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Comparative Economics of Weed Management Treatments in Upland Rice at Western Mid Hill of Nepal

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Abstract: Weeds cause drastic reduction on yield and quality of rice. 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 AD at NARC research station, Dasarathpur, Surkhet, Nepal. The experiment consisted of six treatments viz: control, farmer's practice hand weeding, dry land weeder, pendimethalin with one hand weeding, hand weeding plus Bispyribac sodium and pendimethalin plus bispyribac sodium which were tested in one factor RCBD design with four replications. Pendimethalin plus bispyribac sodium was found efficient among all the treatments for the weed control. The highest grain yield (2.63 ton/ha) was also observed under the same treatment while lowest yield under control plot (0.99 ton/ha). The pendimethalin plus bispyribac sodium recorded the highest net returns and B: C ratio and was the most efficient and economical weed management option in upland rice.

Keywords: Upland rice; Weed Management; Economics; Herbicides

1. Introduction

Upland rice is grown in rainfed fields as dry direct-seeded rice, much like wheat or maize cultivation.[1-9] 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.[10]

The productivity of upland rice continues to remain low about 0.8 t ha^{-1}. Climatic and soil conditions are the major physical constraints of the upland rice productivity. The upland soil is acidic in nature and deficient in nitrogen, phosphorus with aluminum and manganese toxicity.[11-21] Drought and weeds in upland rice are also the severe problems. Upland rice environments vary widely among the locations.[20] Cultivar improvements, use of farmer participatory methods to reduce erosion, weed management are areas where research advances are being made.

Though the upland rice has lots of prospective for food security especially in remote areas but at the same time it suffers from different problem like disease, pest, climatic adversity, lower fertility and weed infestation. Among these, weed is the main problem as it causes losses from 10-90%.[6] Direct seed rice is likely to have high level of weed infestation than transplanted rice and make it more difficult to manage.[3,4,17] Traditionally, weeds were controlled through manual weeding. Though its effectiveness, it is getting increasingly difficult 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 direct seeded upland rice through chemical weed control.[11,14] Thus, this study was conducted to evaluate the different weeds management treatments and understand the weed dynamic in the upland rice and identify effective and economical weed management methods.

2. Materials and Methods

This study was conducted in mid-western Nepal in Surkhet district, Lakhbesi municipality at the experimental field of Agriculture Research Station field in amalgamation with CIMMYT, Nepal. The experiment was laid out in Randomized Complete Block Design (RCBD) with six weed management treatments (Table 1) 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 m 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 100kg/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 days after sowing (DAS). Recommended

Table 1. Weed management treatments tested in upland rice

S.NO	Treatments	Weed management treatments details
1	T1 (CTRL)	Weed check (no weeding)/ Control
2	T2 (DLW)	Manually running dry land weeder twice (15 DAS & 30 DAS)
3	T3 (FPH)	Farmers practice hand weeding twice (15 DAS and 30 DAS)
4	T4 (HN)	One hand weeding at 15 DAS + post emergence bispyribac sodium at 30 DAS @ 0.5ml/liter water
5	T5 (PH)	Pre emergence pendimethalin @5.5ml/liter water + one hand weeding 15 DAS
6	T6 (PN)	Pre emergence pendimethalin 5.5ml/liter water + post emergence Bispyribac sodium 0.5ml/liter water (15DAS)

Table 2. Effect of different weed management treatments on plant height of Upland rice

	Rice plant height (cm)				
	30 DAS	60 DAS	45 DAS	75 DAS	90 DAS
Control	32	68.9	65	85.2[b]	101.6
DLW	32.7	76.3	66.2	90.5[b]	108.1
FPH	31.3	74.8	67.3	94[b]	110
HN	38.6	71.3	62.6	93.1[b]	107.9
PH	33.1	81.9	72.1	106.4[a]	115.4
PN	34.5	70.4	65.6	93.9[b]	101.6
SEm(±)	2.93	3.94	2.89	3.63	5.12
LSD(0.05)	NS	NS	NS	10.95*	NS
CV(%)	3	3.7	2.3	3.4	4

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; ¥ Details in Table 1

Table 3. Effect of weed management treatment on rice yield attribute.

