no weeding)/ control	0^{c} (1.9)	0^{c} (0)	0^{d} (0)	2.73^{b} (542)	2.885^{a} (767.5)	2.646^{a} (500.8)	50.8^{c}	230.8^{a}	211.2^{b}
Manually running dry land weeder twice (15 and 30 DAS)	-1.14^{c} (9.4)	3.09^{b} (3.2)	-0.28^{d} (-5.6)	2.76^{b} (576)	2.795^{b} (632)	2.654^{a} (452)	48.8^{c}	165^{b}	293.5^{a}
Farmers' practice of HW twice (15 and 30 DAS)	-5.64^{d} (-3.8)	5.58^{b} (21.8)	-1.98^{d} (32.1)	2.88^{a} (764)	2.724^{b} (530)	2.699^{a} (444)	108.8^{a}	46.3^{cd}	39.5^{c}
One HW at 15 DAS *fb* bispyribac-sodium PoE at 0.4 g/ha 30 DAS	-7.85^{e} (-10.1)	14.79^{a} (29)	12.65^{b} (34.4)	2.94^{a} (880)	2.458^{c} (289)	2.31^{c} (206.5)	85.7^{b}	27.7^{de}	35.8^{c}
Pendimethalin PE 1.5 g/ha *fb* 1 HW 15 DAS	41.06^{a} (62.3)	17.33^{a} (39)	4.72^{c} (34.8)	1.60^{d} (41)	2.385^{c} (243.5)	2.521^{b} (332.5)	7.6^{d}	17.5^{e}	40.6^{c}
Pendimethalin PE 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS	33.94^{b} (46.4)	15.42^{a} (24.6)	27.43^{a} (42.7)	1.80^{c} (64)	2.440^{c} (279)	1.92^{d} (83.5)	15.2^{d}	59.4^{c}	22.8^{c}
LSD (p=0.05)	2.115**	2.895**	1.913**	0.061**	0.083**	0.051	10.97**	26.47**	36.30**
Gran mean	10.06	9.37	7.09	2.45	2.614	2.459	52.8	91.1	107.2

Note: Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance, *mean significant and **mean highly significant and the value in parenthesis is original value sodium (15.2 g/m^2). Similarly, during second weeding, the weed biomass was highest under control plot (230.8 g/m^2) and lowest in the pendimethalin *fb* HW (17.5 g/m^2). During harvesting, weed biomass was found to be statistically same under framer's practice, HW *fb* bispyribac-sodium, pendimethalin *fb* HW and pendimethalin *fb* bispyribac-sodium which was lower than that of control and dry land weeder plot. This was attributed to the weed free environment provided by different weed control treatments (Gaire *et al.* 2019).

The different combination of weed management practices have significant effect in the weed control efficiency. At 15 DAS, the highest weed control efficiency was found with pendimethalin *fb* HW (41.06) followed by pendimethalin *fb* bispyribac-sodium (33.94), dry land weeder plot (-1.14), control plot (-1.14), farmer practice (-5.64) and least of HW and bispyribac-sodium (-7.85) respectively. Similarly, the highest weed control efficiency was found under pendimethalin *fb* HW (17.33) which was statistically at par with and pendimethalin *fb* bispyribac-sodium (15.52) and HW *fb* bispyribac-sodium (14.79) being lowest efficiency of control plot. During harvesting, it was found highest under pendimethalin *fb* bispyribac-sodium (27.43) followed by hand weeding *fb* bispyribac-sodium (12.65), pendimethalin *fb* HW (4.72) respectively.

Weed dynamics

Sedges: During the 1st weeding time, the infestation of the sedge was significantly high in upland rice. The highest sedge density was found in HW *fb* bispyribac-sodium (2.113) while the lowest was in pendimethalin *fb* HW (1.572) indicating pendimethalin efficacy in suppressing these weeds emergence (**Table 2**). During the second weeding the highest sedge infestation was found in pendimethalin *fb* bispyribac-sodium (2.321), and least in HW *fb* bispyribac-sodium (1.773) indicating reduced efficacy of pendimethalin on sedges with the passing of time after its application.

Broad-leaved weeds (BLW): The highest infestation of BLW was found in dry land weeder used plot (0.96) at 1st weeding; in pendimethalin *fb* HW (2.19) 2nd weeding and in farmer practice (2.66) at harvesting. The least BLW density was found with HW *fb* bispyribac-sodium (0.38) and pendimethalin *fb* HW (0.38) at 15 DAS, with HW *fb* bispyribac-sodium (0.619) at 30 DAS and with pendimethalin *fb* bispyribac-sodium (1.406) at rice harvest. The bispyribac-sodium was proved to control the BLW, hence lowest BLW density was found in bispyribac-sodium treated plot at rice harvest.

