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Study on Growth Parameters and Yield of Spring Rice Hardinath-1 as Influenced by Different Planting Methods in Bardiya District of Nepal

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ABSTRACT

Rice (*Oryza sativa*) is a major staple crop and the principal food grain crop in Nepal, which ranked in first position among cereal crops in terms of area, production, and preference. It can be grown in different agroclimatic conditions from the terai to the high hills. Rice cultivation methods can vary based on the technology and resources available to farmers. Rice transplanting is a crucial step in rice cultivation and can be done manually or mechanically. It influences plant establishment, resource efficiency, growth uniformity, and overall yield. A field experiment was carried out in a farmer's field to evaluate the different rice planting methods of spring rice seedlings at Geruwa rural municipality of Bardiya during the spring season of 2024. The experiment was laid out in a Randomized Complete Block Design with five replications and four treatments. Treatments were 4-wheeler transplanting, 3-wheeler transplanting, manual transplanting, and direct seeding using a drum seeder. Ten sample plants from each treatment plot were taken for the collection of data on phenology, growth parameters, and yield attributing characters. Significant differences among planting methods were observed for plant height, number of tillers, effective tillers, grain yield, and harvest index, while thousand-grain weight did not differ significantly among treatments. In terms of plant height, the plant transplanted by a 4-wheeler had the highest (100.14 cm), whereas direct seeded by a drum seeder was the smallest at 90.60 cm. Plant transplanted by 4-wheeler led in effective tillers count of 371.18 tillers/square meter, followed by 3-wheeler and manually transplanted plant with tiller numbers 342.06 and 319.68 per square meter, respectively, while DSR by drum seeder produced 294.46 tillers/square meter. Maximum grain yield (0.52kg/m^2) and harvest index (0.23) were found in rice transplanted by a 4-wheeler. The plant transplanted by a 4-wheeler had the longest panicle of 25.32 cm, whereas the drum-seeder treatment had the shortest (23.86cm). The plant transplanted by a 4-wheeler had the highest thousand-grain weight (21.6 gm), whereas the manually transplanted and DSR by drum seeder had the lowest (20.8 gm). Based on the results, the 4-wheeler showed the best result in terms of grain yield and biomass yield as compared to other methods. Therefore, the 4-wheeler transplanting method could be recommended for higher grain yield to the spring rice growers.

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Introduction

Agriculture remains the primary source of livelihood for the majority of Nepal's population and serves as a key driver of the national economy, with the Agriculture, Forestry, and Fishing sector contributing 24.12% to the country's Gross Domestic Product (GDP) (MoALD, 2022). Rice (*Oryza sativa* L.), an annual self-pollinated semi-aquatic crop belonging to the Poaceae family, is the principal staple food crop of Nepal and ranks first among cereals in terms of area, production, and consumer preference.

Globally, rice is cultivated in more than 100 countries, with total production estimated at 519 million tonnes in 2021–2022, representing a slight increase compared to the previous year (Hossen et al., 2022). In Nepal, rice is grown across diverse agro-ecological zones ranging from the Terai plains to high hills, covering 1,477,378 ha with a production of 5,130,625 metric tonnes and an average productivity of 3.47 t ha^{-1} (MoALD, 2022). Rice contributes over 40% of the daily caloric intake of Nepalese people and accounts for approximately 13.6% of the national Agricultural Gross Domestic Product,

indicating its critical role in food security and economic stability (MoALD, 2022). In Nepal, rice is widely cultivated during the rainy season, which is also referred to as the major season. Spring rice (Chaite Dhan) covers 7% of the rice-growing area (Regmi, 2023). Despite its importance, rice productivity growth in Nepal has remained slow, averaging only about 0.16% annually over the past five decades, which is insufficient to meet increasing population demand. Yield variability ranging from 45–55% is attributed to traditional subsistence farming practices, labor shortages, climate variability, and inconsistent rainfall patterns (IRRI, 2023).

