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Performances of Transplanted Spring Rice Under Different Weed Management Techniques in Kapilbastu, Nepal

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A B S T R A C T

At Banganga, Kapilbastu, Nepal, a field experiment was conducted in the spring of 2021 to determine the performances of transplanted spring rice under different weed management techniques. With five treatments and four replications, the experiment was structured as a single-factorial Randomized Complete Block Design (RCBD). The treatments consisted of Pretilachlor 50% EC (dose: 500 ml a.i. per acre) as pre-emergence herbicide, Pretilachlor 50% EC (dose: 500 ml a.i. per acre) as pre-emergence herbicide plus hand weeding at 20, 40 DAT, Hand weeding at 20 DAT, 40 DAT, 60 DAT, Cono-weeding at 20 DAT, 40 DAT, 60 DAT and control. The plots treated with Pretilachlor plus hand weeding recorded a significantly higher plant height (99cm), higher number of effective tillers per meter square (11.97), higher panicle length (26cm), and higher number of grains per panicle (200.60) at 90 DAT. The sterility percentage and the no. of grains per panicle were not affected by the weed management practices. Cono-weeding was found statistically superior in terms of grain yield (6.09 Mt ha^{-1}) and harvest index (42.10 %). The experiment concluded that the weed management practices affect the grain yield of transplanted spring rice.

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Introduction

Rice *(Oryza sativa L.)* is the world's most significant staple cereal crop, providing carbohydrate, protein and calories to more than half of the world's population (Simkhada and Thapa, 2022). In Nepal, it is grown on 1,458,915 ha (around 47.1% of the total cultivated area) (MoALD STAT, 2020). It is cultivated in every household owning land in Nepal and it is an important aspect of our national food security as well as a source of income for millions of rural populations. Therefore, in Nepal, it is often quoted that, "rice is life". Despite ranking first among all cereal crops in Nepal, rice output and productivity are 5,550,878 metric tons and 3.80 metric tons per hectare, respectively, which is considered as low when compared to Nepal's potential yield (MoALD STAT, 2020). Kapilbastu is one of the major rice producing district of Nepal having a total rice production area of 66,495 ha (MoALD STAT, 2020). Out of 66,495 hectare total rice area, spring rice is grown in 325 hectare area and have the production of 1,435 Mt with an average productivity of 5.10 Mt ha^{-1}, greater than the national spring rice productivity (4.66 Mt ha^{-1}) (MoALD STAT, 2020).

Rice is grown in a variety of environments, including irrigated lowlands, mid-deep lowlands, deep water lowlands and uplands (Mahajan et al., 2014; Patel and Ghosh, 2019). Transplanting in puddled soil with continuous flooding is a major method of rice cultivation in Kapilbastu, Nepal. Rice production is affected by both biotic and abiotic factors in transplanted condition. Weed infestation is one of the serious biotic constraints imposing great threats in the global rice production particularly in developing countries like Nepal where still subsistence farming is followed by the majority of the population. Weed affects rice by competing for nutrient, light, water and space accounting nearly one third of crop loss (Kabdal et al., 2018). Moreover, weeds by the virtue of their high adaptability and faster growth dominate the crop habitat and reduce the yield potential of the crop. Transplanted rice crops are subjected to a diverse weed flora that includes grasses, sedges and some broadleaf weeds, resulting in yield reductions of up to 48% and an annual loss of 15 million tonnes owing to weed competition (Patel and Ghosh, 2019). According to Veeraputhiran and Balasubramanian, 2014, 45-51 % yield reduction was caused by weeds in transplanted rice. Therefore, for successful rice production, weed competition must be avoided and a weed-free environment must be provided during the vital phase of rice growth.

Most transplanted rice growers in Nepal manually weed their fields two or three times per season, rising labour costs and increasing labour scarcity causing a search for alternative solutions (Rao and Ladha, 2013; Manisankar et al., 2021). Cono-weeding is one of the mechanically based weed management technique which is used to effectively eliminate weeds between paddy crop rows. The pushing movement is used to operate this tool manually. The rotors' direction provides a back and forth movement in the top 3 cm of soil, which aids in weed uprooting. The cono-weeder is shown in the figure 1. Labour shortage and ease of operation has caused the exponential increase in use of chemical (Pandey and Kandel, 2020) which also offers the most effective, economical and practical way of weed management. However, widespread use of chemical herbicides poses a sustainability threat due to the development of resistant weeds and changes in the weed flora (Singh et al., 2016). Therefore, chemical herbicides must be used judiciously (Anwar et al., 2012) by integrating with other weed management practices like hand weeding, mechanical method (cono-weeding), appropriate agronomic practices (such as row spacing, seeding rates) and different plant extracts (Chauhan, 2012), so that there is minimum risk to the environmental components. In this limelight, the goal is to find out the best weed management strategies for controlling weeds in transplanted spring rice by integrating chemical pesticide with different mechanical methods of weed management. In addition, this study also compares the performance and yield of transplanted spring rice.

