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Performance Evaluation of Spring Rice Variety Chaite-5 with Varied Age of Seedlings and Plant Spacing in Rajapur, Bardiya District of Nepal

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***Abstract*— *Despite the considerable potential for spring rice production in Bardiya District, the average yield remains below the national average. Various factors affect spring rice production, with seedling age and spacing being significant determinants of productivity. The utilization of older seedlings and improper spacing often lead to decreased yields in transplanted rice systems. Therefore, this study aimed to identify the optimal seedling age and planting spacing for Spring rice cultivars (Chaite-5) in transplanted rice systems. A field experiment was conducted to evaluate the performance of spring rice (var. Chaite-5) grown with different seedling ages and planting configurations in Rajapur, Bardiya during the spring season of 2022. The experiment included seedlings from four age groups (19, 22, 25, and 28 days) and three planting geometries (15×15cm, 20×20cm, and 25×25cm). Various parameters such as plant height, number of tillers per hill, effective tillers per hill, panicle length, filled grains, total grains per panicle, sterility percentage, thousand-grain weight (TGW), and grain yield were recorded. The findings revealed that the growth cycle was shortened by 19-22 days for young seedlings (13-day-old) compared to older seedlings (28-day-old), indicating accelerated growth with the transplantation of younger seedlings. Moreover, 22-day-old seedlings exhibited significantly higher numbers of tillers per hill (19) and effective tillers per hill (11), along with higher thousand-grain weight (18.88 g) and grain yield (5121.88 kg/ha). Similarly, crops planted with a spacing of 20 ×20 cm demonstrated significantly higher numbers of tillers per hill (19), effective tillers per hill (10.97), higher thousand-grain weight (20.15 g), and grain yield (5106.50 kg/ha).*

***Keywords*— Seedling, Spacing, Transplantation, Yield**

I. INTRODUCTION

Rice (Oryza sativa L.) holds a paramount position among cereal crops globally, playing a vital role in sustaining the dietary needs of more than half of the world's population daily (Chauhan *et al.*, 2011). With approximately 2.5 billion people, predominantly in developing nations, relying on rice as a staple food, its consumption is pervasive, with Asia alone accounting for 90% of consumption. In contrast, the remaining 10% is distributed among America, Africa, Australia, and Europe (Dahipahle and Singh, 2018).

In Nepal, rice production takes precedence as the primary agricultural pursuit, contributing around half of the nation's total cereal output (Ghimire *et al.*, 2013). The diverse topography of Nepal, ranging from the low-lying Terai to the towering mountains, fosters a rich variety of rice ecosystems. These ecosystems accommodate various landraces tailored to diverse agro-climatic conditions and farmers' preferences. Known as "Dhaan" in Nepali, rice belongs to the Poaceae Family and significantly contributes to the country's agricultural Gross Domestic Product (GDP) by constituting 50% of total edible cereal production and providing more than 50% of the required caloric intake for Nepalese citizens (Basnet, 2008).

Achieving uniformity in population and regulating the growth and yield of rice crops depend significantly on the age of seedlings at the time of transplanting (Zhimomi *et* al., 2021). Proper transplanting at the right age enhances effective tiller and crop growth with significant differentiation (Reuben *et al.*, 2016). However, delayed transplanting or using aged seedlings more than 25 days old results in poor seedling establishment and the production of fewer tillers, leading to lower yields (Li *et al.*, 2020). Transplanting delays are common in the rain-fed lowland fields of the central Terai region of Nepal due to unpredictable rainfall patterns and a lack of weather forecasting facilities. The farmers prepare the rice seedling nursery depending on the onset of rains, and unknown patterns of rainfall, they are compelled to plant either too young seedlings or old aged seedlings (Shah and Yadav 1970, VLW Bara report 2022). Early plantation during heavy rainfall and flooding conditions lead to low survival rates of seedlings due to anaerobic conditions, root rot caused by fungal development, and hot weather combined with stagnant water for more than a week (Dhungana *et al.*, 2020). Therefore, understanding the appropriate seedling age is crucial for sustainable rice cultivation.

Optimizing seedling age and row spacing are pivotal factors in enhancing rice yield. Proper spacing regulates plant density per unit area, directly influencing yield. While narrow spacing fosters intense competition among plants for nutrients, air, and light resulting in weaker growth and reduced yield, wider spacing may lead to decreased grain yield due to diminished competition and increased straw production (Alam *et al*., 2012; Sultana *et al.*, 2012). Optimal spacing ensures efficient utilization of solar radiation and nutrients, facilitating proper growth and development of rice plants (Mohaddesi *et al.*, 2011). Closer spacing hampers intercultural operations, leading to more competition among plants for nutrients, air, and light, resulting in weaker plants and reduced yield (Alam *et al*, 2012). Wider spacing also increases competition among crop plants and weeds.

Furthermore, seedling age at transplanting significantly impacts rice production, influencing tiller production, panicle length, and grain yield. Younger seedlings tend to exhibit superior growth characteristics yielding more tillers and higher grain yield than older counterparts (Ginigaddara and Ranamukhaarachchi, 2011). The use of over-aged seedlings hampers the overall performance of the crop leading to drastically reduced yields (BRRI, 1981), as farmers are often unaware of this factor in rice production. Studies have shown that seedlings aged 21 days contribute to higher grain yields compared to those aged 28 days, with an optimal age of 25 days resulting in maximal panicle production, grain weight, and overall yield (Kewat et al., 2002; Krishna et al., 2008; Abou-Khalifa, 2005).

Bardiya is one of the major rice-producing districts, with rice cultivation spanning an area of 1600 hectares, resulting in a total production of 8688 metric tons and an average yield of 5.43 metric tons per hectare (MOALD, 2023). Rajapur municipality and Geruwa rural municipality within the Bardiya district have been identified as key rice production zones under the Prime Minister's Agriculture Modernization Project (PMAMP). However, rice farmers in these areas lack awareness regarding the optimal seedling density per hill required to achieve maximum yield. Therefore, there exists a significant disparity between the demand for rice and the current domestic production. This gap could be narrowed by promoting the widespread cultivation of spring rice along with the adoption of appropriate agronomic management practices.

Prior research has predominantly investigated seedling age and spacing, primarily on rainy-season rice. However, given the unique ecological and cultivation conditions of spring rice, it is essential to conduct trials specifically examining the effects of row spacing and seedling age on yield. Consequently, this study was undertaken to evaluate the influence of different seedling ages and spacing configurations on the performance, yield, and economic considerations of spring rice. The objective of this study is to explore the combined impacts of row spacing and seedling age on the yield and its components of spring rice in the Bardiya district, addressing key factors influencing rice productivity in the region.

II. MATERIALS AND METHOD

2.1 EXPERIMENTAL SITE

The experiment was conducted within farmers' plots in Mahuliya village, representing the Terai region, which is a designated Rice Super Zone implementation site under the Prime Minister's Agriculture Modernization Project (PMAMP) in Bardiya, during the spring season of 2022. The geographical coordinates of the site are 28°39'N latitude and 81°10'E longitude. Bardiya district experiences a tropical climate characterized by hot summers and cold winters. Meteorological data for the 2022 cropping season were obtained from NASA Power as shown in Fig 2. The average monthly rainfall during the experimental period was recorded at 1.08 mm/day, with the highest rainfall occurring in June (3.64 mm/day) and the lowest in April (0.16 mm/day). Previous studies have suggested that a minimum rainfall of 1250 mm is required for the vegetative growth of rice. The mean maximum temperature ranged from 34.06°C to 44.38°C during the experimental period, with the highest temperatures observed in May and the lowest in February. Similarly, the mean minimum temperature during the cropping period ranged from

16.77°C to 29.21°C, with the highest temperatures occurring in May and the lowest in February.