To address these challenges, the Government of Nepal implemented the ten-year Prime Minister Agriculture Modernization Project (PMAMP) under the Agriculture Development Strategy to enhance agricultural productivity through structured interventions such as super zones, zones, blocks, and pockets. Bardiya district of Lumbini Province, a major rice-producing area within the Terai region, hosts a designated rice super zone and cultivates rice on 47,957 ha during the main season with a productivity of 2.88 t ha^{-1}, while spring rice is grown on 1,600 ha with a higher productivity of 5.43 t ha^{-1} (MoALD, 2022). Rice establishment methods vary depending on available resources and technology, including manual transplanting, mechanical transplanting, and direct-seeded rice (DSR). Manual transplanting, though allowing precise seedling placement, is labor-intensive and increasingly unsustainable due to rising labor scarcity and water depletion (Bhatt et al., 2023). Mechanical transplanting improves efficiency, reduces labor requirements, and enables timely planting, yet adoption remains limited due to high initial investment costs and technical challenges associated with mat-type nursery preparation (Rahaman et al., 2022). Similarly, DSR eliminates nursery raising and transplanting operations by directly sowing pre-germinated seeds using drum seeders, reducing labor and time requirements; however, its adoption is constrained by farmers' preference for conventional practices, limited technical knowledge, and higher weed competition risks during crop establishment (Rao et al., 2007). Mechanized transplanting systems, particularly four-wheel riding transplanters, have demonstrated substantial labor savings, requiring approximately three man-days per hectare compared to thirty-three man-days under conventional methods (Chandran et al., 2020; Manjunatha et al., 2009). Promoting appropriate crop establishment technologies is therefore essential to enhance productivity, improve resource-use efficiency, and reduce dependency on rice imports. Understanding the comparative advantages and limitations of different rice establishment methods can support farmers, extension workers, researchers, and policymakers in facilitating the transition from subsistence-oriented production systems toward sustainable and commercial rice farming in Nepal.

Materials and Methods

This describes the methodology used for obtaining and analyzing data relevant to this study.

Research site

The trial and the preference analysis were conducted in Geruwa rural municipality in a farmer's field in Bardiya district. Geruwa is situated between $28^0$24' and $28^0$35' North latitude and $81^0$8' and $81^0$15' East longitude.

Agrometerological condition

The experimental site lies in the subtropical humid climate belt of Nepal. The metrological data for the cropping season of 2024 was recorded from NASA POWER. The highest rainfall was recorded during June, and the minimum rainfall was in the month of March, during the crop growth period. The mean maximum temperature during the experimental period ranged from 28^0 C (March) to 41^0C (May). Similarly, the mean minimum temperature during the cropping period ranges from 16^0C (March) to 29^0 C (June). Average relative humidity was maximum in June (45%) and minimum in April (29%).