Treatments¥	No. of effective tiller per m^2	Grain per panicle	Sterility (%)
Control	238[b]	73.9[b]	31.4[a]
DLW	210[b]	80.2[a]	18.1[a]
FPH	240[b]	87.9[a]	13.4[ab]
HN	238[b]	98.1[a]	11[ab]
PH	245[b]	83.6[a]	15.9[ab]
PN	369[a]	109.4[a]	9.5[b]
SEm(±)	26.8	7.68	5.15
LSD(0.05)	80.9*	23.15*	15.52*
CV(%)	9.2	22.6	48.4
Grand mean	257	88.9	16.5

Table 4. Effect of different weed management practices in straw yield, grain yield and harvest index of Upland rice at Surkhet (2017).

Treatments¥	Straw yield (t/ha)	Grain yield (t/ha)	Harvest index
Control	1.88[b]	0.989[c]	0.35[c]
DLW	1.91[b]	1.453[bc]	0.431[ab]
FPH	2.29[ab]	1.783[b]	0.442[ab]
HN	2.33[ab]	1.919[b]	0.452[ab]
PH	2.65[ab]	1.616[b]	0.387[bc]
PN	2.95[a]	2.628[a]	0.471[a]
SEm(±)	0.274	0.154	0.022
LSD(0.05)	0.825**	0.465**	0.067*
CV(%)	14.4	4.8	5.6
Grand mean	2.33	1.731	0.423

dose of inorganic fertilizers i.e. nitrogen, phosphorus, and potash @ 60: 30: 20 kg ha^{-1} was applied using Urea (46%N), DAP (18% N, 46% P_2O_5) and MOP (60% K_2O).

In the weedy check plot, complete weed growth was allowed along with the rice crop throughout the crop duration, whereas the respective methods of weed control treatments were implemented in other treatments as in described in Table 1.

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 were subjected to analysis of variance (ANOVA) and 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 too.[13]

3. Results and Discussions

3.1. Rice plant height and Leaf Area Index (LAI)

Rice plant height at 30, 45, 60 and 90 DAS (Table 2) and LAI at all growth stages was not significantly affected by various weed management treatments. However, plant height at 75 DAS, the highest plant height under Pendimethalin + hand weeding (106.4 cm) was significantly higher than other treatments.

3.2. Effect of different weed management practices on various yield attributes and yield of Upland rice

3.2.1. Yield attributes

Maximum number of effective tillers per m^2 was recorded in Pendimethalin + Bispyribac sodium which was statistically different with all the remaining treatments (Table 3). Higher the weed density caused the lower effective tillers and lesser filled grains per panicle.[21] Statistically similar result was obtained for grain per panicle for all the treatments except control plot. More sterile grains were observed under control plot which was statistically at par with all the treatments except Pendimethalin + Bispyribac sodium.

3.2.2. Yield

The highest straw yield was observed in Pendimethalin + Bispyribac sodium (2.95 t/ha) and was statistically at par with Pendimethalin + hand weeding, hand weeding + Bispyribac sodium and farmer's practice weeding (Table 4). The lowest straw was yielded under weedy check plot and was statistically similar with dry land weeded plot. Parameswari and Srinivas[14] stated that the huge

Table 5. Effect of different weed management treatments on weed control efficiency, total weed density and weed biomass at different growth stage in Upland rice at Surkhet (2017)

Treatments[¥]	Weed density control efficiency								
	@ 15 DAS			@ 30 DAS			99 DAS		
	Weed control efficiency (%)	Weed density (/m^2)	Weed biomass (gram/m^2)	Weed control efficiency (%)	Weed density (/m^2)	Weed biomass (gram/m^2)	Weed control efficiency (%)	Weed density (/m^2)	Weed biomass (gram/m^2)
Control	0^{c}(1.9)	2.73^{b}(542)	50.8^{c}	0^{c}(0)	2.885^{a}(767.5)	230.8^{a}	0^{d}(0)	2.646^{a}(500.8)	211.2^{b}
DLW	-1.14^{c}(9.4)	2.76^{b}(576)	48.8^{c}	3.09^{b}(3.2)	2.795^{b}(632)	165^{b}	-0.28^{d}(-5.6)	2.654^{a}(452)	293.5^{a}
FPH	-5.64^{d}(-3.8)	2.88^{a}(764)	108.8^{a}	5.58^{b}(21.8)	2.724^{b}(530)	46.3^{cd}	-1.98^{d}(32.1)	2.699^{a}(444)	39.5^{c}
HN	-7.85^{e}(-10.1)	2.94^{a}(880)	85.7^{b}	14.79^{a}(29)	2.458^{c}(289)	27.7^{de}	12.65^{b}(34.4)	2.31^{c}(206.5)	35.8^{c}
PH	41.06^{a}(62.3)	1.60^{d}(41)	7.6^{d}	17.33^{a}(39)	2.385^{c}(243.5)	17.5^{e}	4.72^{c}(34.8)	2.521^{b}(332.5)	40.6^{c}
PN	33.94^{b}(46.4)	1.80^{c}(64)	15.2^{d}	15.42^{a}(24.6)	2.440^{c}(279)	59.4^{c}	27.43^{a}(42.7)	1.92^{d}(83.5)	22.8^{c}
SEm (±)	0.702	0.02	3.64	0.96	0.027	8.78	0.635	0.0172	12.04
LSD(0.05)	2.115**	0.061**	10.97**	2.895**	0.083**	26.47**	1.913**	0.051	36.30**
CV (%)	22.4	0.5	5.4	13.6	0.9	9.7	7.4	0.5	3.4
Gran mean	10.06	2.45	52.8	9.37	2.614	91.1	7.09	2.459	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; [¥] Details in Table 1