The physicochemical analysis of the experimental soil revealed it to be loamy in texture, with a neutral pH of 6.84. The soil exhibited medium levels of total nitrogen (0.08%) and organic matter (1.68%), while available phosphorus and potassium were found to be low, at 20.06 kg/ha and 121.2 kg/ha, respectively.

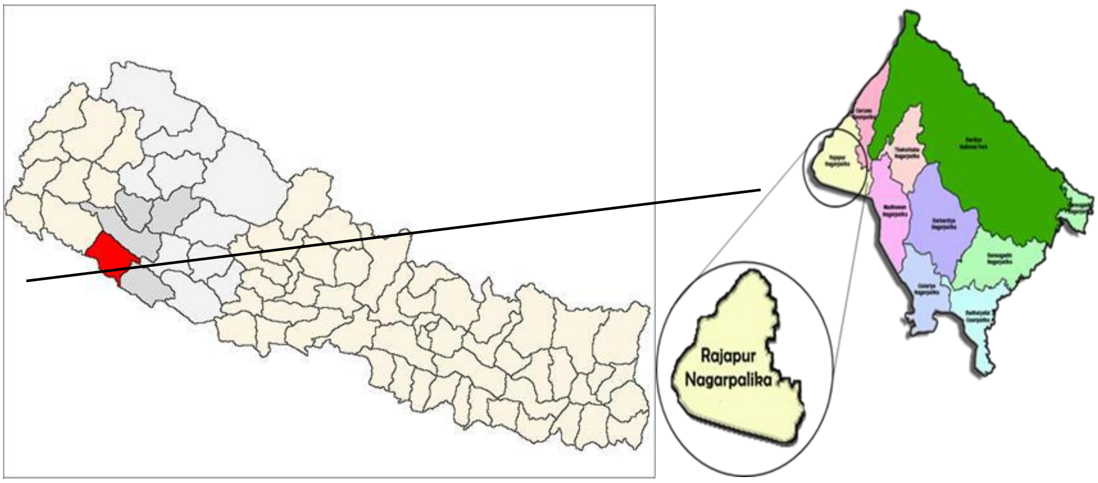

Fig.1. Map of Nepal showing the research location

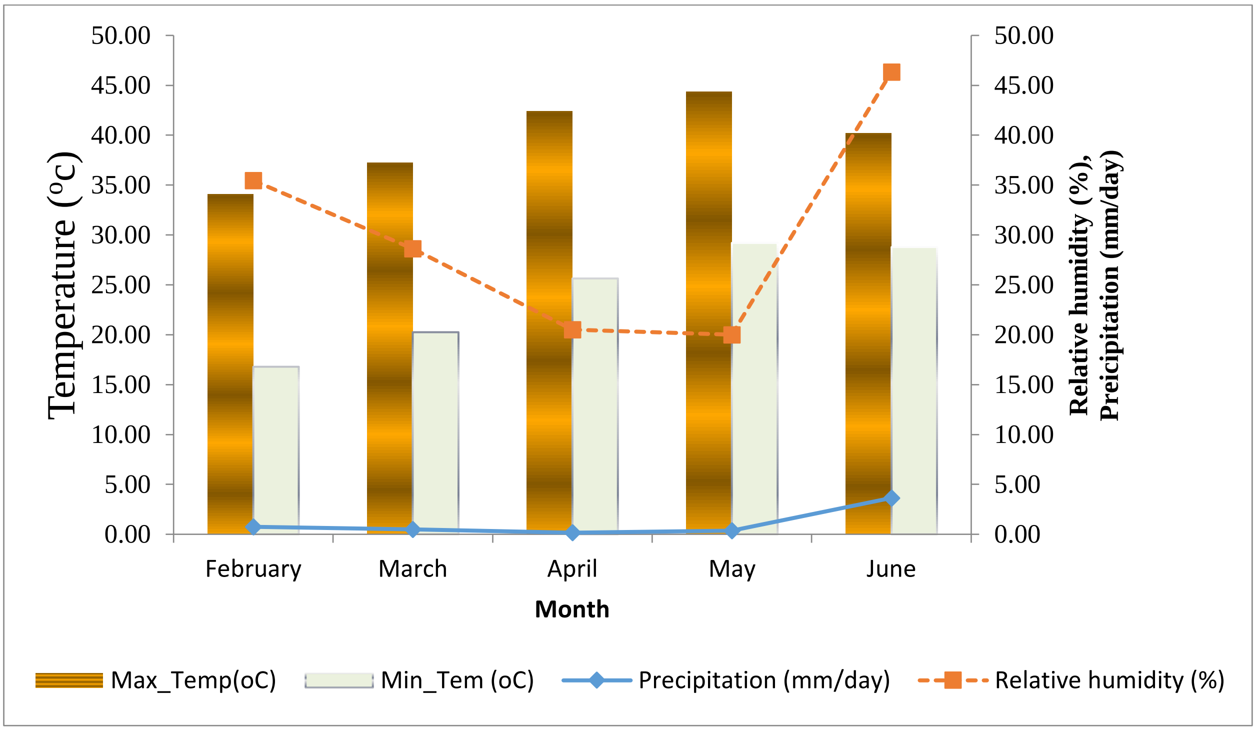

Fig.2. Meteorological data of research location obtained from NASA power.

2.2 Experimental detail

The experiment followed a two-factor split-plot design with three replications and a total of 12 treatments. The treatments comprised combinations of two factors: seedling age and row spacing. The seedling age factor included four levels (19 days, 22 days, 25 days, and 28 days), denoted as A1, A2, A3, and A4, respectively. The row spacing factor consisted of three levels (15 cm × 15 cm, 20 cm × 20 cm, and 25 cm × 25 cm), denoted as R1, R2, and R3, respectively. The treatment combinations and layout of the experimental field is presented in Tables 1 and 2 respectively. The experimental design utilized a split-plot design with three replications and 12 treatments. Each plot measured 3 m × 2 m, with a spacing of 1 m between replications and 0.5 m between treatments.

Table 1. Different treatment combinations are applied in each replication

Treatment	Combinations	Symbols
T1	19 days seedling at 15cm×15cm spacing	A1R1
T2	19 days seedling at 20cm×20cm spacing	A1R2
T3	19 days seedling at 25cm×25cm spacing	A1R3
T4	22 days seedling at 15cm×15cm spacing	A2R1
T5	22 days seedling at 20cm×20cm spacing	A2R2
T6	22 days seedling at 25cm×25cm spacing	A2R3
T7	25 days seedling at 15cm×15cm spacing	A3R1
T8	25 days seedling at 20cm×20cm spacing	A3R2
T9	25 days seedling at 25cm×25cm spacing	A3R3
T10	28 days seedling at 15cm×15cm spacing	A4R1
T11	28 days seedling at 20cm×20cm spacing	A4R2
T12	28 days seedling at 25cm×25cm spacing	A4R3

Table 2. Layout of experimental field

Replication 1		
S1A1	S2A2	S3A4
S1A2	S2A3	S3A2
S1A3	S2A1	S3A1
S1A4	S2A4	S3A3
Replication 2		
S2A3	S3A4	S1A3
S2A2	S3A3	S1A1
S2A1	S3A1	S1A4
S2A4	S3A2	S1A2
Replication 3		
S3A1	S1A1	S2A3
S3A3	S1A3	S2A4
S3A4	S1A4	S2A2
S3A2	S1A2	S2A1

2.3 Cultivation Practices

2.3.1 Nursery Preparation

Seeds were sown in trays placed on well-prepared nursery beds. The nursery beds were irrigated on four different dates spaced three days apart starting from the 23rd of February 2022. Before sowing, seed priming was conducted. Seeds were broadcasted over a film of water on the wet bed. Before sowing, the seeds were treated with a salt solution (200-300 gm salt in 1 liter water). Manual sowing of seeds was carried out in the trays. Approximately 1.5-2 kattha of seed bed area was required per bigha of rice field. Adequate irrigation, drainage, and well-fertilized soil were essential for optimal seedbed preparation. Nurseries were not established in areas where the previous year's paddy crop had been threshed to prevent varietal admixture.

