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Research Article

Effect of different weed management practices on growth and yield of spring rice (*Oryza sativa* L.) in Banke, Nepal

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ABSTRACT

Rice (*Oryza sativa* L.) is the most important crop in Nepal, despite having significant contribution to food security and agricultural economy, its production is being affected greatly by weed infestation. A field experiment was conducted during the spring season of 2022 to evaluate the different weed management practices in transplanted spring rice at Radhapur, Banke, Nepal. Seven weed management treatments were laid in Randomized Complete Block Design (RCBD) with three replications. The treatments were pre-emergence application of Pendimethalin 50% EC, 1 kg a.i./ha, at 3 DAT, post-emergence application of Bispyribac Na 10% SC, 25 g a.i./ha, at 28 DAT, pre-emergence application of Pendimethalin followed by post-emergence Bispyribac Na, Pre-emergence application of Pendimethalin followed by one hand weeding at 40 DAT and Farmer's practice i.e. one hand weeding at 40 DAT along with two controls (weedy free and weedy check). The rice variety Hardinath-1 was used in the experiment. Data regarding the weed flora, weed density, weed dry weight, rice growth, yield attributes and yield was recorded and analyzed. Weed flora in the experimental plot comprised of 11 weed species viz. five were broadleaf weeds belonging to four families, four grasses belonging to Poaceae family whereas three sedges belonging to Cyperaceae family. Sedges weeds were dominant as compared to broadleaf and grasses. The highest number of effective tillers per m^2 (413) and number of grains per panicle (101.33) were obtained in Pendimethalin followed by Bispyribac Na treated plot. The plot treated with combination of pre-emergence followed by post emergence recorded significantly the lowest weed density (9.67 weeds/m^2) at 60 DAT. This treatment significantly gave higher grain (4780 kg/ha), straw yield (4318 kg/ha) yield, harvest index (52.55%), other traits like sterility (22.19%) was recorded least and thousand grains weight was significantly higher (23.61g). The yield on weedy check plot produced the lowest yield as compared to weed free plot. Sedges weeds such as *Cyperus difformis, Cyperus iria* and *Fimbristylismiliaceae* were dominant as compared to dicots such as *Amaranthus spinosus, Chenopodium album* and grasses such as *Echinochloa crus-galli, Echinochloa colonum* at the experimental field. The ultimate overall analysis revealed that the application of pre-emergence followed by post-emergence herbicide was the best treatment so far as compared to other weed management treatments considering various data regarding variables.

Keywords: Herbicide, Dominant weeds, Spring rice

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple foods in the world as over half of the world's population depends on rice in their diet. It is grown in a diverse environment ranging from tropical plains to the foot of the mountain in Nepal. It is cultivated at the altitude of 3,050 MSL Jumla to lowest point 59 MSL, Kachankawal of our country (Paudel M., 2011). In fiscal year 2019/20 all over the Nepal rice was cultivated in 1,458,915 ha with production of 5,550,878 MT with the productivity of 3.80 Mt/ha, (MOALD, 2021). Besides this the area of cultivation of spring rice in comparison to main season rice is less but the productivity of the spring rice is 4.48 MT/ha with 3.61MT/ha for main season rice (MOALD, 2021).

The total area cultivated under rice in Banke was 31,500 ha and the production was 109,500 MT with productivity of 3.48MT/ha in the fiscal year 2076/77 (MOALD, 2021). Similarly the total area under rice in Banke district under main season and spring rice was 31,155 and 345 ha with total production of 107500 and 1,639 MT giving productivity of 3.46 and 4.75 MT/ha respectively in the fiscal year 2076/2077 (MOALD, 2021).

In Banke district, farmers mainly practice transplantation method in rice cultivation. Here the climatic and edaphic conditions are highly favorable for weed growth even in transplanted methods of rice cultivation. This has been leading to a significant yield loss of rice for years. As weeds are among the main biological reasons to deteriorate attainable rice yield potential this ultimately reduces profitability and approach to meet future rice demand. So, there should be proper weed management practice to minimize weed infestations. Weed must beproperly managed to avoid economic losses in cropproduction (Shrestha *et al.*, 2019). It should consist of both chemical and non-chemical approaches and focuses on keeping weed populations below a certain threshold level. This research is being carried out to increase awareness in farmers of the importance of weed management in rice cultivation and to demonstrate the effects of various weed control methods on productivity. The study is also carried out to compare the performance and yield of spring rice under various weed management techniques.