Materials and Methods

Study Site

The experiment was carried out in the PMAMP Project Implementation Unit (PIU), Rice Super Zone, Kapilbastu, Chankipur, Banganga municipality's command area in the year 2021. It has a total size of 1,938 square kilo meters and is located in the northern section of Kapilbastu at latitude 27 38'44" N and longitude 83 10'16"E. The research site is a low-lying plain with alluvial clay soil that is roughly 65 meters above sea level. This study was carried out to solve the weed management challenges experienced by the local people in transplanted spring rice, as it is one of the most significant area for rice production. The research site is depicted in Figure 2.

Agro-Meteorological Characters

The experiment was place in Nepal's tropical region, where summers are scorching hot and winters are mildly cold. During the monsoon season, it received the majority of its rainfall. The highest temperature observed throughout the research period was 34°C around harvest time, with the lowest temperature in February being 16°C. In June, the maximum relative humidity was 69 percent, while the lowest relative humidity was 33 percent in March.

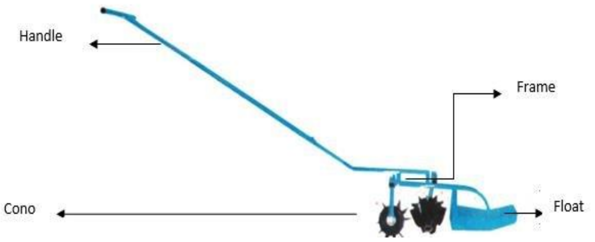

Figure 1. Diagram showing cono-weeder and its parts.
Adopted from: (Adewale and Oluwadunsin, 2020)

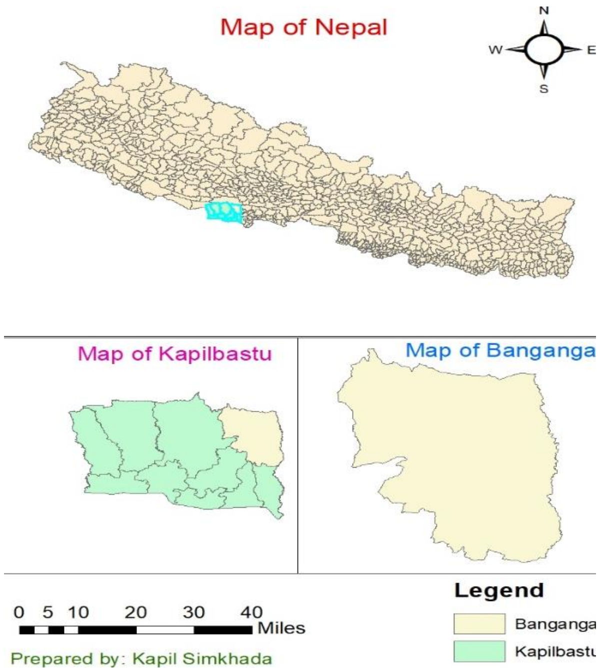

Figure 2. Map of Nepal showing Kapilbastu district and Banganga municipality where the study was carried out.

Variety Used in the Research

Chaite-5 is the rice variety used in the experiment. It was released in 2018 and recommended for terai and Inner-terai up to 700 meter above sea level (Agriculture Diary, 2021). It has growth duration of 120-125 days having an average productivity of 4.6Mt ha^{-1} (Agriculture Diary, 2021).

Equipments' used in the Research

Tractor was used in ploughing and harrowing operations to make the soil ready for transplantation. Weed was removed with a cono-weeder at 20, 40, and 60 DAT. Pushing movement is used to operate the cono-weeder. The rotors' direction provides a back and forth movement in the top 3 cm of soil, which aids in weed uprooting.

Design of the Experiment

The experiment used a randomized complete block design (RCBD) with five treatments and four replications for each treatment. The individual plots were 3*3 metre square in size, with a 20 cm row to row spacing and a 20 centimetre plant to plant distance. The distance between replications was 1 meter, and the distance between treatments was 50 cm. The overall testing area on the field was 323 meters square. Each plot was also separated by 1 meter from the outside field edge.