amount of nitrogen, phosphorous and potassium was removed by the weeds in weedy check plot resulting in lower uptake of nutrients by rice causing low biomass yield. Similarly, the highest grain yield was recorded in Pendimethalin + Bispyribac sodium (2.63 t/ha) which was statistically different with all the remaining treatments with lowest grain yield from control plot (0.99 t/ha) which was statistically same with dry land weeder 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.[16] The lowest yield was obtained under weedy check plots which might be due to competition from weeds, which reduced LAI and allowed less light transmission producing less biosynthate and ultimately low dry matter production.[14] Harvest index was found to be highest under Pendimethalin + Bispyribac sodium while lowest under control plot.

3.3. Effect of weed management treatments on weed control efficiency, weed density and weed biomass

3.3.1. Weed density

During harvesting of crop, weed population was more in control plot (2.646) which was statistically at par with density in dry land weeder plot (2.654) and farmer practice hand weeding (2.699) which was followed by Pendimethalin + hand weeding (2.521) and hand weeding + Bispyribac sodium (2.31) respectively with lowest density in Pendimethalin + Bispyribac sodium (1.92) treated plot. Weed population at different time interval was also found significant to different weed management practices.

3.3.2. Weed biomass

Weed biomass at 1st weeding was found to very significant to different weed management practices (Table 5). The highest dry matter accumulation was found in farmer's practices (108 g/m^2) followed by hand weeding + Nomine gold (85.7 g/m^2). Similarly, the dry matter accumulation for dry weeder used plot was 48.8 g/m^2, 50.8 g/m^2 for control plot and lowest under Pendimethalin + Hand weeding (7.6 g/m^2) and in Pendimethalin + Bispyribac sodium (15.2 g/m^2). Similarly, during second weeding, the dry matter accumulation of the weeds was found to be highest under control plot (230.8 g/m^2) and lowest in the Pendimethalin + hand weeding (17.5 g/m^2). During harvesting, weed dry matter accumulation was found to be statistically same under framer's practice, hand weeding + Bispyribac sodium, Pendimethalin + hand weeding and Pendimethalin + 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.[1,5,8,9,18]

3.3.3. Weed control efficiency

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

3.4. Weed dynamics in upland rice

3.4.1. Sedges

During the 1st weeding time, the infestation of the sedge was very much significant in upland rice. The highest sedge number was found in hand weeding + Bispyribac sodium (2.113) while the lowest number in Pendimethalin+ Hand weeding (1.572) treated plot. This is because Pendimethalin suppresses the emergence of weed effectively. During the second weeding the highest sedge infestation was found in Pendimethalin+ Bispyribac sodium (2.321), and least in

Table 6. Effect of different weed management treatments on weed dynamics in upland rice at Surkhet (2017)