Research site map

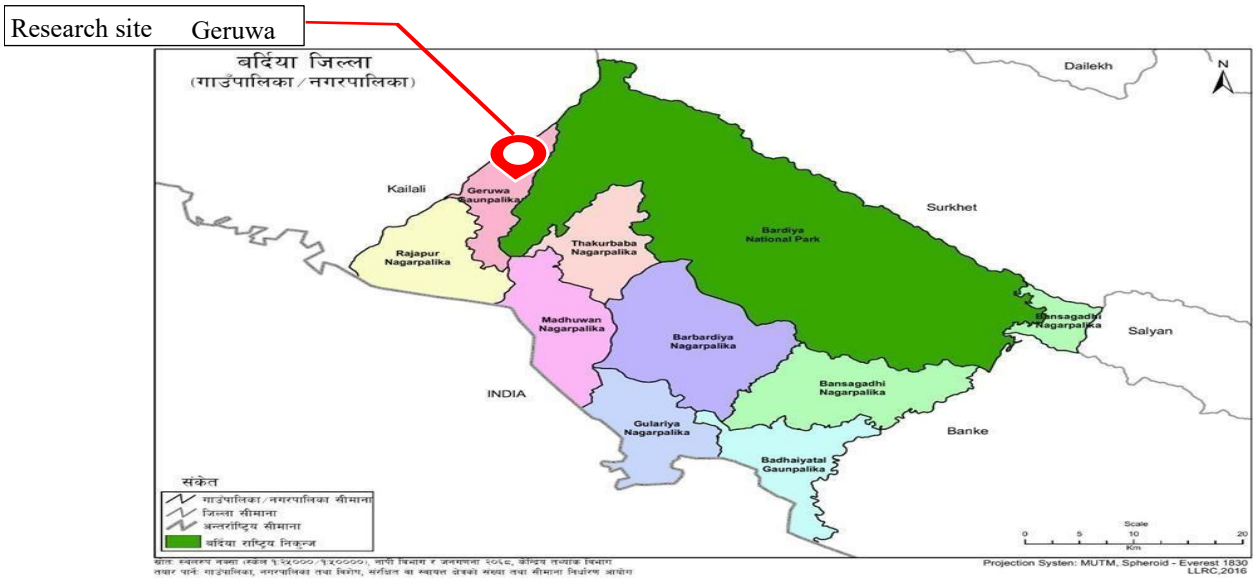

Figure 1. Detailed map of Bardiya district

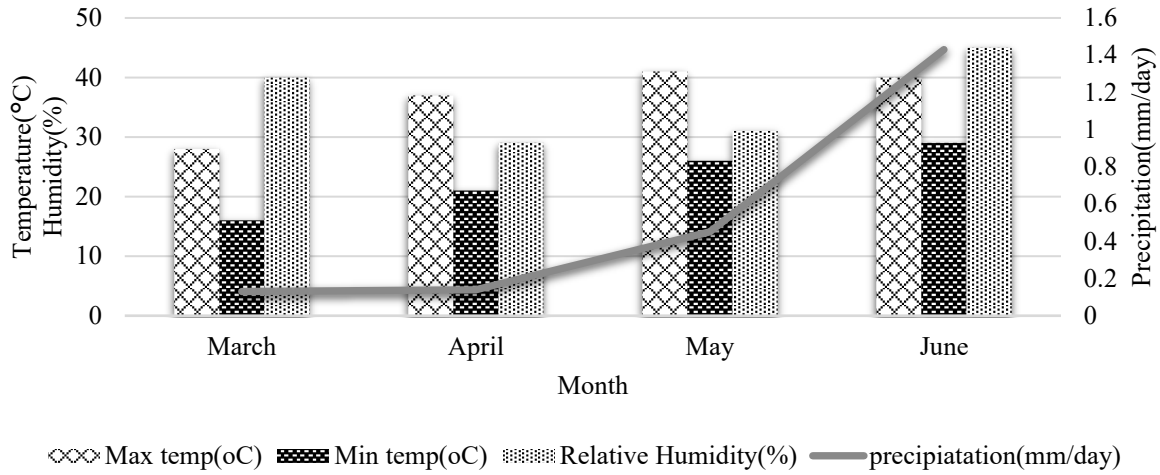

Figure 2. Meteorological data obtained from NASA power

Sample and sampling techniques

First, the preliminary survey for major problems related to rice planting methods was carried out near the areas of the rice super zone. The field research for the performance and yield of different rice planting methods was conducted in the field of a farmer. The samples were collected from the replications made on the plots of rice fields. Ten samples were taken from each of the plots. The samples from each plot were taken randomly.

The transplanting depth for mechanical and manual transplanting methods was maintained according to standard operational practices of each planting method, generally ranging between 2–4 cm in puddled soil conditions.

Experimental design

The experiment was conducted using a randomized complete block design with five replications and four treatments. The individual plot size measured 3 × 2 m², while the spacing between replications was maintained 50 cm, and the spacing between treatments was 100 cm.

Table 1. Details of treatment

Treatment indication sign	Details of treatment
T1	4-wheeler transplanter
T2	Manual transplanting
T3	3-wheeler transplanter
T4	DSR by drum seeder