2.3.2 Main Field Preparation

The land was plowed twice to achieve a good tilth. The field was flooded 1-2 days before plowing, and the surface was kept covered with water. Main field preparation involved puddling, and a rotavator was employed three times for this purpose. Thirty-six plots each measuring 3m×2m were created. Different ages of seedlings were transplanted at three different plant spacings.

2.3.3 Manure and Fertilizer

In the nursery bed, manure and fertilizer were applied as per requirements. In the main field, chemical fertilizers such as urea (46% N), DAP (18% N, 46% P_2O_5), and MOP (60% K_2O) were applied at rates of 120:60:40 kg NPK/ha. FYM was incorporated into the soil 15 days before transplanting at a rate of 10t/ha. FYM was incorporated into the soil 15 days before transplanting at a rate of 10t/ha. Half of the nitrogen dose and the full doses of phosphorus and potash were applied as basal doses during transplanting, while the remaining half of the nitrogen was applied as top dressing.

2.3.4 Uprooting of Seedlings

Seedlings of different ages were uprooted individually from the trays at the time of transplanting, ensuring that the roots were not damaged. Water was supplied before uprooting to facilitate the process.

2.3.5 Transplanting of Seedlings

Seedlings of different ages (19, 22, 25 & 28 days) were transplanted at varying distances 15×15 cm, 20×20 cm & 25×25 cm. Planting three seedlings per hill was recommended.

2.3.6 Irrigation

Rice requires abundant water especially during critical stages such as vegetative growth, panicle initiation, and grain filling. Irrigation was scheduled at 7 days after transplanting (DAT) 30 DAT during tillering, and subsequently in a monthly alternating dry and wet pattern. Water was sourced from pumps and waterways.

2.3.7 Weed Management

Pre-emergence herbicides were applied within three days of transplanting followed by hand weeding at 15-20 DAT and 45 DAT to effectively manage weeds.

2.3.8 Plant Protection Methods

Integrated pest management practices were employed to prevent rice stem borers, and chemical pesticides were used only in cases of severe infestation.

2.3.9 Harvesting

Manual harvesting was conducted using traditional sickles. The central 1m square area of each plot was marked and harvested separately.

2.3.10 Threshing

Rice heads were sun-dried and manually threshed. Grains were cleaned by winnowing, and their weight was measured using an electric balance. Moisture content was determined using a portable digital moisture meter available at the PMAMP office.

2.4 Observation and Measurement

2.4.1 Growth Parameters

Plant Height: Ten random plants from each plot were tagged and measured for plant height at 15-day intervals with final measurements taken on 90 DAT.

Number of Tillers per Square Meter: One-meter row length was marked on the 8th row of each plot, and the total number of tillers was counted at 15-day intervals from 30 DAT to 90 DAT.

2.4.2 Yield and Yield Attributing Parameters

Number of Effective Tillers per Square Meter**:** The number of panicle-bearing tillers was counted from a 1m row length on the 8th row of any side of the plot before harvest.

Panicle Length: Twenty panicles were randomly selected from each plot, and their lengths were measured using a scale.

Number of Filled Grains per Panicle: The number of filled grains per panicle was counted from each selected panicle.

Spikelet Sterility Percentage: The percentage of spikelet sterility was calculated using the formula provided.

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

Thousand-Grain Weight: Thousand filled grains from each plot were counted and weighed using an electronic digital balance.

Grain Yield: Grain yield was determined from the net plot area of each plot, adjusted for moisture content, and expressed in kilograms per hectare.

$$\text{Grain yield (kg/ha)} = \frac{(100\text{-MC}) \times \text{plot yield (kg)} \times 10000 \text{ (sq.m)}}{(100\text{-}14) \times \text{net plot area (sq.m)}}$$

2.5 Statistical Analysis

Data were arranged systematically based on various observed parameters and analyzed using R studio with R stat Software of 4th edition. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% level of significance. Analysis of variance (ANOVA) was employed to test differences among the factors.

III. RESULT AND DISCUSSION

3.1 Agronomic Characters

3.1.1 Plant Height

The height of rice plants was significantly influenced by varying spacing configurations throughout their growth stages, as illustrated in Table 3. Notably, the tallest plants consistently emerged when spaced at 20 cm × 20 cm intervals. Specifically, at 30 days after transplanting (DAT) the tallest plants measuring 55.25 cm were observed in the 20 cm × 20 cm spacing followed by 15 cm × 15 cm (49.90 cm) and 25 cm × 25 cm spacing (48.84 cm). Likewise, at 45 DAT the tallest plants (75.01 cm) were noted in the 20 cm × 20 cm spacing followed by the 15 cm × 15 cm spacing. By 60 DAT the tallest plants (100.48 cm) were recorded in the 20 cm × 20 cm spacing followed by 25 cm × 25 cm. This pattern persisted with the tallest plants observed at 20 cm × 20 cm spacing at 75 DAT (105.16 cm) and 90 DAT (109.08 cm). The increased plant height associated with 20 cm × 20 cm spacing compared to narrower spacing (15 cm × 15 cm) can be attributed to enhanced spatial availability and reduced competition for nutrients. This observation diverges slightly from the findings of Banjade et al. (2023), who reported that plant height peaked with a 30 cm × 30 cm spacing. Additionally, Ram et al. (2014) observed that closer spacing (25 cm × 25 cm) resulted in significantly taller plants and a higher leaf-area index compared to wider spacing (30 cm × 30 cm), likely due to heightened competition for solar light interception and utilization under closer spacing. Despite the recognized significance of spacing and seedling age during the initial stages of crop development, as highlighted by Durga et al. (2015) and Zhimomi et al. (2021), these factors did not exert a significant impact on overall plant height.

In terms of seedling age, notable disparities were evident, except at 30 DAT and 45 DAT, as delineated in Table 3. At 60 DAT, the tallest plants originated from 22-day-old seedlings (96.56 cm), followed by 28-day-old seedlings (93.12 cm). Subsequently, at 75 DAT, the tallest plants were observed in 22-day-old seedlings, followed by 28-day-old seedlings (98.78 cm). Likewise, at 90 DAT, the plant height of 22-day-old seedlings surpassed that of 19-day-old seedlings (106.43 cm). These findings are in accordance with those of Shrestha et al. (2019), who reported that transplanting at an early age yielded significantly taller plants, with a height increase of 4 cm. The prolonged growth period provided by early transplanting allowed plants to accumulate more photosynthates, consequently leading to increased plant height, as observed by Sarkar et al. (2011). Similarly, Naresh (2012) documented that plants exhibited up to a 9 cm increase in height when comparing seedlings aged 20 to 60 days in Andhra Pradesh, India. Moreover, Ram et al. (2014) noted that older seedlings at ten days also displayed significantly greater height.