	First weeding @15DAS			Second weeding @ 30 DAS			Harvesting@99DAS		
Treatments[¥]	**grasses**	**Broadleaf**	**sedges**	**Grasses**	**Broadleaf**	**sedges**	**grasses**	**Broad leaf**	**sedges**
Control	2.664b (464.5)	0.376[c] (2.5)	1.879 (74.5)c	2.770a (589)	1.186[d] (16)	2.070 (162.5)b	2.586a (386.5)	1.608[e] (41)	2.2070 (16.50)b
DLW	2.667b (466)	0.964[a] (9.50)	1.99 (100.5)b	2.575b (382)	1.776[b] (60)	2.275(190) ab	2.582a (384)	1.715[d] (52)	2.27 (16)b
FPH	2.817a (657.5)	0.736[ab] (5.50)	2.003 (101)b	2.573b (376)	1.744[b] (55.5)	1.989 (98.5)c	1.59c (39.5)	2.655[a] (452.5)	1.989 (8.75)c
HN	2.871a (747)	0.376[c] (2.50)	2.113 (130)a	2.348c (225)	0.619[e] (4.5)	1.773 (59.5)e	1.990b (99)	1.981[c] (96)	1.773 (11.50)bc
PH	0.075d (0.5)	0.376[c] (2.75)	1.572 (37.5)e	1.190e (15.5)	2.190[a] (156.5)	1.854 (71.5)d	1.570cd (37.5)	2.446[b] (279.5)	1.854 (15.50)b
PN	0.806c (6.5)	0.537[bc] (3.5)	1.728 (53.5)d	1.494d (32)	1.522[c] (33.5)	.321 (213.5)a	1.517d (33)	1.406[f] (26)	2.321 (24.50)a
SEm(±)	0.0385	0.085	0.033	0.034	0.055	0.025	0..021	0.028	0.025
LSD(0.05)	0.1161**	0.256**	0.10**	0.105**	0.167**	0.078**	0.063**	0.086**	0.078*
CV (%)	1.8	12.3	0.5	1.2	3.5	1.8	2	1.2	1.8
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; [¥] Details in Table 1

Table 7. Economics of different weed management treatments in upland rice

Treatments[¥]	**Cost of cultivation (Rs/ha)**	**Gross return (Rs/ha)**	**Net return (Rs/ha)**	**B:C ratio**
Control	20140[c]	27696[c]	7556[bc]	1.375[bc]
DLW	27758[b]	40678[bc]	12920[bc]	1.462[bc]
FPH	50885[a]	49935[b]	-950[c]	0.985[c]
HN	47765[a]	53726[b]	5962[bc]	1.139[bc]
PH	28758[b]	45235[b]	16478[b]	1.588[b]
PN	23014[c]	73572[a]	50558[a]	3.197[a]
SEm (±)	1488.5	4325.6	4675.5	0.151
LSD (5%)	4486.9*	13038.6*	14093.6*	0.457**
CV%	0.6	4.8	15.2	4.3
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; [¥] Details in Table 1

hand weeding + Bispyribac sodium (1.773). At the time of second weeding the effect of Pendimethalin was reduced as the time passes so more sedge was present in the field (Table 6).

3.4.2. Broadleaf

The highest weed infestation was found in dry land weeder plot (0.96) during 1st weeding time whereas highest in Pendimethalin + hand weeding (2.19) and in farmer practice (2.66) at 2nd harvesting, respectively. Similarly, the least weed density was found in hand weeding + Bispyribac sodium (0.38) and Pendimethalin + hand weeding (0.38) @ 15 DAS, hand weeding + Bispyribac sodium (0.619) @ 30 DAS and Pendimethalin + Bispyribac sodium (1.406) during harvesting. Bispyribac sodium suppresses the broad leaf so lowest broad leaf weeds population was found under Bispyribac sodium treated plot during harvesting (Table 6).

3.4.3. Grasses

During the 1st weeding time highest grasses were found in plot with farmer's practice and hand weeding + Bispyribac sodium followed by control and dry land weeder and lowest in Pendimethalin + hand weeding treated plot. During the 2nd weeding, the highest grass infestation was found in control plot (2.77) followed by dry weeder (2.5), farmer practice (2.573), hand weeding + Bispyribac sodium (2.348), Pendimethalin + Bispyribac sodium (1.494) and least in Pendimethalin + hand weeding (1.190) respectively. At the time of harvesting, the control (2.59) and dry weeder plot (2.58) had highest grass infestation followed by hand weeding + Bispyribac sodium (1.99), farmer practice (1.59), Pendimethalin + hand weeding (1.57) and least in Pendimethalin + Bispyribac sodium (1.517) respectively (Table 6).

3.5. Economics

The cost of cultivation was higher for farmer's practice hand weeding. Significantly higher gross return, net return and B: C ratio was found under Pendimethalin + Bispyribac sodium (Table. 7).

4. Conclusions

Among the different weed management treatments, highest yield (2.65 ton/hectare), net return (Rs.50558) and B: C ratio (3.197) with lowest weed density and weed biomass was observed with pendimethalin + Bispyribac sodium and may be used for maximum profitability of upland rice.

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Conflicts of Interest

The authors declare no conflict of interest.

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