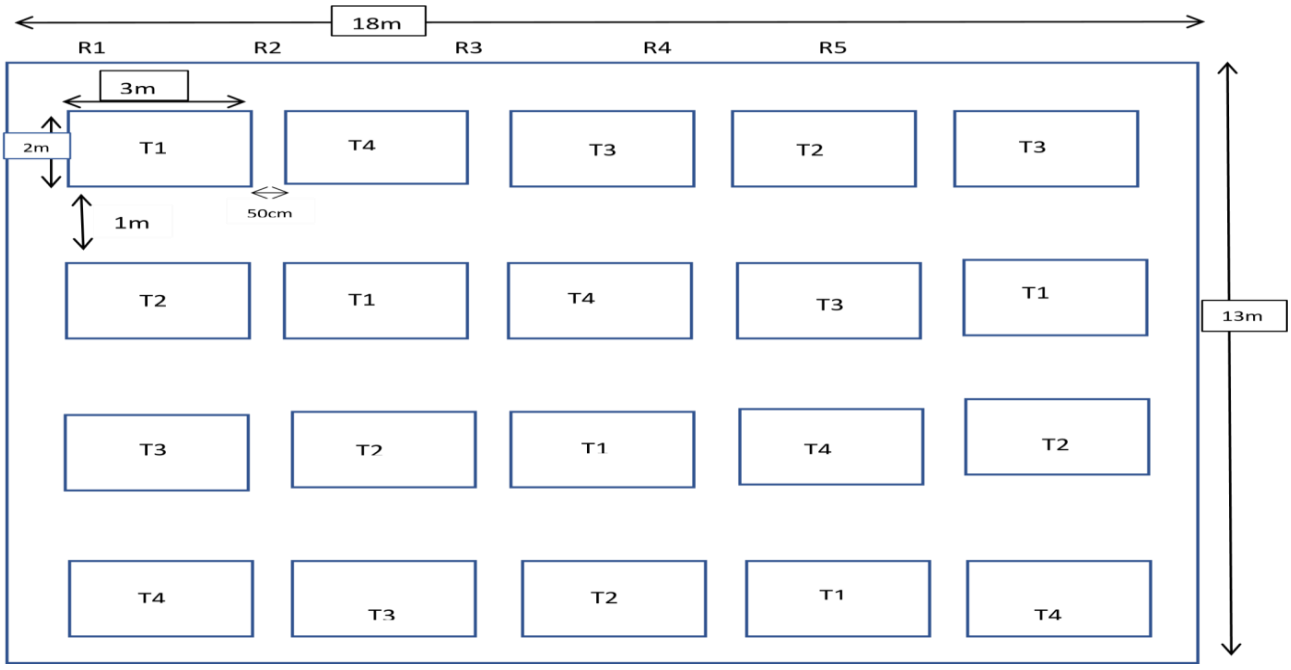

Figure 3. Plot layout

Data analysis technique

Statistical tools such as Excel and RStudio were used for analysis of variance and other data analyses after arranging the data systematically by various observed parameters. The data was analyzed, and the findings were discussed and related to available literature.

Agriculture practices

Nursery preparation

The seed was sown in a well-prepared nursery bed in the third week of February. A dry nursery bed with an area of 15 m² was prepared. Seed priming was done before sowing. The seed was broadcast over a film of soil on the wet bed, and seedlings were also grown on seed trays for mechanical transplanting.

Main field preparation

The main field was prepared by ploughing twice with a rotavator two weeks before transplanting. A total of five replications and 20 plots were made, with each plot measuring 3 m × 2 m. Puddling was done before transplanting.

Manure and fertilizer

Manure and fertilizer were applied to the nursery bed as required, with 150 kg of FYM and 200 g of urea added during bed preparation. In the main field, FYM (500 kg) and chemical fertilizers, including urea (46% N), DAP (18% N, 46% P_2O_5), and MOP (60% K_2O), were applied according to the recommendation. Half the dose of nitrogen and the full doses of phosphorus and potash were applied as a basal dose during transplanting, while the remaining half dose of nitrogen was applied as a top dressing 40–45 days after transplanting.

Transplantation of seedling

Rice seedlings (30 days old) were uprooted one by one for manual transplanting. The seedling trays were used for mechanical transplanting, while direct seeding was done using a drum seeder in a well-prepared puddled field. Mechanical transplanting operations were conducted at a uniform operational speed recommended by the equipment operators to ensure consistent planting conditions across plots.

Figure 4. Seedlings transplanting by a 4-wheeler

Figure 5. Seedlings transplanting through a 3-wheeler

Figure 6. Manual transplanting

Figure 7. Direct seeding through the drum

Irrigation

Rice requires more water at critical stages: vegetative, panicle initiation, and grain filling stage. Irrigation was supplied by a water pump.

