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Original Article: Effect of Weed Management Practices on Weeds in Spring Rice in Nepal

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ABSTRACT

The productivity of spring rice is higher than the main season (summer) rice in Nepal although the production is less. Eliminating the competitive effect of weeds can add to increased crop yield and biomass production. Herbicides, one of the methods of weed control, offer numerous advantages over traditional manual weed control. However, they have negative effects on the environment, which can be mitigated through the implementation of an integrated weed control approach. A field experiment was carried out at Bateshwor, Dhanusha, Nepal involving different combinations of manual weeding, pretilachlor, and bispyribac-sodium to determine their impact on the weed dynamics in spring rice (Cv. Hardinath-1). The most prominent weed flora in the experimental plot comprised of 8 weed species (3 broad-leaf weeds, 3 grasses, and 2 sedges). Weeds were most persistent when manual weeding was performed although both weed density and dry weight were highest in Control. The least weed density and dry weight were found when both pretilachlor and bispyribac-sodium were used at 20 days after transplanting. Weed control efficiencies were better in this combination which ultimately resulted in the highest grain yield and the highest BC ratio.

Introduction

Rice is the main cereal crop of Nepal in terms of production, cultivated area and its link to livelihood of Nepalese people [1]. It is grown in summer (main season), winter (boro rice), and spring (chaite rice). Spring is the second most popular season for cultivation of rice in Nepal. Although the production of spring rice is only 558,320 Mt, the productivity is 4.67 Mt/ha in Nepal [1] which is actually higher than summer rice because of abundant sunny days, better irrigation and fertilizer use efficiency and less problem of weeds [2]. Irregular supply of water (i.e. flood, severe drought and sometimes both in the same cropping season) and infertile soil due to its inherent acidity or salinity are the most common bottlenecks of rice production in the rainfed ecosystem [3]. Competition between rice and weeds occur for light, nutrients, moisture, and space [4] which are limited in the field. Fifty to eighty percentage reduction in the yield in puddled transplanted rice can result from uncontrolled weeds [5]. The dominant weed flora in rice fields include *Echinocloa crusgalli*, *Leptochloa chinensis*, and *Echinocloa colonum* among grasses, *Cyperus difformis*, *Fimbristylis miliacea*, and *Cyperus iria* among sedges and *Marselia quadrifolia*, *Bergia capensis*, *Amania baccifera*, *Ludwigia parviflora*, and *Eclipta alba* among broad-leaf weeds [6].

Herbicides are widely used to control weeds. The use of pretilachlor, pendimethalin, bispyribac-sodium, butachlor, propanil, etc. has become the most common practice in Nepalese rice cultivation system [7]. Grassy weeds are more prevalent than broad-leaf weeds and sedges in the rice field [8]. Every time herbicides are used to suppress grasses, it often leads to the emergence of broad-leaf weeds and annual sedges, which then compete with the main crops and severely reduce productivity [9]. Weed management poses a significant challenge at Bateshwor, Dhanusha because of lack of technical knowhow regarding the use of herbicides combined with prevalent conventional farming system that lowers the suitability for mechanical weeding and, on the other hand, makes use of costly manual laborers for weeding. Individual control approaches aren't expected to control weeds sufficiently on their own, but when implemented in an integrated manner, they provide satisfactory weed management [10]. However, employing multiple methods might not always be economical for the farmers. In rice field, hand weeding and herbicides when used together in an integrated approach can help in effectively controlling the diverse weed flora in nursery [11] as well as in the main field [12]. Keeping this in view, a field experiment was conducted involving different combinations of hand weeding and herbicides so as to achieve effective weed control and higher profitability to the farmers.

Materials and Methods

Design of experiment

The field experiment was conducted at Bateshwor, Dhanusha, Nepal using Hardinath-1 variety of spring rice. The experiment was laid out in Randomized Complete Block Design (RCBD) with 7 treatments (Table 1).

Each treatment was replicated 3 times. Altogether there were 21 individual plots. Each individual plot (4 m x 2 m) contained 10 rows of 20 plants. The crop spacing was 20 cm x 20 cm, plot-plot spacing was 40 cm and block-block spacing was 1 m.