The preemptive competition is the most important competition for a plant species to emerge and grow among seedling of another competitive species (Rao *et al.*, 2007). Weed are the major burden for rice growing farmer, weed management is a huge challenge both for the researcher and farmers (Juraimi *et al.*, 2013). A variation in rainfall pattern due to unpredictable drought and due to the rising temperature intensifies the crop weed competition pressure (Ramesh *et al.*, 2017). In some rice growing area the infestation of both annual and perennial weeds can cause the yield losses of up to 50% (Tshewang *et al.*, 2016). Unavailability of weed resistance rice variety, lack of appropriate agronomic practices to control weed and lack of awareness on demerits of weed infestation in farmers creates more loss on yield. Weeds compete for resources such as nutrients, water and sunlight which would otherwise be available for crop. In addition, weeds harbor pests and diseases (Tshewang & Chauhan, 2016).

Different methods of weed managements practices like Physical, Mechanical, Cultural, Biological, and Chemical are used to control weed in the rice cultivation. Based on the feasibility of farmers and economical in nature, farmers in respected niches adopted of different types of weed management practices viable to them. The methods of weed control rice depend on the critical period of weed control, weed species and methods adopted. (Raj &

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Syriac, 2017). Herbicides are used to control weeds. But, because of problem about the evolution on herbicide resistance in weeds and less effectiveness of used herbicides there need to adopt other weed management practices to control weed (Chauhan, 2012). Generally, the economic principle of weed management is based on benefit-cost ratio but the scientists need to find eco-friendly practices with objective of controlling them.

Weed management has become the most important and inevitable aspect of crop management for achieving a higher rice yield. Increase in labor cost and labor scarcity has been major drivers for farmers to seek alternatives of manual weeding. So, chemical herbicide application has become a popular practice for managing weeds in different rice cultures. Since cultural and mechanical methods of weed control are time consumingand laborious so farmers mainly depend more on herbicides result several concerns like food safety, ground water and atmospheric contamination, increased weed resistance to herbicides, destruction to beneficial organisms, and concerns about endangered species have also increased with indiscriminate use of herbicides. Use of same herbicide in the same crop at the same area leads to shift in weed flora. Judicious selection of herbicide, correct time of application, proper dose and method of application are important factors to be considered for higher weed control efficiency and crop yield (Jacob *et al.*, 2014)

Nominee (Bispyribac-Na 400 g/l) is a new post-emergence herbicide for the control of Echinochloa crus-galli and a wide range of weeds in rice crop. Bispyribac Na is a selective herbicide which is effective to control grasses, sedges and broad leaf weeds in rice commodity (Schmidt *et al.*,1999). Application done from the third/fourth unfolded leaf up to the tillering stage presents a good control of weeds and a good plant compatibility, ensuring a yield increase (Risi *et al.*, 2004).Bispyribac Na is also found effective in controlling number of weeds, including grasses (Echinochloacrusgalli and E. colonum), broadleaves (S. montevidensis, Ludwigia spp. and Ammannia coccinea) and sedges (F. miliacea). It was also recorded that sole application of bispyribac Na caused more than 80% reduction in total weed density and about 78% reduction in weed dry weight (Khaliq *et al.*, 2011).

Pendimethalin acts both pre-emergence, that is before weed seedlings have emerged, and early post-emergence. It is used to control annual grasses and certain broadleaf weeds which interfere with growth, development, yield and quality of agricultural crops. Pendimethalin is available in granular, dispersible granular, and emulsifiable concentrate formulations. Pendimethalin is mainly applied as a pre-emergence spray, early postemergence (rice), and late postemergence spray (maize and sorghum) applications.

MATERIALS AND METHODS

Experimental site and climatic data

The experiment was conducted at the farmer’s field of Khajura-1, Radhapur, Banke. Its geographical coordinates are 28.072588 N and 81.525642 E and 146 m above the mean sea level.

As per the weather data obtained from Regional Agriculture Research Center located at Khajura, Banke under Nepal Agriculture Research Council, the average maximum temperature recorded was 42.7˚C in the month of May, 2022 while the minimum temperature recorded was 12.8˚C in February 2022. During experimental periods, rice plants received maximum rainfall of 58 mm in June 2022 and minimum rainfall of 5 mm in April 2022. The relative humidity was highest in February 2022 and lowest in April 2022.

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The composite soil sample was taken from the experimental field and sent to Soil and Fertilizer Testing Laboratory, Khajura, Banke for soil testing. As per the report obtained from the lab, the soil type was found to be clay loam (sand: 34.18%, silt: 38.74%, clay: 27.08%), slightly acidic (6.2 pH) with low content of organic matter (1.723%), low N (0.086%), medium P (25.709 kg/ha) and medium K (141.681 kg/ha).