Table 3. Plant height of Chaite-5 as influenced by different ages of seedlings under different spacing at Bardiya,Nepal

Treatment	Plant height(cm)				
Spacing	30DAT	45DAT	60DAT	75DAT	90DAT
15×15cm	49.90^{b}	69.05^{b}	88.42^{b}	98.75^{b}	104.02^{c}
20×20cm	55.25^{a}	75.01^{a}	100.48^{a}	105.16^{a}	109.08^{a}
25×25cm	48.84^{b}	67.90^{b}	89.75^{b}	96.75^{b}	105.69^{b}
$SEM_1\pm$	0.626	0.598	0.946	0.83	0.19
$LSD_a(0.05)$	2.46	2.35	3.71	3.26	0.78
CV(a)%	4.2%	2.9 %	3.5%	2.9%	0.6%
F-test	*	**	**	**	***
Age of seedlings					
28 days old	49.99^{b}	69.95^{a}	93.12^{b}	98.78^{b}	102.87^{c}
25 days old	51.13^{ab}	70.10^{a}	89.89^{b}	98.44^{b}	106.16^{b}
22 days old	48.84^{b}	71.66^{a}	96.56^{a}	105.00^{a}	109.59^{a}
19 days old	51.36^{ab}	70.91^{a}	91.96^{b}	98.67^{b}	106.43^{b}
$SEM_2\pm$	0.723	0.691	1.092	0.95	0.23
$LSD_b(0.05)$	2.53	2.03	3.21	3.87	2.28
CV(b)%	5%	2.9 %	3.5%	3.9%	2.2%
F-test	NS	NS	**	**	***
Grand mean	51.33	70.65	92.88	100.22	106.26

*Note: Treatment means separated by DMRT and columns represented with the same letter(s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.1.2 Number of Tillers per Hill

The number of tillers per hill exhibited notable variations based on spacing across all growth stages, as shown in Table 4. At 30 days after transplanting (DAT), the highest number of tillers (17.14) was recorded with 20 cm × 20 cm spacing, followed by 25 cm × 25 cm spacing (16.39). This differs slightly from the findings of Ghimire et al. (2023), who reported that 30 days after transplanting, the maximum number of tillers (23.23 tillers/plant) was observed in rice planted at 25 cm × 20 cm spacing, succeeded by 20 cm × 20 cm (22.03 tillers/plant). Similarly, at 45 DAT, the 20 cm ×

20 cm spacing displayed the highest number of tillers (18.59), followed by 25 cm × 25 cm spacing (16.05). By 60 DAT, the maximum number of tillers (17.34) was observed at 25 cm × 25 cm spacing, followed by 20 cm × 20 cm spacing (16.83). The tiller counts increased and peaked at 60 DAT before undergoing a decline due to tiller mortality. By 75 DAT, the highest tiller count (14.95) was associated with 20 cm × 20 cm spacing, followed by 25 cm × 25 cm spacing (13.75). Subsequently, at 90 DAT, the highest tiller count (12.73) was observed with 20 cm × 20 cm spacing, trailed by 25 cm × 25 cm (11.65) and 15 cm × 15 cm (8.01) spacing, respectively. These findings suggest that 20 cm × 20 cm spacing was most efficacious in augmenting tiller count.

Regarding seedling age, notable variances were observed in tiller count, as elucidated in Table 4. At 30 DAT, the maximum tiller count (18.61) was noted with 22-day-old seedlings, succeeded by 19-day-old seedlings (15.76). Similarly, at 45 DAT, the peak tiller count was recorded with 22-day-old seedlings (18.86), followed by 19-day-old seedlings (16.57). At 60 DAT, 75 DAT, and 90 DAT, significantly higher tiller counts (18.51, 14.98, and 12.13, respectively) were documented with 22-day-old seedlings, trailed by 19-day-old seedlings (15.84, 13.05, and 11.14, respectively). Analogous results were reported by Dhungana et al. (2020), who observed noteworthy disparities in total tillers per hill based on seedling age during transplantation. They noted greater tiller counts (10.94) in plants with 20-day-old seedlings and lower counts (10.22) in those with 30-day-old seedlings.

Table 4. Effect of Spacing and Seedling Age on Tiller Number of Chaite-5 at Bardiya, Nepal

Treatment	Tillers per hill				
Spacing	30DAT	45DAT	60DAT	75DAT	90DAT
15×15cm	14.10^{b}	14.89^{b}	12.77^{b}	10.38^{c}	8.01^{c}
20×20cm	17.14^{a}	18.59^{a}	16.83^{a}	14.95^{a}	12.73^{a}
25×25cm	16.39^{a}	16.05^{b}	17.34^{a}	13.75^{b}	11.65^{b}
SEM_1±	0.28	0.42	0.34	0.25	0.14
LSD_a(0.05)	1.13	1.66	1.35	1.02	0.58
CV(a)%	6.3%	8.9%	7.6%	6.9%	4.8%
F-test	**	**	**	***	***
Age of seedlings					
28 days old	14.31^{c}	15.21^{c}	15.78^{b}	11.55^{c}	9.23^{c}
25 days old	14.83^{c}	16.41^{b}	14.46^{c}	12.53^{b}	10.68^{b}
22days old	18.61^{a}	18.86^{a}	18.51^{a}	14.98^{a}	12.13^{a}
19 days old	15.76^{b}	16.57^{b}	15.84^{b}	13.05^{b}	11.14^{b}
SEM_2±	0.33	0.48	0.39	0.30	0.17
LSDb(0.05)	0.76	0.84	1.04	0.55	0.71
CV(b)%	4.9%	5.2%	6.7%	4.3%	6.7%
F-test	***	***	***	***	***
Grand mean	15.87	16.51	15.64	13.03	10.8

*Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.2 Yield attribute

3.2.1 Effective Tillers per Hill

A significant result was found for effective tillers per hill due to spacing, as shown in Table 5. The treatment featuring 20 cm × 20 cm spacing exhibited the highest number of effective tillers (10.97), followed by 25 cm × 25 cm spacing with 9.80 tillers. This stands in contrast to the findings of Ram et al. (2014), who noted significantly higher counts of effective tillers per hill, panicles per hill, and grains per panicle in wider 30 cm × 30 cm spacing compared to closer spacing. Notably, seedling spacing did not exert influence on test weight but did impact tillers per square meter, as observed by Banjaeda et al. (2023). The peak count of effective tillers per hill was recorded at 20 cm × 20 cm spacing, showcasing a significant disparity from other spacing alternatives.

Regarding seedling age, the highest count of effective tillers (11.44) was attained with 22-day-old seedlings, trailed by 19-day-old seedlings (9.83). Similar findings were reported by Dhungana et al. (2020), who observed greater counts of effective tillers per hill in plants with 20-day-old seedlings (9.9) compared to those with 30-day-old seedlings (9.3). Conversely, the lowest count of effective tillers (8.26) was documented with 28-day-old seedlings. Additionally, another group of researchers noted a substantial reduction in total tiller production with delayed planting (Nayak et al., 2003). Ali et al. (2013) identified that 15-day-old seedlings exhibited superior efficacy in producing effective tillers compared to other seedling ages. The phenomenon of early planting potentially fosters more productive tillers due to the enhanced development of early-formed tillers up to the reproductive phase of the crop, while late planting may lead to tiller mortality owing to inadequate photosynthates, thereby diminishing the count of effective tillers.