Sowing and intercultural operations

A fine tilled raised bed, 9 m long and 1.1 m wide, was prepared for nursery raising. After spreading the layer of seed, it was covered by 1-2 cm of fine soil layer with hand. Later, land preparation and field layout was done for transplanting. The field was flooded and puddling was done by repeated ploughing using a rotavator. After puddling, transplanting was done manually for which experienced labors were hired who planted 3 seedlings per hill while following the specified geometry and spacing. Plots and blocks were differentiated from each other by bunds.

Weeding operation in different treatments was carried out as designated (Table 1). Pretilachlor 50% EC at 0.6 kg a.i. ha^{-1} was mixed with dry sand and the mixture was broadcasted in the respective plot after transplanting and spray of bispyribac-sodium 10% SC at 25 g a.i. ha^{-1} was done at 20 or 30 DAT using a knapsack sprayer with a flat-fan nozzle [13]. Spray of profenofos 40% + cypermethrin 4% EC was done at the grain filling stage of rice to control the rice earhead bug (*Leptocorisa oratorius*) infestation.

Table1. Treatments used in the experiment

S.N.	Treatment name	Description
1	Control	Non-weeded check
2	HW20	Hand weeding at 20 DAT
3	HW20 + HW40	Hand weeding at 20 DAT and 40 DAT
4	Pre + Bis20	Pretilachlor + Bispyribac-sodium at 20 DAT
5	Pre + HW30	Pretilachlor + Hand Weeding at 30 DAT
6	Pre + Bis30	Pretilachlor + Bispyribac-sodium at 30 DAT
7	Pre + Bis20 + HW40	Pretilachlor + Bispyribac-sodium at 20 DAT + Hand weeding at 40 DAT

Note: Pretilachlor= Pretilachlor 50% EC at 0.6 kg a.i. ha^{-1}, Bispyribac-sodium= Bispyribac-sodium 10% SC at 25 g a.i. ha^{-1}, and DAT= Days after Transplanting.

Data recording

Weeds observed in experimental site were identified and recorded. Photos from the internet and weed catalogues were used for the identification of weeds. All weeds that occurred inside the 1 m x 1 m quadrat randomly placed in each plot were uprooted. They were counted to calculate the weed density followed by drying and weighing to calculate the dry weight. The same method was used to calculate dry weight of rice plants as well. Samples were initially shade-dried for 24 hours and then oven-dried at the laboratory of National Rice Research Program, Hardinath, Dhanusha using a hot air oven. The temperature of 70 °C was maintained constant for 72 hours [14] and finally the samples were weighed in an electronic balance.

The Weed Control Efficiency (WCE), Weed Persistence Index (WPI), and Crop Resistance Index (CRI) were calculated using the recommended formula. WCE was calculated using following formula given by Mani *et al.* (1973). [15]

$$WCE = \frac{WPc - WPt}{WPc} x \quad 100 \qquad (1)$$

Where, WPc= Weed density (No./ sq.m) in control plot and WPt= Weed density (No./ sq.m) in treated plot.

Similarly, WPI is calculated using the following relation given by Rana & Kumar (2014). [16]

$$WPI = \frac{Dt}{Dc} \times \frac{WPc}{WPt} \qquad (2)$$

Where, Dt= Dry weight of weed in treated plot, Dc= Dry weight of weed in control plot, WPc= Weed density (No./sq.m) in control plot, and WPt= Weed density (No./sq.m) in treated plot.

Likewise, CRI is calculated using the following relation given by Rana & Kumar (2014). [16]

$$CRI = \frac{CDt}{CDc} \times \frac{WDt}{WDc} \qquad (3)$$

Where, CDt= Dry weight of crop in treated plot, CDc= Dry weight of crop in control plot, WDt= Dry weight of weed in treated plot, and WDc= Dry weight of weed in control plot.