Plant materials

Hardinath-1 is the most popular *Chaite* (spring) rice in Banke. It was originated in Srilanka and was released in Nepal in 2004 recommended for Terai and Inner terai. It matures in 120 days and has an average yield potential of 4.03 tha^{-1}; as well as long and smooth grain with good cooking and eating quality that depends on its soft to medium gel consistency.
The entire experimental field is divided into several blocks equal to the number of replications (R) of treatments (T). There were seven treatments for weed management;

Table 1. Details of Treatment

Treatments	Details
T1	Weed check
T2	Weed free (manual weeding at 15 days interval)
T3	Pendimethalin 30% EC (2 DAT)
T4	Bispyribac Na 10% SC (28 DAT)
T5	Pendimethalin followed by Bispyribac Na
T6	Pendimethalin followed by one hand weeding at 40 DAT
T7	Farmer’s practice; one hand weeding at 40 DAT

Note: Pendimethalin 30% EC was applied at the rate of 1 kg a.i./ha and Bispyribac Na 10% SC was applied at the rate of 25 g a.i./ha)

Crop management

At first, the nursery bed was prepared by ploughing the field twice, enriched with manure, fertilizer, and zinc, and prepared for sowing seeds of the Hardinath-1 rice variety treated with fungicides followed by even broadcasting of seeds, mulching with straw, and irrigation through furrows. The experimental plot/main field was ploughed three times and converted into an experimental plot of 2m × 2m, 21 such plots were made. Transplantation of seedings was done on 28th May 2022 with three seedlings per hill at a spacing of 20 cm × 20 cm. Fertilizer was applied at 120:60:40 NPK kg/ha using urea, DAP, and MOP, with P and K and half of N applied as a basal dose, and the remaining N top-dressed at tillering and panicle initiation stages. Intercultural operations included weeding treatments as per experimental design: weedy check, hand weeding at 40 DAT, pre-emergence (Pendimethalin) at 3 DAT, post-emergence (Bispyribac Na) at 28 DAT, and combinations of these. Irrigation was provided through canals, ensuring sufficient water during critical stages. Harvesting was done manually with sickles, followed by sun drying, threshing, winnowing, and cleaning, and grain and biological yields were recorded.

Data collection

Observation recorded on rice

Phenological observations

It was taken from fixed 5 plants randomly from each plot. The phenological observation was recorded at panicle initiation, booting, flowering, heading, milking, soft and hard dough and physiological maturity. Approximately 75% development of each of the stage was treated as completion of that particular stage and the data was expressed as days after transplanting (DAT).

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Biometrical observation

Plant height (cm)

Randomly selected and tagged 5 plants from different rows except border row were used for the measurement of plant height. Plant height was measured at 15 days interval from 30DAT up to 75 DAT. The average of 5 plants was expressed as plant height in cm. It was measured from base to tip of the upper leaves of the main stem.

Number of tiller per square meter

Tiller per square meter was counted from the plants in between 2nd and 4th row from 40 cm × 40 cm area. Sampling rows at 15-days intervals from 30th days after sowing up to 75 DAT after sowing and mean was calculated.

Yield attributing characters of rice

Length of panicle (cm)

Randomly selected 20 panicles were taken from sixth and seventh rows outside from the net plot to measure length of panicle. This was done just before harvesting and the mean was calculated.

Number of filled grains per panicle and sterility percentage

The number of filled grains per paniclewas counted and weighted in electronic balance by taking the grains from same 20 panicles (taken for measuring length) just before harvesting. At the same time, number of filled and unfilled grains was counted to determine the number filled grains per panicle and sterility percentage. Sterility percentage was calculated using following formula and expressed in percentage.

$$\text{Sterility percent (\%)} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Thousand grain weight (TWG) (g)

Thousand grains were counted from the randomly selected grain yield of net plot and weighed with the help of electronic balance at exact moisture content and mean was calculated and expressed in gm at 14% moisture level.

Grain and straw yield (kg/ha)

The crop from the net plot was harvested to record the grain yield. Grain yield and straw yield were taken at harvest of crop from each net plot. The crop was dried, threshed, cleaned and again sun dried and final weight was taken. Moisture was measured with the help of the Wile 65 grain moisture meter. Grain yield at 14% moisture was calculated using the formula suggested by Poudel. (1995)

$$\text{Grain yield (kg ha}^{-1}\text{) at 14\% moisture} = \frac{(100-MC)\times plot\ yield\ (kg)\times 10000(m2)}{(100-14)\times netplot\ area\ (in\ square\ meter)} \quad \ldots\ldots\ldots\ldots(2)$$

Where, MC is the moisture content percentage of the grains

$$\text{Grain yield (kg/ha) at 0\% moisture} = \text{Grain yield (kg ha}^{-1}\text{) at 14\% moisture} \times 0.86 \quad \ldots\ldots(3)$$

Straw yield was obtained by deducting grain yield from total biomass yield of net plot.