3.2.2 Panicle Length

Spacing had a highly significant effect on the average panicle length, as shown in Table 5. The longest panicle length (27.08 cm) was recorded with 20 cm × 20 cm spacing, followed by 25 cm × 25 cm spacing (25.41 cm). Ghimire et al. (2023) reported that the greatest panicle length (23.68 cm) was observed with 25 cm × 20 cm spacing, followed by 20 cm × 20 cm (22.18 cm). Panicle length was also significantly influenced by the age of seedlings. The longest panicle length (27.07 cm) was recorded with 22-day-old seedlings, followed by 19-day-old seedlings (26.43 cm). Shrestha et al. (2019) also observed significantly longer panicles when transplanted at an earlier age compared to later transplanting. Correspondingly, Naresh (2012) noted panicles that were 1.1 cm longer in Andhra Pradesh, India. Concerning hybrid varieties, Kumar (2001) demonstrated that panicles were 1 cm longer when transplanted at 20 days compared to 25 and 30 days seedlings. The average panicle length exhibited a highly significant response to various spacing treatments.

3.2.3 Filled Grain per Panicle

The number of filled grains per panicle was greatly affected by spacing as shown in Table 5. The most filled grains per panicle (216.91) were found with 20 cm × 20 cm spacing, followed by 15 cm × 15 cm spacing (186.25). According to Rajesh and Thanunathan (2003), employing wider spacing resulted in diminished competition both below and above ground, leading to enhanced grain filling, increased grain weight, and a greater number of filled grains per panicle. The lowest count of filled grains (185.00) was observed at 25 cm × 25 cm spacing.

Likewise, significantly higher counts of filled grains per panicle (218.22) were obtained with 22-day-old seedlings, followed by 25-day-old seedlings (198.22). Conversely, fewer filled grains (179.67) were recorded with 28-day-old seedlings. Ghimire et al. (2023) observed that the highest count of filled grains per panicle (125.25) was associated with a spacing of 25 cm × 20 cm, which exhibited statistical similarity to spacing configurations of 20 cm × 20 cm (122.75) and 25 cm × 15 cm (119.25). Conversely, the lowest count of filled grains (107.25) was noted for 15 cm × 15 cm spacing, which displayed statistical similarity to 20 cm × 15 cm (109.5). In general, it can be inferred that wider spacing facilitated greater grain production per panicle compared to narrower spacing, attributable to reduced competition for nutrients, air, and light, thereby improving the growth environment for crops, as documented by Moro et al. (2016).

3.2.4 Total Grain per Panicle

Spacing and the age of seedlings didn't have a significant effect on the total grains per panicle, as shown in Table 5. However, according to a study by Ram *et al.* (2014), grains per panicle were significantly higher in wider 30 cm × 30 cm spacing than in closer spacing.

Table 5. Different yield attributing characters of Chaite-5 as affected by the spacing and age of seedlings at Bardiya, Nepal

Treatment		Yield attributes		
Spacing	Effective tillers(per hill)	Panicle length(cm)	Filled Grain	Total Grain Per Panicle
15×15cm	7.63^{c}	25.41^{c}	186.25^{b}	274.33^{a}
20×20cm	10.97^{a}	27.08^{a}	216.91^{a}	318.75^{a}
25×25cm	9.80^{b}	26.56^{b}	185.00^{b}	302.50^{a}
SEM1±	0.11	0.07	3.61	14.59
LSDa(0.05)	0.43	0.30	14.20	57.30
CV(a)%	4%	1%	6.4%	16.9%
F-test	***	***	**	NS
Age of seedlings				
28 days old	8.26^{c}	25.80^{c}	179.67^{c}	291.44^{a}
25 days old	9.23^{b}	26.09^{bc}	198.22^{b}	301.56^{a}
22 days old	11.44^{a}	27.07^{a}	218.22^{a}	308.89^{a}
19 days old	9.83^{b}	26.43^{b}	188.33^{c}	292.22^{a}
SEM2±	0.12	0.08	4.17	16.85
LSDb(0.05)	0.51	0.49	8.84	35.45
CV(b)%	5.5%	1.9%	4.6%	12%
F-test	***	***	***	NS
Grand mean	9.46	26.35	196.05	298.52

*Note: Treatment means separated by DMRT and columns represented with the same letter(s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.2.5 Sterility Percentage

The sterility percentage was greatly affected by spacing, as shown in Table 6. The highest sterility percentage (37.46%) was seen with 15 cm × 15 cm spacing, followed by 25 cm × 25 cm spacing (32.21%). A significantly lower sterility percentage (29.49%) was found with 20 cm × 20 cm spacing.

Regarding the age of seedlings, the highest sterility was observed in 19-day-old seedlings (35.08%), which was statistically similar to 28-day-old seedlings (33.82%) and 25-day-old seedlings (33.32%). The lowest sterility percentage was recorded with 22-day-old seedlings (29.98%).

3.2.6 Thousand-Grain Weight

Thousand-grain weights were greatly affected by plant spacing, as shown in Table 6. The weight was higher in 20 cm × 20 cm spacing (20.15 gm) followed by 15 cm × 15 cm spacing (17.92 gm). Similarly, a significantly higher thousand-grain weight (18.85 gm) was obtained with 22-day-old seedlings, which was statistically similar to 19-day-old seedlings (19.15 gm). A lower thousand-grain weight (17.80 gm) was recorded with 28-day-old seedlings.

Ghimire et al. (2023) recorded that thousand-grain weights were significantly higher for seedlings transplanted at wider spacings as 25 cm × 20 cm (25.03 gm) and compared to narrower spacing treatments 20 cm × 20 cm (24.63 gm). Consistent with these findings, Rajesh and Thanunathan (2003) and Akondo and Hossain (2020) observed similar results, suggesting that employing broader spacing mitigated competition both below and above ground, consequently leading to increased thousand-grain weight.

3.2.7 Grain Yield

Grain yield was significantly affected by both spacing and the age of seedlings, as shown in Table 6. The highest grain yield (5106.50 kg/ha) was recorded with 20 cm × 20 cm spacing, which was statistically similar to 15 cm × 15 cm spacing (5058.41 kg/ha). The lowest yield (4833.05 kg/ha) was recorded with 25 cm × 25 cm spacing. Similarly, the maximum yield was obtained with 22-day-old seedlings (5121.88 kg/ha), which was statistically similar to 25-day-old seedlings (5076.89 kg/ha).

Spacing exerted a discernible impact on rice yield, with the maximum yield achieved at 20 cm × 20 cm spacing, a result that exhibited statistical significance compared to other spacing configurations. Shrestha et al. (2019) observed a notable decrease in rice yield when older seedlings, surpassing 25 days of age, were transplanted. Consistent with these findings, Naresh (2012) noted a reduction in grain yield of 676 kg per hectare when transplanted after 20 days for long-duration varieties. Multiple studies (Adhikari et al., 2004; Gautam et al., 2010; Mahato and Pathic, 1997) have demonstrated a significant decline in grain yield when comparing 20-day-old seedlings with those aged 65 days. Saphi et al. (2015) reported a yield decrease ranging from 20% to 30% when transplanting seedlings aged 35 to 55 days compared to 25-day-old seedlings. Correspondingly, Alam et al. (2002) identified significantly lower grain yield when very young seedlings (21 days old) were transplanted compared to those aged 28 to 35 days in Mymensingh, Bangladesh.