Weed management

Pre-emergence herbicide (Pretilachlor 50 EC @ 5 ml in 1 liter of water) was applied within three days of transplanting for weed management, followed by hand weeding at 20–25 days after transplanting (DAT) and as needed.

P*lant protection method*

Insecticide was used for rice bug infestation.

Harvesting

Manual harvesting was done using a sickle when the crop was fully matured (90–95 days after transplanting). The harvesting was carried out separately for each plot.

After harvest, grain moisture content was measured using a portable grain moisture meter. Grain yield values were standardized to 14% moisture content to allow comparison among treatments.

Threshing

The rice heads were left to sun-dry and then threshed manually. The grains were cleaned by winnowing, and their weight was measured using an electric balance. The moisture content was measured using a portable moisture meter.

Data collection and observation

The following growth parameters and yield attributes were collected from the experimental plots at the appropriate times.

Biometric observations

Plant height (cm)

Ten plants from different rows, excluding the border and destructive rows, were selected randomly and tagged. Plant height was measured from the base of the plant to the top of the panicle in cm at 30, 45, 60, and 75 days after transplanting (DAT). The mean plant height was calculated from the tagged main tillers of each hill.

Number of tillers per hill

Tillers from 10 randomly selected hills in each growing stage were counted, and the average tillers per plant were calculated. The main stem was also included in the calculation of total tillers per hill.

Yield attributing characters of rice

Number of effective tillers per square meter

The number of effective tillers per m² was calculated for each plot just before harvesting the crop. Tillers with filled grains were recorded as effective tillers, while those without filled grains were recorded as non-effective tillers.

Panicle length

Ten randomly selected panicles from each hill were used to measure the panicle length, and the mean value was taken as the panicle length in cm. The panicle length was measured from the base of the rachis to the tip of the panicle.

Thousand grain weight (gm)

Thousand grains were randomly selected from the grain yield of each plot and weighed at about 14% moisture content.

Grain yield

The weight of grain from each net plot was recorded. The data was converted and reported as grain yield per square meter (kg/ m^2) at 14% moisture level.

Straw yield

The straw obtained from the net plot area of each plot was sun-dried for 3-4 days and weighed.

Harvest Index (HI)

Harvesting index was calculated as follows:

$$\mathrm{HI} = \frac{\text{Economic yield}}{Biological\ yield} \quad (1)$$

Results and Discussion

The research findings were thoroughly analyzed and presented in the appropriate section, utilizing tables and figures as needed. The obtained results were then discussed, considering potential outcomes and supported by existing literature in the field.

Biometrical observations

Plant height (cm)

The study revealed that transplanting rice seedlings by different transplanting methods significantly influenced the plant height of spring rice. The average plant height varied from 25.38 cm to 100.14 cm at 30 DAT and 75 DAT, respectively (Table 2). At 30 DAT, the 4-wheeler transplanting resulted in the tallest plants, with an average height of 34.24 cm (Table 2). Plants treated with the 3-wheeler method were slightly shorter, averaging 32.62 cm. The manual planting method produced smaller plants, with a height of 28.76 cm, while the drum seeder resulted in the shortest plants, measuring 25.38 cm (Table 2). The 4-wheeler method significantly outperformed the others in promoting early plant growth.

At 45 DAT, after transplanting, plant heights varied based on the planting method. Plants treated with the 4-wheeler method continued to grow the tallest, reaching an average height of 58.72 cm. The 3-wheeler method produced slightly shorter plants at 55.14 cm. Both the manual planting and drum seeder methods resulted in similar, smaller plant heights, with averages of 51.62 cm and 50.92 cm, respectively. The statistical analysis shows that the 4-wheeler method significantly outperformed the others, while the manual and drum seeder methods produced comparable results. At 60 DAT, the 4-wheeler method once again resulted in the tallest plants, with an average height of 76.68 cm. The 3-wheeler method was followed, with plants reaching 69.46 cm (Table 2).

The manual and drum seeder methods produced smaller plants, with heights of 64.40 cm and 61.74 cm,

respectively (Table 2), and these two methods showed no significant difference between them.