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Harvest Index

Harvest index (HI) was computed by dividing grain yield at 0% moisture with the total dry matter yield (grain yield at 0% moisture and straw dry weight) as per the formula.

$$\text{Harvest index (HI)} = \frac{Grain\ yield}{Biomass\ yield\ (Biological\ yield)} \quad \ldots\ldots\ldots\ldots.(4)$$

Observations recorded on weed

Weed identification

Weed sampling was done in every 30 days interval starting from 30 DAT till 90 DAT. Weeds from sampling area i.e. from 40*40 cm^2 were observed in between 2^{nd} row and 4^{th} row, identified and recorded with their categories as broad leaf weeds, grasses and sedges according to their morphology. Photos taken from internet and weed catalogue were used for the identification of weeds.

Weed density

Number of weeds emerged was counted in area between rows of rice, i.e., from 40cm×40cm at 30, 60 and 90 DAT. Total number of weeds was calculated by summation of total broadleaf weeds, sedges and grasses.

Weed dry weight

Weed fresh weight of weeds found in area between rows of rice, i.e., from 40cm×40cm was measured at 30, 60 and 90 DAT. Total weed fresh weight was calculated by summation of total broadleaf weed fresh weight, sedges fresh weight and grasses fresh weight and values were converted to per meter square. Three weed samples for each category of weed (sedges, broadleaf and grasses) were kept at 30 DAT, 60 DAT and 90DAT. Later the samples were oven dried at 70 degree Celsius for three days to bring moisture percent to 0 degree Celsius for calculating dry weed weight.

Weedy control efficiency (WCE %)

Weedy control efficiency (WCE) expresses the percentage reduction in weed population due to weed management practices over weed check. The WCE was calculated using following formula given by Mani et al. (1973).

$$\text{WCE}(\%) = \frac{\text{WPc} - \text{WPt}}{\text{WPc}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots(5)$$

Where,

WPc= Weed population (No. m^{-2}) in unweeded plot

WPt= Weed population (No. m^{-2}) in treated plot

Weed control index (WCI%)

Weedy control index (WCI) expresses the percentage reduction in weed dry weight due to weed management practices over weed check. The WCI was calculated using following formula given by Mani *et al.* (1973) and Das (2008).

$$\text{WCI}(\%) = \frac{\text{WDWc} - \text{WDWt}}{\text{WDWc}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

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Where,
WDWc= Weed dry weight (g/m^2) in unweeded plot
WDWt= Weed population (g/m^2) in treated plot

Statistical analysis

The recorded data was analyzed using MS-Excel 2019 Data were subjected to analysis of variance (ANOVA) and data related to weed species was transformed by square root transformation before analysis of variance. R-studio was for data analysis. ANOVA was constructed and significant data were subjected to DMRT for mean separation with reference to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Biometric data

Plant height

Weed management practices significantly influenced the plant height at all growth stages. Different weed management techniques have a considerable impact on rice plant height at all growth stages. The combination of pre-emergence at 3 DAT and post-emergence at 28 DAT, resulted in the tallest plants at all growth phases after weed free treatment. The treatment combining pre-emergence at 3 DAT, followed by 28 DAT, and statistically significant with control, resulting in the highest plant height (35.67 cm) at 30 days after transplanting where control plot had lowest (28.33 cm). Similarly, the treatment of combination pre-emergence at 3 DAT and post emergence 28 DAT resulted in the plant height at 45 DAT (62.33 cm) being much higher than the control, which had the lowest plant height (47.00 cm).

Table 2. Plant height as influenced by different weed management practices at Radhapur, Banke, 2022

Weed management practices	Plant height (cm)			
	30 DAT	45 DAT	60 DAT	75 DAT
Weed free (Manual hand weeding at 15 days interval)	41.33^{a}	70.67^{a}	86.67^{a}	91.67^{a}
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	35.67^{bc}	62.33^{ab}	81.00^{ab}	87.33^{ab}
Pendimethalin 30% EC followed by one HW at 40 DAT	36.33^{b}	58.67^{bc}	79.67^{ab}	78.00^{bc}
Bispyribac Na 10% SC	33.66^{bc}	54.67^{bcd}	74.67^{bc}	77.33^{bc}
Pendimethalin 30% EC	32.00^{bcd}	57.33^{bc}	76.00^{bc}	78.67^{bc}
Farmer's practice; one HW at 40 DAT	31.33^{cd}	51.00^{cd}	67.00^{cd}	70.00^{cd}
Weed check	28.33^{d}	47.00^{d}	58.67^{d}	64.67^{d}
Grand mean	34.09	57.38	74.80	78.23
SEm±	1.19	4.85	6.09	9.64
LSD (0.05)	4.15	8.39	9.40	11.82
CV%	6.84	8.21	7.06	8.49

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding.