Table 6: Different yield attributing characters of Chaite-5 as affected by the spacing and age of seedlings at Bardiya, Nepal

Treatment	Yield attributes		
Spacing	Sterility%	Thousand Grain Wt (gm)	Grain Yield(kg/ha)
15×15cm	37.46[a]	17.92[b]	5058.41[a]
20×20cm	29.49[c]	20.15[a]	5106.50[a]
25×25cm	32.21[b]	17.67[b]	4833.08[b]
SEM_1 ±	0.58	0.17	12.80
LSD_a (0.05)	2.30	0.67	50.27
CV(a)%	6.2%	3.2%	0.9%
F-test	**	***	***
Age of seedlings			
28 days old	33.82[a]	17.80[b]	4891.02[b]
25 days old	33.32[a]	18.48[ab]	5076.89[a]
22 days old	29.98[b]	18.88[a]	5121.88[a]
19 days old	35.08[a]	19.15[a]	4907.56[b]
SEM_2 ±	0.67	0.19	14.78
LSDb(0.05)	1.72	0.80	56.81
CV(b)%	5.3%	4.4%	1.1%
F-test	***	*	***
Grand mean	33.05	18.58	4999.33

*Note: Treatment means separated by DMRT and columns represented with the same letter(s) are non-significant at a 5% level of significance, *** indicates a 1% level of significance, ** indicates a 5% level of significance, * indicates a 10% level of significance, DAT: days after transplanting, NS= non-significant, LSD: Least Significant Difference, SEm: Standard error of the mean deviation, CV: Coefficient of Variance*

3.3 Interaction Effect of Age of Seedlings and Planting Spacing on Various Growths and Yields Parameter

3.3.1 Interaction effect of age of seedlings and planting spacing on the number of tiller

The interaction effect of the age of seedlings and planting spacing on the number of tiller was significant only 60 DAT and 75 DAT as shown in Table 7. Maximum tiller number (20.83) was produced by the treatment 20×20cm spacing and 22 days seedling which was followed by the treatment 25×25cm and 22 days old seedling (18.87) at 60 DAT. At 70 DAT, the maximum tiller number (17.26) was produced by the treatment 20×20cm spacing and 22 days seedling which was followed by the treatment 25×25cm and 22 days old seedling (15.23).

Table 7: Interaction Effect of Spacing and Age of Seedlings on the number of tillers

	No of tiller(60DAT)		
Treatments	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	11.13f	14.53e	15.67de
25 days old	11.70f	14.50e	17.17bcd
22 days old	15.83cde	20.83a	18.87b
19 days old	12.40f	17.47bcd	17.67bc
LSD(0.05)	1.80		
F-test	*		
CV%	6.7%		
SEM±	0.69		
	No of tiller(75DAT)		
Treatments	Spacing		
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	9.16g	13.40cd	12.08e
25 days old	9.68fg	13.85c	14.08c
22 days old	12.46de	17.26a	15.23b
19 days old	10.23f	15.31b	13.60c
LSD(0.05)	0.96		
F-test	*		
CV%	4.3%		
SEM±	0.51		

Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAT: days after transplanting

3.3.2 Interaction Effect of Spacing and Age of Seedlings on Effective Tillers per Hill and Filled Grain

The interaction of spacing and age of seedlings on effective tillers per hill was significant as shown in Table 8. The highest number of effective tillers per hill (13.33) was recorded with 20×20cm spacing and 22-day-old seedlings, followed by 25×25cm spacing and 22-day-old seedlings (12.10). Other treatments resulted in significantly lower numbers of effective tillers per hill. In terms of filled grain, the highest number (238.00) was found in 20×20cm spacing with 22-day-old seedlings, whereas the lowest (153.33) was recorded in 15×15cm spacing with 28-day-old seedlings.

Table 8: Interaction *Effect of Spacing and Age of Seedlings on Effective Tillers per Hill and Filled Grain*

Effective tillers per hill			
Treatments		Spacing	
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	6.93^{h}	9.76^{de}	8.10^{fg}
25 days old	7.50^{gh}	10.73^{c}	9.46_{de}
22 days old	8.90^{ef}	13.33^{a}	12.10^{b}
19 days old	7.20^{gh}	10.06^{cd}	9.53^{de}
LSD(0.05)	0.88		
F-test	*		
CV%	5.5%		
SEM±	0.22		
Filled grain			
Treatments		Spacing	
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	153.33^{h}	210.67^{b}	175.12^{fg}
25 days old	193.21^{cde}	211.00^{b}	190.67^{def}
22 days old	213.00^{b}	238.00^{a}	203.00^{bcd}
19 days old	185.66^{efg}	208.00^{bc}	171.33^{g}
LSD(0.05)	15.32		
F-test	*		
CV%	4.6%		
SEM±	7.23		

Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAT: days after transplanting

3.3.3 Interaction effect of spacing and age of seedlings on sterility % and grain yield of chaite-5 in Rajapur, Bardiya

The interaction of spacing and age of seedlings on sterility % was significant as shown in Table 9. The highest sterility % (40.04) was recorded in 15×15cm spacing of 19 days seedlings which was statistically at par with 15×15cm spacing of 28 days seedlings (38.45%) and 25 days seedlings (37.91%). The lowest sterility percentage (26.77%) was recorded in 20×20 cm spacing of 22 days seedling.

In the case of grain yield, the highest grain yield (5315.00 kg/ha) was found in 20×20cm spacing of 22-day-old seedlings whereas low grain yield (4856.47 kg/ha) was recorded in 25×25cm spacing of 19 days seedlings.

Table 9: Interaction effect of spacing and age of seedling on sterility % and grain yield

Sterility%			
Treatments		Spacing	
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	38.45[ab]	32.81[cde]	30.21[def]
25 days old	37.91[ab]	28.95[fg]	33.11[cd]
22 days old	33.44[c]	26.77[g]	29.74[efg]
19 days old	40.04[a]	29.43[fg]	35.78[bc]
LSD(0.05)	2.98		
F-test	*		
CV%	5.3%		
SEM±	1.17		
Grain Yield			
Treatments		Spacing	
Age of seedlings	15×15cm	20×20cm	25×25cm
28 days old	4991.33[c]	4931.00[cd]	4750.67[e]
25 days old	5133.67[b]	5227.33[ab]	4869.37[d]
22 days old	5195.33[b]	5315.00[a]	4955.33[d]
19 days old	4991.33[cd]	4952.36[cd]	4856.47[d]
LSD(0.05)	98.40		
F-test	***		
CV%	1.1%		
SEM±	25.60		

Note: Treatment means separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, DAT: days after transplanting

3.4 Correlation regression

To understand the relationship between growth parameters, yield attributing traits, and grain yield, simple correlation coefficients were analyzed.