Treatment Details

The treatments consisted of Pretilachlor 50% EC (dose: 500 ml a.i. per acre) as pre-emergence herbicide, Pretilachlor 50% EC (dose: 500 ml a.i. per acre) as pre-emergence herbicide plus Hand weeding at 20 DAT and 40 DAT, hand weeding at Hand weeding at 20 DAT, 40 DAT, and 60 DAT, Cono-weeding at 20 DAT, 40 DAT, and 60 DAT and weed free or control as shown in the Table 1.

Table 1. Details of treatment used in the research.

Treatment no.	Treatment details
T1	Pretilachlor 50% EC (dose: 500ml a.i. per acre
T2	Pretilachlor 50% EC (dose: 500ml a.i. per acre) plus hand-weeding at 20, 40 DAT
T3	Hand weeding at 20 DAT, 40 DAT, 60 DAT
T4	Cono-weeding at 20 DAT, 40 DAT, 60 DAT
T5	Control

Cultivation Practices

Preparation of nursery

The nursery bed was ploughed with rotavator and levelled. MOP, DAP and Urea was applied basally in the nursery bed at the rate of 0.5 kg, 0.7 kg and 3 kg respectively. The soaked seeds were sown after puddling in the morning. Second dose of the Urea was applied after 10-14 DAS. The seedlings were ready for transplanting at 21 DAS.

Preparation of main field

Before transplanting the rice seedlings, the land was ploughed three times, followed by planking and puddling, to ensure good soil tilth for sowing.

Fertilizer application

At a rate of 120:40:40 kg NPK per ha, nitrogen, phosphorus, and potassium were sprayed as recommended by the (AITC, 2022). In all treatments, a third of nitrogen, the entire dose of phosphorus, and the full dose of potassium were used as a basal dose. The remaining two-thirds of the nitrogen dose was top-dressed onto the standing crop in two equal splits at the tillering and panicle initiation stages of the crop.

Seed rate and sowing

On February 14, 2020, the seeds were sowed on a slightly raised puddled seedbed with at least 1cm of water thickness. The seeds were distributed at a rate of 40-50 kg ha^{-1} using the broadcasting method. Seedlings were transplanted into the main field at a spacing of 20 cm * 20 cm after 4-5 weeks. Salt was applied to the seeds first (250 g salt in one-litre water). During the transplanting operation, manual labour was used.

Irrigation

Water was accessible at all times during the experiments. Rice requires a lot more water than other cereals, so irrigation was done from the first week of mid-February to mid-June in such a way that the field was moist all the time in the plots. Tillering, panicle initiation, and grain filling are the most essential stages for irrigation. Irrigation was turned off completely 10-15 days before harvest.

Weeding and inter-cultural operation

Weed control was done through different herbicide, cono-weeding and hand-weeding as per treatments. Weeds were allowed to grow along with the rice crop throughout the crop cycle without any management in control plots.

Observations recorded on rice

Based on the treatment, weed control was performed with a range of herbicides, hand weeding, and cono-weeding techniques. Weeds were allowed to grow alongside the rice crop in control plots throughout the crop cycle without being controlled.

Plant height (cm)

Except for the boundary row and the destructive row, 10 plants were randomly picked and tagged from different alternate rows, i.e. one plant from the second row, another from the fourth row, and so on. From 30 DAT to 90 DAT, plant height was monitored at 15 days interval. Plant height was calculated as the average of 10 plants. It was measured from the base to the tip of the main stem's upper leaves.

Number of tillers per square meter

From 30 DAT to 90 DAT, tiller per square meter was counted from plants removed from destructive sample rows at 15 day intervals and the mean was recorded. In the third row of each plot, a one metre row length was marked to count the number of tillers.

Number of effective tillers per square meter

The effective tillers per square meter were measured in each plot from one full length of row right before the crop was harvested, and the average values were used to calculate the effective tillers per square meter. Tillers with full grains were classified as effective tillers.

Length of panicle (cm)

The length of the panicle was measured by randomly selecting 20 panicles from each hill. This was done right before harvesting, and the average was determined.

Number of grains per panicle and sterility percentage

By extracting grains from 20 panicles right before harvesting, grains were counted and weighted on an electronic balance (panicles which were selected for length measurement). The number of filled and unfilled grains were counted at the same time in order to determine the number of filled grains per panicle and the sterility %. The percentage of sterility (SP) was estimated using the formula below.

$$\text{SP (\%)} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

Thousand grain weight (TGW) (g)

Thousand grains were counted from a randomly chosen grain yield of a net plot of 1 meter square, weighed with an electronic balance at accurate moisture content and the mean was determined and expressed in grams at a moisture level of 14 percent.