At 60 DAT, the tallest plant height (81.00 cm) was observed at same treatment which was statistically significant with control (58.67 cm). Plant height at 75 DAT was significantly highest (87.33cm) at treatments of combination of pre-emergence at 3 DAT followed by post emergence 28 DAT and the lowest at control (64.67 cm). Plant height increases with number of transplanting days and plant height is found superior in the combination of pre emergence

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at 3 DAT followed by post emergence at 28 DAT as demonstrated by **Table 2.** Similar results were obtained by (Bhurer *et al.*, 2013).This is due to less interference of crop and weed and availability of nutrient during vegetative growth and development as weed is tough competitor with paddy. Uremis and Arslan (2005) also found that plant height is significantly affected by the plant height.

Number of tillers per m^2

Number of tillers per square meter was significantly influenced by weed management practices during all growth stages. 30 days after transplanting, the highest number of tillers per square meter (282.67) was recorded on combination of pre-emergence at 3 DAT followed by post emergence at 28 DAT whereas found least on control (235.00). After 45 days after transplanting, combination of pre-emergence at 3 DAT followed by post emergence at 28 DAT which is also followed by showed the maximum number of tillers per square meter (366.00) whereas found lowest at control (253.67). At 60 DAS maximum number of tillers (413.00) was observed at combination of pre-emergence at 3 DAT followed by post emergence 28 DAT which was also followed by lowest at control (352.67). The tiller number increased and reached a maximum at 60 DAT and thereafter was a decline in tiller number per hill due to tiller mortality. At 75 DAT, the highest number of tiller (338.00) were recorded at pre-emergence at 3 DAT followed by post emergence at 28 DAT which is also found lowest at control (275.67).The result can be seen in **Table 3**.

Table 3. Number of tillers per m^2 of rice as influenced by different weed management practices at Radhapur, Banke,2022

Weed management practices	Number of tillers per m^2			
	30 DAT	45 DAT	60 DAT	75 DAT
Weed free (Manual hand weeding at 15 days interval)	298.33^{a}	379.00^{a}	433.00^{a}	338.00^{a}
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	282.67^{ab}	366.00^{ab}	413.00^{ab}	326.67^{ab}
Pendimethalin 30% EC followed by one HW at 40 DAT	266.67^{abc}	344.33^{abc}	393.33^{ab}	310.67^{abc}
Bispyribac Na 10% SC	257.67^{bcd}	318.00^{bc}	372.00^{b}	310.00^{abc}
Pendimethalin 30% EC	265.00^{abc}	339.00^{bc}	382.33^{ab}	305.00^{abc}
Farmer's practice; one HW at 40 DAT	235.00^{cd}	313.00^{c}	356.33^{b}	286.33^{bc}
Weed check	228.667^{d}	253.67^{d}	352.67^{b}	275.67^{c}
Grand mean	262	330.43	386.09	307.48
SEm±	77.68	154.45	213.69	135.06
LSD (0.05)	33.56	47.33	55.671	44.25
CV%	7.20	8.05	8.10	8.09

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding.

This might be due to the availability of nutrients to paddy in weed managed field as there is lowest weed density resulting in ample availability of space, nutrient, and light for proper growth and development. Similar results were observed by (Hasanuzzaman *et al.*, 2009).

Yield attributing traits

Panicle Length

The mean value of panicle length was greatly influenced by the weed management practices. The longest panicle length was found longest (22.03 cm) in the combination of post

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emergence at 28 DAT and pre-emergence at 3 DAT and found lowest on control (16.75 cm). It can be seen in **Table 4**. (Hasanuzzaman *et al.*, 2009) also found similar results.

Thousands of grain weight

Thousands of grain weight are greatly influenced by the weed management practices. As in **Table 4**, the highest grain weight was observed highest (23.61 g) in the combination of pre-emergence at 3 DAT followed by post emergence at 28 DAT. Similar data were observed by (Narwal *et al.*, 2002).

Number of grains per panicle

The number of grains per panicle was found significantly influenced by weed management practices. The highest grain per panicle (103.33) was found in the combination of pre-emergence at 3 DAT followed by post-emergence at 28 DAT. This might be due to less competition between paddy and weed at different times of the growth stage by different combinations of weed management treatment which is aligned with **Table 4**. Naik *et al.*, (2019) also found the similar results.

Sterility

Sterility % was significantly influenced by weed management practices. As shown in **Table 4**, higher sterility % (31.14%) were observed in control plot whereas the lowest sterility % (22.19%) were observed in combination of treatment of pre-emergence at 3 DAT followed by post emergence at 28 DAT. This might be due to the better environment provided for the full development of the canopy because of an effective weed control achieved by the mixture of herbicides at the early stage of crop weed competition. The results were also observed by Balasubramanian *et al.* (1996).