Grasses: During the 1st weeding time highest grasses density was found with farmer's practice and HW fb bispyribac-sodium followed by control and dry land weeder and the lowest density of grasses was with pendimethalin *fb* HW. During the 2nd weeding, the highest grass density was found with weedy check control (2.77) followed by dry weeder (2.5), farmer practice (2.573), HW *fb* bispyribac-sodium (2.348), pendimethalin *fb* bispyribac-sodium (1.494) and least in pendimethalin + HW (1.190). At rice harvest, the weedy check control (2.59) and dry weeder plot (2.58) had highest grass density followed by HW *fb* bispyribac-sodium (1.99), farmer practice (1.59), pendimethalin *fb* HW (1.57) and was least in pendimethalin *fb* bispyribac-sodium (1.517).

Table 2. Effect of different weed management treatments on density (no./ m^2) of grasses, broad-leaved weeds and sedges at 15, 30 and 99 days after seeding (DAS) in upland rice

Treatment	15 DAS (at first weeding)			30 DAS (at second weeding)			99 DAS (at harvest)		
	Grasses	Broad-leaved	Sedges	Grasses	Broad-leaved	Sedges	Grasses	Broad-leaved	Sedges
Weedy check (no weeding)/ control	2.664^{b}	0.376^{c}	1.879	2.770a	1.186^{d}	2.070	2.586^{a}	1.608^{e}	2.2070
	(464.5)	(2.5)	(74.5)^{c}	(589)	(16)	(162.5)^{b}	(386.5)	(41)	(16.50)^{b}
Manually running dry land weeder twice (15 and 30 DAS)	2.667^{b}	0.964^{a}	1.99	2.575b	1.776^{b}	2.275	2.582^{a}	1.715^{d}	2.27
	(466)	(9.50)	(100.5)^{b}	(382)	(60)	(190)^{ab}	(384)	(52)	(16)^{b}
Farmers' practice HW twice (15 and 30 DAS)	2.817^{a}	0.736^{ab}	2.003	2.573b	1.744^{b}	1.989	1.59^{c}	2.655^{a}	1.989
	(657.5)	(5.50)	(101)^{b}	(376)	(55.5)	(98.5)^{c}	(39.5)	(452.5)	(8.75)^{c}
One HW at 15 DAS *fb* bispyribac-sodium PoE at 0.4 g/ha 30 DAS	2.871^{a}	0.376^{c}	2.113	2.348c	0.619^{e}	1.773	1.990^{b}	1.981^{c}	1.773
	(747)	(2.50)	(130)^{a}	(225)	(4.5)	(59.5)^{e}	(99)	(96)	(11.50)^{b}
Pendimethalin PE 1.5 g/ha *fb* 1 HW 15 DAS	0.075^{d}	0.376^{c}	1.572	1.190e	2.190^{a}	1.854	1.570^{cd}	2.446^{b}	1.854
	(0.5)	(2.75)	(37.5)^{e}	(15.5)	(156.5)	(71.5)^{d}	(37.5)	(279.5)	(15.50)^{b}
Pendimethalin PE 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS	0.806^{c}	0.537^{bc}	1.728	1.494d	1.522^{c}	2.321	1.517^{d}	1.406^{f}	2.321
	(6.5)	(3.5)	(53.5)^{d}	(32)	(33.5)	(213.5)^{a}	(33)	(26)	(24.50)^{a}
LSD (p=0.05)	0.1161**	0.256**	0.10**	0.105**	0.167**	0.078**	0.063**	0.086**	0.078*
Grand mean	1.984	0.559	1.879	2.158	1.506	2.07	1.973	1.969	2.07

Note: Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance, *mean significant and **mean highly significant and the value in parenthesis is original value

Effect on rice

Rice plant height at all recorded growth stages was not significantly affected by various weed management treatments (**Table 3**) except at 75 DAS at which rice plant height with pendimethalin *fb* HW (106.4 cm) was significantly higher than that of other treatments. Maximum number of effective tillers per m^2 was recorded in pendimethalin *fb* bispyribac-sodium which was statistically higher than all the remaining treatments (**Table 4**). Statistically similar result was obtained for grain per panicle for all the treatments except weedy check control plot.

The highest straw yield was observed in pendimethalin *fb* bispyribac-sodium (2.95 t/ha) and was statistically at par with pendimethalin *fb* HW, HW *fb* bispyribac-sodium and farmer's practice of hand weeding twice (**Table 4**). The lowest straw yield was observed in weedy check plot and was statistically similar to that in dry land weeded plot. Parameswari and Srinivas (2014) stated that the huge amount of nitrogen, phosphorous and potassium was removed by the weeds in weedy check resulting in lower uptake of nutrients by rice and hence low rice biomass yield. The highest grain yield was recorded in pendimethalin PE *fb* bispyribac-sodium PoE (2.63

Table 3. Effect of different weed management treatments on plant height of upland rice