3.4.1 Effective tillers and grain yield

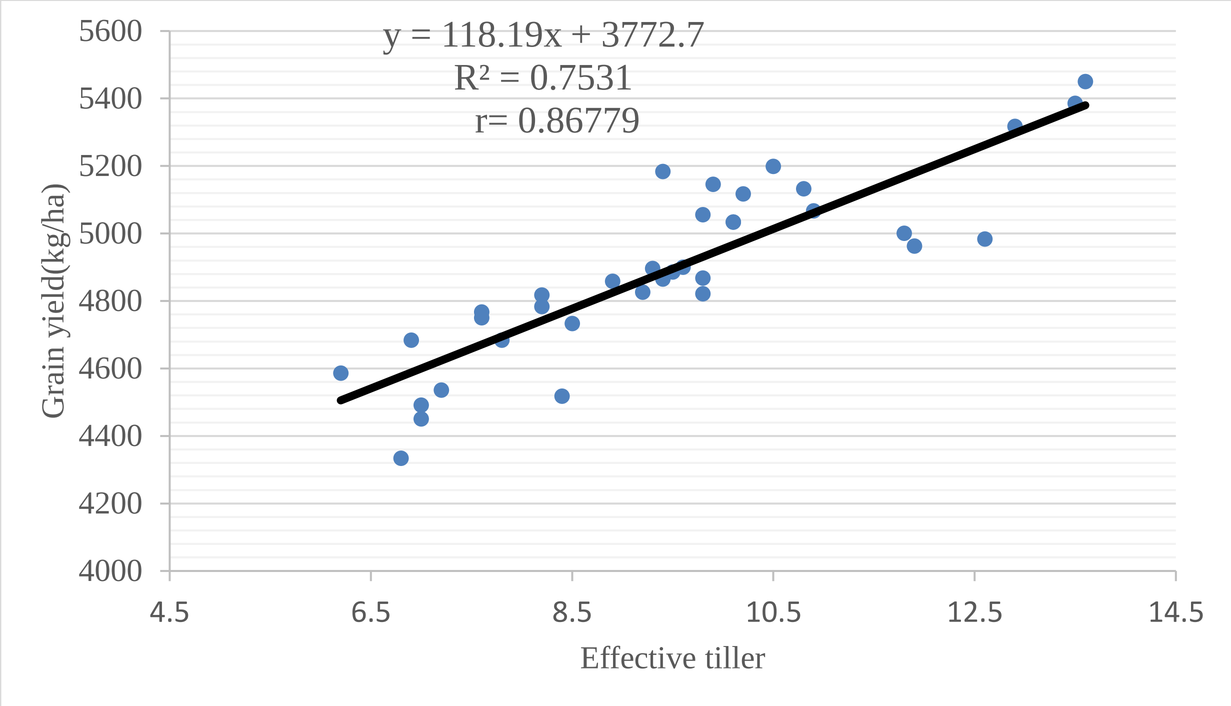

Fig.3. Linear relationship between effective tillers and grain yield of Chaite-5 at Rajapur, Bardiya

There exists a linear relationship between grain yield and effective tillers per hill. Effective tillers contributed to 75.31% of the total grain yield of rice, with the remaining contribution from other factors. A strong and significant correlation (r= 0.867) was found between grain yield and effective tillers per hill, indicating that an increase in the number of effective tillers per hill leads to an increase in grain yield.

3.4.2 Filled grain and grain yield

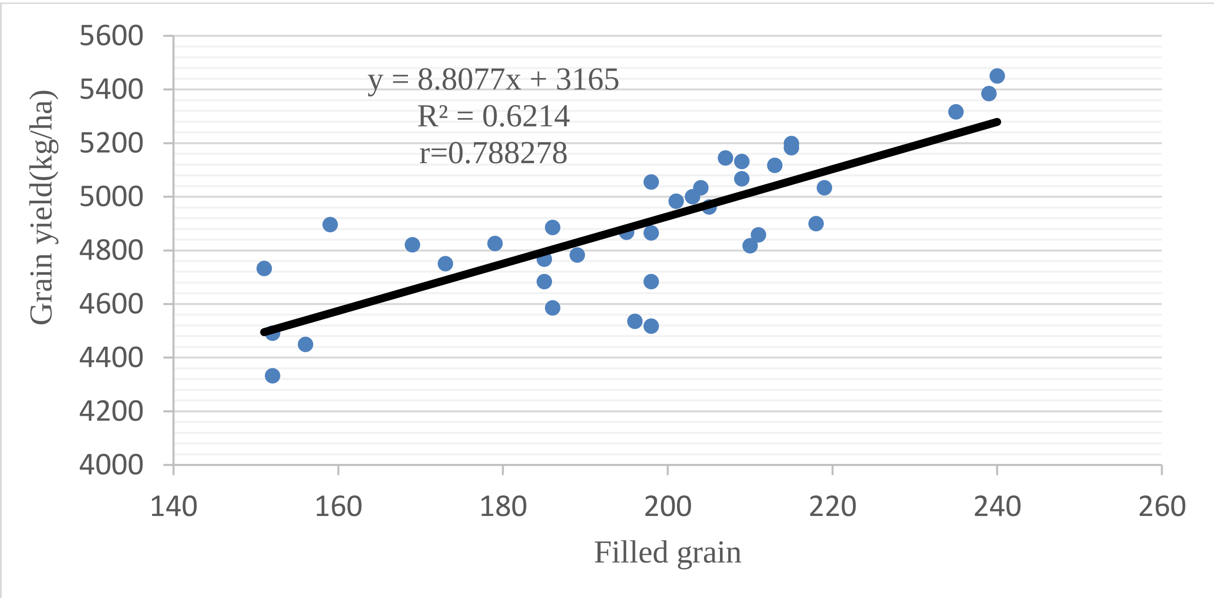

Fig.4. Polynomial relationship between filled grain and grain yield of spring rice as influenced by spacing at Rajapur, Bardiya

Filled grains contributed 62.14% to the paddy grain yield, with the remainder contributed by other factors. A strong and significant correlation (r= 0.788) was observed between grain yield and filled grains, indicating that an increase in filled grains results in higher grain yield.

3.4.3 Total grain per panicle and grain yield

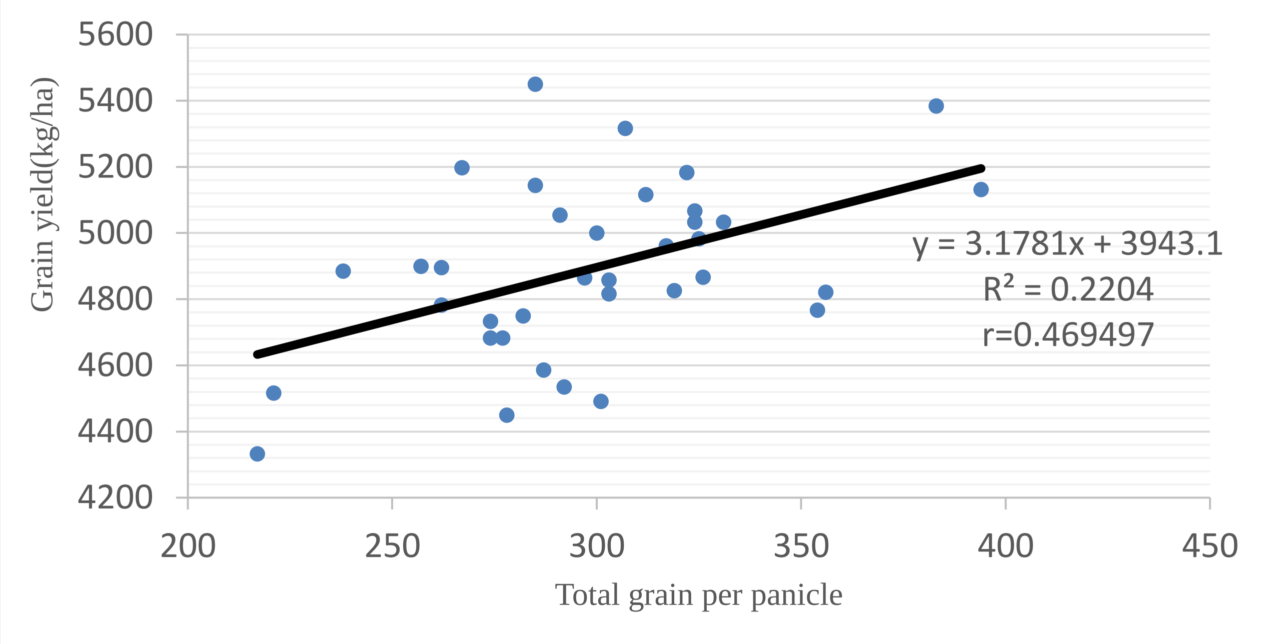

Fig.5: Logarithmic relationship between total grain per panicle and grain yield of Chaite-5 as influenced by planting spacing at Rajapur, Bardiya