Grain and straw yield (Kg ha^{-1})

The grain yield was measured by harvesting the produce from the net plot. Each net plot's grain and straw yields were measured after the crop was harvested. The crop was dried, threshed, cleaned, and sun-dried again before being weighed. Moisture was detected at 14 percent moisture using a moisture meter and the formula given below:

$$\text{GYM} = \frac{(100\text{-MC}) \times \text{Plot yield (kg)} \times 10000\text{m}^2}{(100\text{-}14) \times \text{net plot area (m}^2)}$$

GYM: Grain yield (kg ha^{-1}) at 14% moisture

Harvest index

Harvest index (HI) was calculated by dividing grain yield at 0% moisture with the total dry matter yield (grain yield at 0% moisture and straw dry weight). The formula to calculate HI is given below:

$$\text{HI} = \frac{\text{Grain yield (Economic yield)}}{\text{Biomass yield (Biological yield)}}$$

Statistical Analysis

In four replications, the recorded data on numerous observable parameters were gathered and grouped treatment wise in a systematic manner. MS-Excel was deployed for fundamental statistical analysis, graphing and table creation. For data analysis, R-studio was employed.

Results and Discussions

Plant Height

Weed management strategies were found to have a considerable impact on plant height in the study. On an average, plant heights ranged from 41.20 cm (30 DAS) to 96.60 cm (90 DAS) as shown in the table 2. Plant height was statistically comparable in all treatments except control at 30 DAT. The plot treated with Pretilachlor plus hand weeding at 20, 40 DAT had the longest plant height (44.68 cm) as compared to others and it was statistically similar with other plots except the control one. At 45 DAT, plant height was longest (61.93 cm) in the plot treated with cono-weeding which was significantly different as compared with other plots except the plot treated with Pretilachlor plus hand weeding at 20, 40 DAT.

At 60 DAT, plant height was found longest (71.15 cm) in the plot treated with Pretilachlor plus hand weeding at 20, 40 DAT which was statistically similar with other plots except the control one where lowest plant height (66.52 cm) was recorded. Similarly, at 75 DAT, the longest plant height (92.56 cm) was observed in the plots treated with Pretilachlor plus hand weeding at 20, 40 DAT. As indicated in Table 2, the plot treated with Pretilachlor plus hand weeding at 20, 40 DAT had the highest plant height (99.00 cm) while the control plots had the lowest plant height (94.31 cm) at 90 DAT. The lower plant height in the control plot might be due to high competition between the rice and the weed. Similar result was obtained in the field experiment conducted by Dangol et al. 2020 where longest plant height was obtained in Bispyribac sodium treated plot and lowest in control weedy check plot. Moreover, Akbar et al. 2011 observed that maximum plant height (95.97 cm) was obtained in hand pulling and mechanical pulling followed by chemical herbicides treated plots.

Number of Effective Tillers Per Unit Area

Except at 60 DAT, different weed management strategies had a significant impact on the quantity of tillers per square meter. In the experiment, the average number of rice tillers ranged from 7.45 (30 DAT) to 16.06 (60 DAT). Table 3 shows that the number of tillers per square meter increased from 30 DAS to 60 DAS, then lowered as the crop matured. A similar result was obtained in the experiment conducted by (Dangol et al., 2020). At 30 DAT, the number of tillers of rice in the plots treated with Pretilachlor plus hand weeding at 20, 40 DAT was statistically higher than the rest of the plots. The lowest number of tillers (3.28) in rice was found in control. At 45 DAT the maximum number of tillers (19.15) were found in the plots treated with pre-emergence herbicide Pretilachlor plus hand weeding at 20, 40 DAT and minimum number of tillers (11.1) were found in the control plots. At 60 DAT, maximum number of tillers (16.65) were found in the plots treated with Pretilachlor plus hand weeding at 20, 40 DAT and minimum number of tillers (14.85) were found in the control plots. Similarly, at 75 DAT, maximum number of tillers (13.3) were found in the plots treated with Cono-weeding and minimum number of tillers (11.32) were found in the control plots. At 90 DAT, maximum number of tillers (11.97) were found in the plots treated with Pretilachlor plus hand weeding at 20, 40 DAT while minimum number of tillers (10.19) were found in the control plots. Reduced weed competition during important crop growth phases means more nutrients, water, and light are available to the crops, resulting in more effective tillers per square meter (Dangol et al., 2020).