Table 4. Yield attributes of rice as influenced by different weed management practices at Radhapur, Banke 2022

Weed management practices	Yield attributing characters			
	Panicle length (cm)	Number of grains per panicle	Thousand Grain Weight (TGW)	Sterility %
Weed free (Manual hand weeding at 15 days interval)	22.33^{a}	104.0^{a}	24.78^{a}	20.15^{d}
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	22.03^{a}	101.33^{a}	23.61^{a}	22.19^{cd}
Pendimethalin 30% EC followed by one HW at 40 DAT	20.06^{ab}	89.00^{b}	20.59^{b}	22.25^{cd}
Bispyribac Na 10% SC	18.48^{bc}	77.00^{c}	20.07^{b}	23.19^{c}
Pendimethalin 30% EC	17.63^{bc}	74.33^{c}	19.40^{b}	24.92^{c}
Farmer's practice; one HW at 40 DAT	16.75^{c}	52.67^{d}	17.98^{bc}	28.10^{b}
Weed check	16.54^{c}	49.67^{d}	15.89^{c}	31.14^{a}
Grand mean	19.12	78.29	20.33	24.90
SEm±	0.57	9.25	0.57	5.90
LSD (0.05)	2.86	11.58	2.89	2.61
CV%	8.43	8.31	8.00	5.90

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding.

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Yield attributing parameters

Grain yield

Grain yield is determined by the function of various yields attributing characters (effective tiller per hill, panicle length, Number of grains per panicle, thousand-grain weight, sterility percentage, etc.), environmental factors, input applied, weed competition and their management. The rice yield of grain was significantly affected by weed management practices. A significantly superior grain yield (4780 kg/ha) was recorded with the combination of pre-emergence at 3 DAT followed by post emergence at 28 DAT whereas found lowest on control (1529 kg/ha). The result can be seen in **Table 5**. This might be due to less stress to plant from the competition with weeds for suitable nutrients and space during the stages of establishment. This may also be attributed to the fact that effective weed management at critical stages of the crop weed competition, thereby the yield attributes were the highest resulting in the increase in grain yield. Similar results were observed by Sreelakshmi *et al.* (2016).

Straw yield

Weed management practices significantly influenced the biological yield of the paddy. As shown in **Table 5**, the highest straw yield (4318 kg/ha) was observed in the combination of treatment pre-emergence at 3 DAT followed by post emergence at 28 DAT. The lowest straw yield (2189 kg/ha) was found in control. This might be due to reduced competition by weeds due to frequent elimination of weeds from the field that leads to reduce weed density, weed dry weight and results in good yields. Similar results were observed by Naik *et al.*(2019).

Harvest Index

Harvest index was significantly influenced by weed management practices. **Table 5** below shows that the highest harvest index (52.55%) was observed highest at the combination of treatment of pre-emergence at 3 DAT followed by post emergence at 28 DAT. The lowest harvest index (40.99%) was observed at control.

Table 5. Yield attributing parameters of rice as influenced by different weed management practices at Radhapur, Banke, 2022

Weed management practices	Yield attributing parameters		
	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)
Weed free (Manual hand weeding at 15 days interval)	4870[a]	4352[a]	52.79[a]
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	4780[a]	4318[a]	52.55[a]
Pendimethalin 30% EC followed by one HW at 40 DAT	4603[ab]	4231[a]	52.08[a]
Bispyribac Na 10% SC	4516[ab]	4083[ab]	52.50
Pendimethalin 30% EC	4069[ab]	3873[ab]	51.22[a]
Farmer’s practice; one HW at 40 DAT	3780[b]	3705[b]	50.11[a]
Weed check	1529[c]	2189[c]	40.99[b]
Grand mean	4021	3822	50.32
SEm±	250.13	161.46	0.91
LSD (0.05)	898.51	505.52	3.42
CV%	12.56	7.44	3.82

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding.

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This might be due to greater translocation of photosynthates from source to sink resulting in higher harvest index under weed control treatments as compared to unweeded check. This might also be due to less sharing of supplied nutrients between rice and weeds due to the low weed population in the treated plot. Similar results were confirmatory with the findings of Uma *et al.* (2014).

Weed parameters

Weed flora of Transplanted Rice

The dominant weeds of grass, broad leaved and sedges observed at different growth stages of transplanted rice are listed in table given below. Eleven weed species belonging to seven families were observed in the experimental plots. The grassy weeds observed belong to mostly Poaceae family and some of them to Pontederiaceae and Commelinaceae; and monocot with most of them was annual herb except *Cynodondactylon*. Similarly, all the sedges were from Cyperaceae family and monocot. The broad-leaved weeds were from different families and mostly dicot. Weed management practices significantly reduced the weed density as compared to weedy check plot. Changes in rankings of dominant weeds were observed by (Singh *et al.*, 2007) and (Bagale, 2023).