Among the four transplanting methods, plants transplanted with the 4-wheeler consistently showed the greatest growth, reaching an average height of 100.14 cm at 75 DAT (Table 2). The 3-wheeler method resulted in slightly shorter plants, with a maximum height of 94.18 cm at 75 DAT (Table 2). Manual planting and the drum seeder produced the least growth, with heights of 90.76 cm and 90.60 cm (Table 2).

The plant transplanted by 4-wheeler had the highest height, whereas direct seeded by drum seeder was the smallest, which might be due to the seedlings' height during transplanting (12-15cm), while direct seeded rice seed needed time to germinate and grow.

Number of tillers per hill

At 30 DAT, the number of tillers produced by the plants differed depending on the planting method used. The 4-wheeler method led to the most vigorous tiller growth, with plants producing an average of 8.78 tillers (Table 3). The 3-wheeler method resulted in fewer tillers, with an average of 5.88 (Table 3). Plants that were manually planted and sown using the drum seeder method produced the least number of tillers, with averages of 4.36 and 3.88, respectively (Table 3). This indicates that the 4-wheeler method significantly encouraged early tiller development, while the manual and drum seeder methods were the least effective at this stage. At 45 DAT, the 4-wheeler method resulted in the highest number of tillers, averaging 14.86 per plant. This was significantly more than the other methods, where the 3-wheeler, manual, and drum seeder methods produced similar results, with tiller numbers ranging between 9.56 and 10.42.

At 60 DAT, the 4-wheeler method produced the most tillers, averaging 18.64 per plant. The 3-wheeler, manual, and drum seeder methods had fewer tillers, with averages between 13.84 and 15.28, showing no significant differences among them. The data of 75 DAT was square root(x+0.5) transformed to stabilize the variance and meet the assumption of normality required for statistical comparison. The square root(x+0.5) transformed data showed that at 75 DAT, the 4-wheeler method produced the most tillers (4.36 per plant), the 3-wheeler followed with 4.13, while the manual method had 4.01 tillers, and the drum seeder resulted in the fewest, with 3.81 tillers. The differences were significant, especially between the 4-wheeler and drum seeder methods.

The plant transplanted by the 4-wheeler had the highest number of tillers, while DSR by drum seeder had the fewest tillers. The 3-wheeler transplanted rice had lower height and fewer tillers compared to the 4-wheeler transplanted plant, which might be due to poor seedling quality. The 4-wheeler had good stability in the puddled field, due to which row accuracy and depth uniformity were maintained, which helped in better crop establishment.

Yield and yield attributing characters

Effective tillers per square meter

In the research, the 4-wheeler method resulted in the highest number of effective tillers, with an average of 371.18 tillers per square meter (Table 4).

The 3-wheeler and manual methods produced fewer tillers, with averages of 342.06 and 319.68, respectively (Table 4), though they were not significantly different from each other. The drum seeder method had the lowest number of effective tillers, averaging 294.46 per square meter (Table 4).

My findings support (Bhatt et al., 2023) result that mechanical transplanting produces more effective tillers compared to manual transplanting. Rana et al., (2014) discovered that manually transplanted rice produced more effective tillers than direct-seeded rice. ***Panicle length***

Panicle length, a crucial trait influencing grain production and crop yield, exhibited a non-significant difference among different transplanting methods. The average length of the panicle was recorded to be 24.59cm (Table 5). The 4-wheeler method resulted in the longest panicles, with an average length of 25.32 cm (Table 5). The 3-wheeler and manual methods produced slightly shorter panicles, measuring 24.72 cm and 24.48 cm, respectively (Table 5), though there was no significant difference between them. The drum seeder method had the shortest panicles, with an average length of 23.86 cm (Table 5).

Vijay et al., (2023) also discovered that the plant transplanted by a 4-wheeler had the longest panicle and the manually transplanted plant had a shorter panicle, while DSR by drum seeder had the shortest panicle of 23.86 cm, which is similar to (Singh et al., 2006) findings.

Thousand grain weight

Thousand grain weight, a crucial parameter for assessing grain yield quality, showed no significant differences among the treatments. The 4-wheeler method had an average weight of 21.6 grams per thousand grains, while the 3-wheeler method averaged 21.0 grams. Both the manual and drum seeder methods also produced an average weight of 20.8 grams per thousand grains. Since all the treatments resulted in similar weights, it suggests that the method of planting did not significantly affect the grain weight.