Table 2. Different weed management strategies effect plant height at Banganga, Kapilbastu, in 2021.

Treatments	Plant height (cm)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Control	37.33^{b}	53.07^{C}	66.52^{b}	87.13^{c}	94.31^{b}
T3	41.23^{a}	54.35^{bc}	66.95^{ab}	88.90^{bc}	94.63^{b}
T4	41.40^{a}	61.93^{a}	67.70^{ab}	89.98^{ab}	96.85^{ab}
T1	41.38^{a}	57.15^{bc}	70.05^{ab}	91.03^{ab}	98.25^{a}
T2	44.68^{a}	58.75^{ab}	71.15^{a}	92.56^{a}	99.00^{a}
SEm (±)	0.11	0.14	0.12	0.082	0.089
Grand mean	41.2	57.05	68.47	89.92	96.60
LSD 005	3.62	4.32	3.96	2.54	2.75
CV (%)	5.70	4.92	3.75	1.83	1.85

Note: The treatment means with same letters do not differ significantly at 5% level of significance.

Table 3. Different weed control strategies influence the number of effective tillers per square metre at Banganga, Kapilbastu, in 2021.

Treatments	Number of effective tillers per metre square				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Control	3.28^{c}	11.1^{b}	14.85	11.32^{b}	10.19^{c}
T3	7.53^{b}	13.45^{b}	15.98	11.92^{ab}	10.50^{bc}
T4	7.93^{b}	17.13^{a}	16.35	13.3^{a}	11.78^{ab}
T1	8.23^{b}	19.05^{a}	16.45	12.56^{ab}	10.78^{abc}
T2	10.3^{a}	19.15^{a}	16.65	13.02^{a}	11.97^{a}
SEm (±)	0.063	0.11	0.10	0.043	0.042
Grand mean	7.45	15.98	16.06	12.42	11.04
LSD 005	1.97	3.53	3.26	1.32	1.30
CV (%)	17.12	14.35	13.19	6.91	7.63

Note: The treatment means with same letters do not differ significantly at 5% level of significance.

Table 4. Different weed control strategies effect yield qualities in Banganga, Kapilbastu, in 2021.

Treatments	Yield attributing characters			
	Panicle length (cm)	Number of grains per panicle	Sterility percentage (%)	1000 grain weight (g)
Control	22.75^{d}	178.6	31.87^{a}	18.89
T3	23.65^{cd}	183.5	31.67^{a}	19.16
T4	24.2^{bc}	182.20	25.70^{b}	19.25
T1	25.3^{ab}	195.60	24.15^{b}	20.02
T2	26^{a}	200.60	25.64^{b}	20.07
SEm (±)	0.039	0.78	0.14	0.62
Grand mean	24.38	189.10	27.81	19.48
LSD 005	1.29	24.15	4.42	1.90
CV (%)	3.25	8.29	10.32	6.3

Note: The treatment means with same letters do not differ significantly at 5% level of significance.

Panicle Length

The weed management practices had a significant impact on panicle length where the mean panicle length was 24.38 cm as shown in the table 4. It shows that plots treated with Pretilachlor plus hand weeding at 20, 40 DAT had the longest panicle length of 26 cm, which was statistically equal to plots treated with Pretilachlor alone at the 5% level of significance. The control plots had the shortest panicle length (22.75 cm), which was statistically equal to the plots treated with hand weeding. The weed may be draining nutrients in the control plots, resulting in shorter panicle length. A similar result was obtained in the experiment conducted by Dubey et al. 2017 and Dangol et al. 2020.

Number of Grains Per Panicle

At the 5% level of significance, weed management strategies had no effect on the quantity of grains per panicle. Table 4 shows that the average number of grains per panicle ranged from 178.6 in control plots to 200.6 in plots treated with Pretilachlor plus hand weeding at 20, 40 DAT, with a mean of 189.10. Presence of weeds throughout the crop cycle in control plots resulted in nutrient depletion and decreased absorption of nutrients by the crop, particularly during grain filling. It's possible that the maximum number of grains per panicle in Pretilachlor plus hand weeding treated plots is due to successful weed suppression. Similar results were obtained in the field experiment conducted by Dangol et al. 2020. In contrast to our result, maximum number of kernels per panicle was obtained in hand pulled and mechanically pulled plots followed by chemical herbicides treated plots (Akbar et al., 2011).