Both the grain yield and straw yield were weighed at harvest and converted into returns (NRs.) using contemporary valuation. Using that value, the BC ratio was calculated.

The recorded data were initially tabulated in MS Excel (2016) and effect of weeding treatment on yields was statistically analyzed using R-studio (version 4.2.0). Mean comparison was done using Duncan's Multiple Range Test at 5% level of significance.

Results and Discussion

Weed flora

During the experiment, grasses, sedges as well as broad-leaf weeds (BLW) were identified in the plots. Among the 8 most prominent weeds identified, 3 were BLW (*Sphenoclea zeylanica*, *Ammannia coccinea*, and *Ludwigia perennis* belonging to family Sphenocleaceae, Lathyraceae, and Onagraceae, respectively), 3 were grasses (*Echinocloa colona*, *Echinocloa crus-galli* and *Digitaria sanguinalis* belonging to family Poaceae), and 2 were sedges (*Cyperus iria* and *Fimbrystylis miliacea* belonging to family *Cyperaceae*). Smith (1983) [17] and Parthipan *et al.* (2013) [6] also found these weeds to be prominent in their respective research fields.

Weed density and Dry weight

Weed density and dry weight varied greatly under different weed management practices (Table 2). Up to 30 DAT, use of pretilachlor significantly reduced weed density which was observed in treatments Pre + Bis20 (9.33), Pre + HW30 (2.67), Pre + Bis30 (2.67), and Pre + Bis20 + HW40 (1.33). At 60 DAT, treatments Pre + Bis20 (1.33), Pre + Bis30 (4.67), and Pre + Bis20 + HW40 (1.33) had significantly lower weed density than that of treatment Pre + HW30 (22.67) indicating that the use of bispyribac-sodium offered better weed control than manual weeding performed around the same time. This occurred because the plant enzyme acetolactate synthase (ALS) was inhibited by bispyribac-sodium without which, protein synthesis and development are slowed, which eventually resulted in death of weeds [18]. After 60 DAT, no weeding was performed in the field and higher weed density was observed in all treatments.

Owing to high weed density, the highest dry weight of weed was observed in Control (176.67) while it was the lowest and statistically at par in treatments Pre + Bis20 (5.64), Pre + Bis30 (6.3) and Pre + Bis20 + HW40 (4.49).

At 95 DAT, both narrow-leaf and broad-leaf weeds were significantly suppressed in treatments Pre + Bis20, Pre + HW30, Pre + Bis30, and Pre + Bis20 + HW40 as shown by low values of both density and dry weight of weeds. Conversely, higher weed density and dry weight in treatments HW20 (107.67) and HW20 + HW40 (78) indicate that herbicides were more effective compared to manual weeding. Similar observation was also found by others where control of both dicot and monocot weeds were most effectively done by pretilachlor [18] and also by bispyribac-sodium [19].

Table 2. Weed density and dry weight of weed in spring rice under different weed management practices in Nepal, 2022

Treatment	Weed Density (No. of weeds/m^2)			Dry Weight at 95 DAT (g/m^2)
	30 DAT	60 DAT	95 DAT	
Control	189.33^a	161.33^a	131.67^a	176.67^a
HW20	166^b	76^b	107.67^b	165.67^b
HW20 + HW40	162.3^b	77.33^b	78^c	102.25^c
Pre + Bis20	9.33^c	1.33^d	28.67^d	5.64^e
Pre + HW30	2.67^c	22.67^c	71^c	18.38^d
Pre + Bis30	2.67^c	4.67^d	29.67^d	6.3^e
Pre + Bis20 + HW40	1.33^c	1.33^d	20.33^d	4.49^e
SEm±	18.79	12.39	8.97	16.22
F probability	<0.001	<0.001	<0.001	<0.001

Note: Pre= Pretilachlor 50% EC at 0.6 kg a.i. ha^{-1}, Bis= Bispyribac-sodium 10% SC at 25 g a.i. ha^{-1}. DAT= Days after Transplanting and SEm= Standard Error of Mean. Treatment means represented with same letter(s) are non-significant at 5% level of significance.