Weed Density

Weed density showed an increase with number of days of transplanting to 90 DAT. The highest weed density was observed in control (275 m^2) and found lowest in the combination of pre-emergence followed by post emergence. Similar results were observed in 30, 60 and 90 DAT. At 90 DAT the trend of increasing the weed density declined. At 90 DAT the highest weed density was observed in control (275/m^2) and lowest on the combination of pre-emergence followed by post emergence. The overall result of the treatments can be seen in **Table 6**.

Table 6. Total weed density (number/m^2) as influenced by various weed management practices at Radhapur, Banke, 2022

Weed management practices	Weed density (number/m^2)		
	30 DAT	60 DAT	90 DAT
Weed free (Manual hand weeding at 15 days interval)	1.79^e (3.33)	0.71^f (0.00)	2.06^e (4.67)
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	3.24^d (10)	3.15^e (9.67)	4.37^d (18.67)
Pendimethalin 30% EC followed by one HW at 40 DAT	4.02cd (16)	4.37^d (18.67)	3.88^c (61.67)
Bispyribac Na 10% SC	4.60^c (20.67)	6.06^c (36.33)	8.066^c (74.67)
Pendimethalin 30% EC	5.03^{bc} (25)	6.89^{bc} (47.33)	9.45^{bc} (89)
Farmer's practice; one HW at 40 DAT	6.02^b (36)	7.75^b (60.67)	11.28^b (129)
Weed check	12.56^a (158)	13.94^a (194)	16.58^a (275)
Grand mean	5.32	6.12	8.61
SEm±	0.14	0.15	0.23
LSD (0.05)	1.14	1.22	1.84
CV%	12.06	11.17	12.01

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding. The figures in the parenthesis represent the original value and outside the parenthesis the square root transformation value (√(x+0.5).

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The reduced density of weeds might be due to the application of weed management treatments on interval such that they could not maintain their population for long time and attributed to broad spectrum and season long weed control by the application of pre-emergence followed by post - emergence followed by a hand. This agrees with the findings of (Pal *et al.*, 2009) and (Pant *et al.*, 2023).

Weed dry weight

The effect of the various weed management practices on weed dry weight rice was found significantly different in sedges dry weight, grasses dry weight and broad leaf weed dry weed. Among seven treatments, weedy check plots showed the highest sedges dry weight followed by rest treatments which were found statistically at par with respect to each other.
Significant difference in weed dry weight was observed due to different weed management practices. Among all the treatments, the dry weight of monocot, dicot and sedges was found highest in control and in combination of treatment pre-emergence post emergence the dry weight of monocot, dicot and sedge found least among all treatments. This might be due to the control of weed by different weed management practices at different time intervals either by herbicidal treatment or by hand weeding. The overall result of the treatments can be seen in **Table 7**. These results were partially supported by (Hasanuzzaman *et al.*, 2009) and (Pant *et al.*, 2023).

Table 7. Total weed dry weight (g/m^2) as influenced by various weed management practices at Radhapur, Banke, 2022

Weed management practices	Dry weight of weed (g/m^2)		
	30 DAT	60 DAT	90 DAT
Weed free (Manual hand weeding at 15 days interval)	0.81^c (0.16)	1.71^e (0.00)	0.95^e(0.47)
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	1.02^c(0.54)	1.31^{de} (0.81)	1.37^{de} (1.72)
Pendimethalin 30% EC followed by one HW at 40 DAT	1.35^b(1.33)	1.24^d(1.05)	2.27^e(10.33)
Bispyribac Na 10% SC	1.38^b(1.43)	1.84^c(2.90)	1.94^{cd}(4.20)
Pendimethalin 30% EC	1.50^c(1.76)	2.13^b(4.03)	2.43^c(6.00)
Farmer’s practice; one HW at 40 DAT	1.55^b(1.92)	2.14^b(4.08)	4.01^b(16.00)
Weed check	6.36^a(40)	7.62^a(57.67)	8.19^a(67)
Grand mean	1.99	2.40	3.17
SEm±	0.04	0.03	0.10
LSD (0.05)	0.31	0.25	0.80
CV%	8.72	5.57	14.26

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding. The figures in the parenthesis represent the original value and outside the parenthesis the square root transformation value ($\sqrt{}$(x+0.5).