Thousand Grain Weight (g)

In the study, the average 1000 grain weight was 19.48 grams. The influence of weed management strategies on 1000 grain weight was determined to be non-significant. Table 4 shows that Pretilachlor plus hand weeding at 20, 40 DAT produced the highest (20.07 g) 1000 grain weight and the control plots produced the lowest (20.84 g) 1000 grain weight among the weed management strategies. Akbar et al. 2011, in his field experiment in Pakistan, observed highest 1000 grain weight in hand pulled plots and lowest in control weedy check plots which shows that weed management practice increases the 1000 grain weight which is in resonance to our study results.

Sterility Percentage

Table 4 shows that weed management strategies had a considerable impact on sterility percentage. During the study, the average sterility percentage was 27.81 percent, ranging from 31.87 percent in control plots to 24.15 percent in Pretilachlor alone treated plots. The sterility percentages in the control plots and the plots treated with hand weeding at 20, 40, and 60 DAT were statistically identical. In the field experiment conducted by Dangol et al. 2020, sterility percentage was found insignificant which is in contrast with our result. In his experiment, highest sterility percentage was obtained in Bispyribac Sodium treated plots which is in contrast with our result. Moreover, in the field conducted by Akbar et al. 2011 in Pakistan revealed that weed management strategies increased the percentage of normal kernels viz. Highest percentage of fertile kernels were obtained in hand and manually weeded plots followed by chemically treated plots.

Grain Yield (Mt ha^{-1})

The average grain yield for the study was 4.58 Mt ha^{-1}. Weed control strategies have a substantial impact on grain yield at a 5% level of significance. Grain yield is determined by factors such as effective tillers, filled grains per panicle, test weight, panicle length, etc. Cono-weeding treated plots had the highest grain production (6.09 Mt ha^{-1}) followed by Pretilachlor plus hand weeding at 20, 40, 60 DAT, Pretilachlor alone, Hand weeding at 20, 40, 60 DAT, and control, as indicated in Table 5. Although, number of grains per panicle and 1000 grain weight were statistically higher in the plots treated with Pretilachlor plus hand weeding, maximum yield was obtained in the cono-weeded plots. The lower yield (3.82 Mt ha^{-1}) in control plots might be due to the competition imposed by weeds which reduced Leaf area index and allowed less light transmission in the rice leaf ultimately reducing the bio-synthetic products. Contrary to our result, on the research conducted by Marahatta et al. 2017, maximum yield was obtained in the plots having Sesbania co-culture as compared to sole Bispyribac Sodium application and pre-emergence application of Pendimethalin. Moreover, a pre-emergence application of Pendimethalin and a post-emergence application of Bispyribac Sodium herbicides, followed by hand weeding at 45 DAS, offered up to 85% weed control and higher yield over weedy check than other weed control strategies (Dhakal et al., 2019).

In the study, the average harvest index was found to be 41.04 percent. Weed control strategies had no substantial impact on it, as indicated in Table 5. The plots treated with cono-weeding had the highest harvest index (42.10 percent), while the plots treated with Pretilachlor had the lowest harvest index (40.31 percent). The similar results were obtained in the field study carried out by Akbar et al. 2011 and Dangol et al. 2020.

Table 5. Different weed management strategies effect grain yield (Mt ha^{-1}) and harvest index (percent) at Banganga, Kapilbastu, in 2021.

Treatments	Grain yield (Mt ha^{-1})	Harvest Index (HI, %)
Control	3.82^{c}	41.35
T3	3.88^{c}	41.06
T4	6.09^{a}	42.10
T1	4.25^{bc}	40.31
T2	4.86^{b}	40.40
SEm (±)	0.25	4.09
Grand mean	4.58	41.04
LSD 005	0.77	3.08
CV (%)	10.9	2.25

Note: The treatment means with same letters do not differ significantly at 5% level of significance.

Conclusion

Weed management measures in transplanted spring rice in Kapilbastu, Nepal, significantly reduced weed density. Cono-weeding was found statistically superior compared to other weed management practices for transplanted rice. Higher application of chemical herbicides imposes the soil fertility problems and the weed develops resistance on the long run. Therefore, to achieve successful, long-term weed control in transplanted spring rice, it is essential to use integrated weed management measures. Further research should be performed in accordance with specific ecological niches, with the best possible integration of all weed management strategies to reduce the problem. A thorough investigation of weed biology and ecology in various rice habitats can result in a high economic benefits.

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Competing Interests

There have been no competing interests regarding the publication of this article.

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