Treatment	Rice plant height (cm)				
	30 DAS	60 DAS	45 DAS	75 DAS	90 DAS
Weedy check (no weeding)/ control	32.0	68.9	65.0	85.2^{b}	101.6
Manually running dry land weeder twice (15 and 30 DAS)	32.7	76.3	66.2	90.5^{b}	108.1
Farmers' practice HW twice (15 and 30 DAS)	31.3	74.8	67.3	94.0^{b}	110.0
One HW at 15 DAS *fb* bispyribac-sodium PoE at 0.4 g/ha 30 DAS	38.6	71.3	62.6	93.1^{b}	107.9
Pendimethalin PE 1.5 g/ha *fb* 1 HW 15 DAS	33.1	81.9	72.1	106.4^{a}	115.4
Pendimethalin PE 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS	34.5	70.4	65.6	93.9^{b}	101.6
LSD (p=0.05)	NS	NS	NS	10.95*	NS

Note: Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance, * means significant, NS means non- significant

Table 4. Effect of different weed management treatments on rice yield attributes, straw yield, grain yield and harvest index

Treatment	No. of effective tiller/m^2	Grain per panicle	Sterility (%)	Straw yield (t/ha)	Grain yield (t/ha)	Harvest index
Weedy check (no weeding)/ control	238^{b}	73.9^{b}	31.4^{a}	1.88^{b}	0.989^{c}	0.35^{c}
Manually running dry land weeder twice (15 and 30 DAS)	210^{b}	80.2^{a}	18.1^{a}	1.91^{b}	1.453^{bc}	0.431^{ab}
Farmers' practice HW twice (15 and 30 DAS)	240^{b}	87.9^{a}	13.4^{ab}	2.29^{ab}	1.783^{b}	0.442^{ab}
One HW at 15 DAS *fb* bispyribac-sodium PoE at 0.4 g/ha 30 DAS	238^{b}	98.1^{a}	11^{ab}	2.33^{ab}	1.919^{b}	0.452^{ab}
Pendimethalin PE 1.5 g/ha *fb* 1 HW 15 DAS	245^{b}	83.6^{a}	15.9^{ab}	2.65^{ab}	1.616^{b}	0.387^{bc}
Pendimethalin PE 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS	369^{a}	109.4^{a}	9.5^{b}	2.95^{a}	2.628^{a}	0.471^{a}
LSD (p=0.05)	80.9*	23.15*	15.52*	0.825**	0.465**	0.067*
Grand mean	257	88.9	16.5	2.33	1.731	0.423

Note: Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance, *mean significant and **mean highly significant

Table 5. Economics of different weed management treatments in upland rice

Treatment	Cost of cultivation (`/ha)	Gross return (`/ha)	Net return (`/ha)	B:C ratio
Weedy check (no weeding)/ control	20140^{c}	27696^{c}	7556^{bc}	1.375^{bc}
Manually running dry land weeder twice (15 and 30 DAS)	27758^{b}	40678^{bc}	12920^{bc}	1.462^{bc}
Farmers' practice HW twice (15 and 30 DAS)	50885^{a}	49935^{b}	-950^{c}	0.985^{c}
One HW at 15 DAS *fb* bispyribac-sodium PoE at 0.4 g/ha 30 DAS	47765^{a}	53726^{b}	5962^{bc}	1.139^{bc}
Pendimethalin PE 1.5 g/ha *fb* 1 HW 15 DAS	28758^{b}	45235^{b}	16478^{b}	1.588^{b}
Pendimethalin PE 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS	23014^{c}	73572^{a}	50558^{a}	3.197^{a}
LSD (p=0.05)	4486.9*	13038.6*	14093.6*	0.457**
Grand mean	33053	48474	15421	1.624

Note: Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance, *significant and **mean highly significant t/ha) which was statistically higher than that of the remaining treatments (**Table 4**). The lowest grain yield from control plot (0.99 t/ha) which was statistically same as in dry land weeder used plot. Any reduction in weed pressure can be expected to promote yield as it lessens the strength of the competition for resources between the crop and the weeds (Phuong *et al.* 2005). The lowest yield was obtained under weedy check might be due to competition from weeds that reduced LAI, allowed less light transmission producing less photosynthates and ultimately low dry matter production (Parameswari and Srinivas 2014). Harvest index was highest with pendimethalin PE *fb* bispyribac-sodium PoE and lowest under weedy check control.

Economics

The cost of cultivation was higher for farmers' practice of hand weeding twice. Significantly higher gross return, net return and B:C ratio were obtained with pendimethalin *fb* bispyribac-sodium (**Table 5**).

Among the tested weed management treatments, highest yield (2.65 t/ha), net return (₹ 50558/ha) and B:C ratio (3.197) with lowest weed density and biomass was observed with pendimethalin PE 1.5 g/ha *fb* bispyribac-sodium PoE 0.4 g/ha 15 DAS and may be used for managing weeds and attaining maximum profitability of upland rice.

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