Weed Control Efficiencies and Grain yield

Efficiency of weed control varied greatly among different treatments (Table 3). Lower efficiency of weed control was observed when manual weeding was used for weed management. Combination of pretilachlor and bispyribac-sodium provided highly efficient weed control which was observed in treatment Pre + Bis20 + HW40 (84.58%) followed by Pre + Bis20 (78.27%) and Pre + Bis30 (77.54%) which is similar to the findings of Walia *et al.* (2012) [20].

The experiment shows that pretilachlor was highly effective in decreasing the Weed Persistence Index which was observed in treatments Pre + Bis20 (0.15), Pre + HW30 (0.19), Pre + Bis30 (0.16), and Pre + Bis20 + HW40 (0.17) (Table 3). The WPI in treatment HW20 was more than that of Control indicating that weeds were more persistent in manually weeded plot than in Control.

Weeds that escaped or were incompletely uprooted during manual weeding might have resulted in higher persistence. Mishra *et al.* (2016) [21] also reported higher resurgence of escaped weeds in hand weeded plots as indicated by high WPI values.

Table 3. Weed Control Efficiencies and grain yield in spring rice under different weed management practices in Nepal, 2022

Treatment	Weed Control Efficiencies			Grain Yield (kg/ha)	BC Ratio
	WCE	WPI	CRI		
Control	-	-	-	2854[e]	1.37[ab]
HW20	18.26[c]	1.16[a]	1.2[e]	3513[de]	1.26[bc]
HW20 + HW40	40.35[b]	0.98[a]	2.29[e]	3813[cd]	1.17[c]
Pre + Bis20	78.27[a]	0.15[b]	55.03[b]	5438[a]	1.54[a]
Pre + HW30	45.67[b]	0.19[b]	14.63[d]	4429[bc]	1.28[bc]
Pre + Bis30	77.54[a]	0.16[b]	48.99[c]	5496[a]	1.54[a]
Pre + Bis20 + HW40	84.58[a]	0.17[b]	67.42[a]	4992[ab]	1.24[bc]
SEm±	6.81	0.1	6.01	234	0.038
F probability	<0.001	<0.001	<0.001	<0.001	0.001

Note: Pre= Pretilachlor 50% EC at 0.6 kg a.i. ha^{-1}, Bis= Bispyribac-sodium 10% SC at 25 g a.i. ha^{-1}. WCE= Weed Control Efficiency, WPI= Weed Persistence Index, CRI= Crop Resistance Index, SEm= Standard Error of Mean, and BC= Benefit Cost ratio. Treatment means represented with same letter(s) are non-significant at 5% level of significance

Crop Resistance Index was highest in treatment Pre + Bis20 + HW40 (Table 3). It implies that rice was growing at increasing rate with simultaneous decline in weeds. The reason behind high CRI in that treatment might be the extra weeding operation because instead of one or two, three weeding operations were carried out. CRI was statistically higher in Pre + Bis20 (55.03) than in Pre + Bis30 (48.99) which indicate that delaying the application of bispyribac-sodium by 10 days make crops more susceptible to weed damage.

The grain yield was the highest in treatment Pre + Bis30 (5496) followed by Pre + Bis20 (5438), Pre + Bis20 + HW40 (4992), and the lowest in Control (2854) (Table 3). Despite having statistically similar yield, the BC ratio of Pre + Bis20 + HW40 (1.24) was lower than Pre + Bis20 (1.54) and Pre + Bis30 (1.54) because of one additional weeding operation.

Conclusion

The combination of pretilachlor and bispyribac-sodium gave the highest efficiency of weed control with higher CRI and lower WPI. When compared to alternative treatments such as manual weeding (HW30 and HW20 + HW40), this combination considerably reduced weed density and dry weight. Among the treatments using the combination of herbicides, the most satisfactory weed control was observed in Pre + Bis20 + HW40. However, when CRI, grain yield and BC ratio are considered, Pre + Bis20 was the superior treatment.

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Authors' contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

Conflict of interest

No conflicts of interest have been declared.

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