Grain yield (kg/m^2)

The grain yield per square meter varied significantly across the different transplanting methods. Moisture content did not differ significantly among treatments; yield differences were primarily attributed to treatment effects. The 4-wheeler method achieved the highest yield, producing an average of 0.52 kg/m² (Table 7). The 3-wheeler method also performed well, with a yield of 0.46 kg/m² (Table 7). In contrast, both the manual and drum seeder methods produced lower yields, averaging 0.33 kg/m² and 0.29 kg/m², respectively (Table 7). The results indicate that the 4-wheeler method was the most effective for maximizing grain yield, while the manual and drum seeder methods yielded significantly less.

There was no significant difference in yield between mechanically transplanted rice, i.e., 4-wheeler and 3-wheeler. Manually transplanted rice produced a lower yield than the mechanically transplanted rice. Bhatt et al., (2023) also had similar findings. And DSR by drum seeder had the lowest grain yield, Akbar et al., (2011) also found that the manually transplanted rice produces a higher yield than DSR.

The higher grain yield observed in the four-wheel mechanical transplanter treatment may be attributed to improved planting uniformity and optimal plant spacing,

which likely enhanced light interception and reduced intra-plant competition. Additionally, tray-raised seedlings used in mechanical transplanting often experience less root damage compared to manually uprooted seedlings, resulting in faster establishment and improved tillering capacity. Similar findings have been reported in studies evaluating mechanized rice transplanting systems in South Asia.

Biomass yield (kg/m²)

The biomass yield per square meter varied significantly among the different treatments. The highest biomass yield was achieved with the 4-wheeler method, averaging 2.24 kg/m² (Table 7). The 3-wheeler method followed closely with an average yield of 1.99 kg/m². In contrast, both the manual and drum seeder methods produced lower biomass yields, averaging 1.56 kg/m² and 1.53 kg/m², respectively. This indicates that the 4-wheeler method was the most effective in promoting overall biomass growth, while the manual and drum seeder methods yielded significantly less.

Harvest Index (HI)

The 4-wheeler method had the highest HI at 0.23, followed closely by the 3-wheeler at 0.22. The manual method showed a slightly lower HI of 0.21, while the drum seeder method had the lowest at 0.19. This indicates that the 4-wheeler and 3-wheeler methods were more efficient in producing grain compared to the manual and drum seeder methods.

Table 2. Effect of different planting methods on plant height of rice plant at Geruwa, Bardiya, 2024

Treatments	Plant height(cm)			
	30 DAT	45DAT	60DAT	75DAT
4-wheeler	34.24[a]	58.72[a]	76.68[a]	100.14[a]
3-wheeler	32.62[b]	55.14[b]	69.46[b]	94.18[b]
manual	28.76[c]	51.62[c]	64.40[c]	90.76[c]
Drum seeder	25.38[d]	50.92[c]	61.74[c]	90.60[c]
SEm(±)	0.21	0.16	0.48	0.41
CV (%)	3.17	1.34	3.16	1.98
LSD	1.32	1.00	2.96	2.57
F-test	p ≤0.001	p≤0.001	p≤0.001	p≤0.001
Grand mean	*30.25*	*54.1*	*68.07*	*93.92*

Note: LSD: least significant differences, SEm (±): Standard error of the mean, CV: Coefficient of variation, DAT: Days after transplantation, Treatment means separated by LSD and columns represented with the same letter (s) are non-significant at 5% level of significance

Table 3. Effect of different planting methods on the number of tillers of rice plant at Geruwa, Bardiya, 2024

Treatments	Number of tillers			
	DAT 30	DAT 45	DAT60	DAT 75
4-wheeler	8.78[a]	14.86[a]	18.64[a]	4.36[a]
3-wheeler	5.88[b]	10.42[b]	15.28[b]	4.13[ab]
manual	4.36[c]	10.42[b]	14.52[b]	4.01[bc]
Drum seeder	3.88[c]	9.56[b]	13.84[b]	3.81[c]
SEm(±)	0.1	0.17	0.36	0.05
CV (%)	8.01	6.94	10.51	5.51
LSD	0.63	1.08	2.25	0.31
F-test	p≤0.001	p≤0.001	p≤0.01	p≤0.05
Grand mean	5.72	11.31	15.57	4.07