Weed control efficiency

Weed control efficiency was observed significant in weed management practices. As shown in **Table 8**, among all treatment the combination of pre-emergence followed by post-emergence gives the highest (91.72%) weed control efficiency whereas found least (53.25%) at farmers practice. Weed control efficiency at 60 DAT (92.41%), and 90 DAT (85.28%), were observed highest in the combination of pre-emergence followed by post emergence. The lowest weed control efficiency at 30 DAT (53.25%), 60 DAT (56.66%), and 90 DAT (42.79%) at farmers’ practice. At the later stage the treatments showed lower efficiency which might be due to the emergence of some new weed species at later stages. The growth

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of weeds in the field after the application of herbicides might be due to the high seed bank of weeds in the soil which on suitable condition grows. Similar results were observed by Veeraputhiran & Balasubramanian, (2010) and (Pooja & Saravanane, 2021).

Table 8. Weed control efficiency (%) as influenced by various weed management practices at Radhapur, Banke, 2022

Weed management practices	Weed Control Efficiency (%)		
	30 DAT	60 DAT	90 DAT
Weed free (Manual hand weeding at 15 days interval)	96.72[a]	96.64[a]	90.35[a]
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	91.72[b]	92.41[a]	85.28[b]
Pendimethalin 30% EC followed by one HW at 40 DAT	89.58[b]	88.02[ab]	82.88[b]
Bispyribac Na 10% SC	85.51[c]	82.02[b]	70.93[c]
Pendimethalin 30% EC	78.81[d]	79.39[b]	64.61[d]
Farmer's practice; one HW at 40 DAT	53.25[e]	56.66[c]	42.79[e]
Grand mean	70.76	70.85	72.81
SEm±	2.52	2.68	1.48
LSD (0.05)	3.66	8.26	4.68
CV%	2.91	6.60	3.58

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding.

Weed control index (%)

Weed control index was observed significant in weed management practices. Among all treatments the combination of pre-emergence followed by post emergence weeding gives the highest (92.18%) weed control index whereas found least (54.86%) at Farmers practice at 30 DAT. The weed control index at 60 DAT (84.93%), and 90 DAT (79.96%), were observed highest in the combination of pre-emergence followed by post emergence.

Table 9. Weed control index (%) as influenced by various weed management practices at Radhapur, Banke, 2022

Weed management practices	Weed Control Index (%)		
	30 DAT	60 DAT	90 DAT
Weed free (Manual hand weeding at 15 days interval)	95.18[a]	93.42[a]	86.4[a]
Pendimethalin 30% EC followed by Bispyribac Sodium 10% SC	92.18[ab]	84.93[b]	79.96[b]
Pendimethalin 30% EC followed by one HW at 40 DAT	89.19[ab]	78.28[b]	75.64[b]
Bispyribac Na 10% SC	85.36[b]	67.54[c]	68.42[c]
Pendimethalin 30% EC	72.35[c]	56.78[d]	59.44[d]
Farmer's practice; one HW at 40 DAT	54.86[d]	33.11[e]	45.83[e]
LSD (0.05)	8.60	8.34	4.69
SEm±	2.78	2.70	1.52
CV%	6.91	7.94	4.43
Grand mean	69.95	59.15	59.48

CV: Coefficient of Variation, SEm±: Standard Error of Mean, LSD: Least Significance Difference. Same letters in the column are not significantly different at 5% level of significance. DAT: days after transplanting, HW: hand weeding.

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The lowest weed control index at 30 DAT (54.86%), 60 DAT (33.11%) and 90 DAT (45.83%) at farmers' control. At later stage the treatments showed lower control index which might be due to emergence of some new weed species at later stages. The overall result of the treatments can be seen in **Table 9**. This result is also partially supported by (Ghosh & Mallick, 2013).

CONCLUSION

From the experiment, it was found that the application of post-emergence (Bispyribac-sodium 10% EC) at the rate of 25 gm a.i./ha was the most economical and beneficial method in controlling all mimic weeds at low cost for the weed management in transplanted spring rice which is also exhibited in Table 5, 6, 8 and 9. However, the combination application of pre-emergence Pendimethalin at 3 DAT followed by post-emergence Bispyribac Na at 28 DAT gave an excellent response in yield and yield parameters. This herbicide combination in weed management seems effective for higher yield of Hardinath-1 variety and should be preferred for weed management practices in Banke district.

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Authors' Contributions

Samiksha Bista: Experimentation, data processing, analysis and preparing manuscript of article. Sandesh Bhatta: Project and experiment design, guide to implementation, regular monitoring, providing necessary guidelines for research. Kamal B.K.: Editing manuscript, assistance in data analysis, preparing the research article. Nikita Pandey, Briksha Shreepaili and Bishesh Basnet: Providing necessary guidelines and assistance in research and manuscript.

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

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