Note: LSD: least significant differences, SEm (±): Standard error of the mean, CV: Coefficient of variation, DAT: Days after transplantation, treatment means separated by LSD and columns represented with the same letter (s) are non-significant at 5% level of significance,

Table 4. Effect of different planting methods on effective tiller number per square meter at Geruwa, Bardiya, 2024

Treatments	Effective tillers per square meter
4-wheeler	371.18[a]
3-wheeler	342.06[b]
manual	319.68[b]
Drum seeder	294.46[c]
SEm(±)	3.78
CV (%)	5.09
LSD	23.31
F-test	p≤0.001
Grand mean	331.85

Note: LSD: least significant differences, SEm (±): Standard error of the mean, CV: Coefficient of variation, treatment means separated by LSD and columns represented with the same letter (s) are non-significant at 5% level of significance

Table 5. Effect of different planting methods on panicle length of rice plant at Geruwa, Bardiya, 2024

Treatments	Panicle length(cm)
4-wheeler	25.32[a]
3-wheeler	24.72[ab]
Manual	24.48[ab]
Drum seeder	23.86[b]
SEm(±)	0.16
CV (%)	3.04
LSD	1.03
F-test	Non-significant
Grand mean	24.59

Table 6. Effect of different planting methods on Thousand grain weight of rice plant at Geruwa, Bardiya, 2024

Treatments	Thousand grain weight(gm)
4-wheeler	21.6[a]
3-wheeler	21.0[a]
manual	20.8[a]
Drum seeder	20.8[a]
SEm(±)	0.23
CV (%)	4.96
LSD	1.43
F-test	Non-significant
Grand mean	21.05

Table 7. Grain yield, biomass yield and Harvest Index as influenced by different planting methods at Geruwa, Bardiya, 2024

Treatments	Grain Yield (kg/m^2)	Biomass yield (kg/m^2)	Harvest Index (HI)
4-wheeler	0.52[a]	2.24[a]	0.23[a]
3-wheeler	0.46[a]	1.99[ab]	0.22[a]
manual	0.33[b]	1.56[b]	0.21[ab]
Drum seeder	0.29[b]	1.53[b]	0.19[b]
SEm(±)	0.009	0.07	0.005
CV (%)	10.85	17.59	11.94
LSD	0.06	0.44	0.035
F-test	p≤0.001	p≤0.01	Non-significant
Grand mean	0.4	1.83	0.21

Note: LSD: least significant differences, SEm (±): Standard error of the mean, CV: Coefficient of variation,

Conclusion

Study revealed that the rice transplanted by a 4-wheeler has produced better growth parameters compared to other planting methods. The 4-wheeler transplanting methods resulted in the highest numerical values for plant height, tiller number, effective tillers, grain yield, biomass yield, and harvest index. The drum-seeder treatment generally produced the lowest values. Under the conditions of this study, 4-wheeler transplanting showed potential for improving spring rice productivity compared with the other evaluated planting methods.

Recommendations

- Adopt 4-wheeler transplanting: Yields the highest plant height, tiller count, and yield, making it ideal for maximizing productivity.
- Use high-quality seedlings: Ensure robust, uniform seedlings to improve crop establishment, especially with mechanical methods.
- Limit direct seeding by drum seeder: While labor-saving, it results in lower yields. Choose transplanting for yield-focused goals.
- Monitor for pests, especially yellow stem borer: Regular pest management is crucial to prevent tiller loss and protect yields.

Limitations and Future Research

The study was conducted at a single location during one growing season, which may limit broader generalization. Future studies should include multi-location trials.

Declaration

Author Contribution Statement

Shreya Rai: Site selection, Field preparation, Planting, Harvesting, Data collection, Data analysis, and interpretation of data, involved in paper writing

Samarth Bista: Data collection, data interpretation, and involved in paper writing.

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Conflict of Interest

The author declares no conflict of interest.

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