Total grains per panicle contributed 22.04% to the grain yield of rice, with the remaining contribution from other factors. A strong and significant correlation (r = 0.469) was found between grain yield and the number of total grains per panicle, suggesting that an increase in the number of total grains per panicle leads to an increase in grain yield.

IV. CONCLUSION

Based on the findings it is evident that various growth parameters and yield-attributing parameters were significantly influenced by spacing and seedling age. Regarding growth parameters, plant height showed a significant increase up to 90 DAT, with 20×20 cm spacing resulting in the tallest plants. Similarly, the number of tillers per hill increased up to 60 DAT, with 20×20 cm spacing significantly increasing tiller numbers. Additionally, 22-day-old seedlings produced the maximum number of tillers per hill. In terms of yield and yield attributing parameters, panicle length varied across treatments, with the longest recorded at 20×20 cm spacing. Effective tillers per hill were significantly higher with 20×20 cm spacing, and 22-day-old seedlings also produced the highest number of effective tillers. The average number of filled grains per panicle was influenced by both spacing and seedling age, with 20×20 cm spacing and 22-day-old seedlings resulting in higher numbers of filled grains per panicle. However, thousand-grain weight was not significantly influenced by spacing and seedling age. Sterility percentage was highest at 15×15 cm spacing and with 19-day-old seedlings. Conversely, the lowest sterility was found in 20×20 cm spacing with 22-day-old seedlings. In terms of yield, the 20×20 cm spacing produced significantly higher grain yield, with 22-day-old seedlings also contributing to higher yields. It is important to note that there were similarities in grain yield between 22-day-old and 25-day-old seedlings.

Overall, these findings highlight the importance of spacing and seedling age in optimizing growth parameters and yield-attributing parameters in rice cultivation, with 20×20 cm spacing and 22-day-old seedlings showing promising results for maximizing grain yield. Further research and experimentation may be needed to fully understand and optimize these parameters for enhanced rice production.

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APPENDICES

Appendix 1. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (30 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	4.815	2.408	NaN	NaN
Spacing	2	283.123	141.561	30.0429	0.003896 **
Ea	4	18.848	4.712	NaN	NaN
Age	3	37.193	12.398	1.8944	0.166737
Spacing:Age	6	15.183	2.531	0.3867	0.877945
Eb	18	117.799	6.544	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 2. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (45 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	6.13	3.066	NaN	NaN
Spacing	2	349.76	174.880	40.6744	0.002196 **
Ea	4	17.20	4.299	NaN	NaN
Age	3	16.93	5.642	1.3401	0.292655
Spacing: Age	6	104.30	17.383	4.1289	0.008819 **
Eb	18	75.78	4.210	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 3. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (60 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	28.43	14.21	NaN	NaN
Spacing	2	1048.83	524.41	48.8360	0.001548 **
Ea	4	42.95	10.74	NaN	NaN
Age	3	210.05	70.02	6.6487	0.003242 **
Spacing: Age	6	28.12	4.69	0.4450	0.839069
Eb	18	189.56	10.53	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 4. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (75 DAT)

	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	142.06	71.028	NaN	NaN
Spacing	2	464.06	232.028	28.0302	0.004436 **
Ea	4	33.11	8.278	NaN	NaN
Age	3	274.44	91.481	5.9626	0.005239 **
Spacing: Age	6	88.39	14.731	0.960	0.478791
Eb	18	276.17	15.343	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 5. Mean square from ANOVA for the effect of the treatments on the height of Chaite-5 at Bardiya, Nepal, 2022 (90 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	22.585	11.292	NaN	NaN
Spacing	2	159.607	79.804	167.3735	0.0001394 ***

Ea	4	1.907	0.477	NaN	NaN
Age	3	203.988	67.996	12.7831	0.0001030 ***
Spacing: Age	6	35.089	5.848	1.0994	0.4003369
Eb	18	95.746	5.319	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 6.Mean square from ANOVA for the effect of the treatments on the number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (30 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.237	0.119	NaN	NaN
Spacing	2	60.264	30.132	29.8994	0.003931 **
Ea	4	4.031	1.008	NaN	NaN
Age	3	99.282	33.094	55.7852	2.586e-09 ***
Spacing: Age	6	3.069	0.512	0.8623	0.540523
Eb	18	10.678	0.593	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 7.Mean square from ANOVA for the effect of the treatments on the number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (45 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.861	0.430	NaN	NaN
Spacing	2	85.967	42.984	19.9975	0.008266 **
Ea	4	8.598	2.149	NaN	NaN
Age	3	75.596	25.199	34.3920	1.155e-07 ***
Spacing: Age	6	11.066	1.844	2.5173	0.060140
Eb	18	13.188	0.733	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 8. Mean square from ANOVA for the effect of the treatments on the number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (60 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	4.729	2.364	NaN	NaN
Spacing	2	150.907	75.454	52.8007	0.001332 **
Ea	4	5.716	1.429	NaN	NaN
Age	3	118.401	39.467	35.5647	8.946e-08 ***
Spacing:Age	6	18.842	3.140	2.8298	0.040416 *
Eb	18	19.975	1.110	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 9. Mean square from ANOVA for the effect of the treatments on number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (75 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.396	0.198	NaN	NaN
Spacing	2	134.636	67.318	83.0908	0.0005525 ***
Ea	4	3.241	0.810	NaN	NaN
Age	3	56.423	18.808	58.7910	1.69e-09 ***
Spacing: Age	6	5.252	0.875	2.7361	0.0454730 *
Eb	18	5.758	0.320	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 10. Mean square from ANOVA for the effect of the treatments on number of tillers of Chaite-5 at Bardiya, Nepal, 2022 (90 DAT)

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.322	0.161	NaN	NaN
Spacing	2	147.215	73.607	274.3137	5.239e-05 ***
Ea	4	1.073	0.268	NaN	NaN
Age	3	39.269	13.090	24.8581	1.271e-06 ***
Spacing: Age	6	16.823	2.804	5.3246	0.00258 **
Eb	18	9.478	0.527	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 11. Mean square from ANOVA for the effect of the treatments on the panicle length of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.4554	0.2277	NaN	NaN
Spacing	2	17.6696	8.8348	124.3755	0.0002505 ***
Ea	4	0.2841	0.0710	NaN	NaN
Age	3	8.0867	2.6956	10.8485	0.0002675 ***
Spacing:Age	6	2.7411	0.4569	1.8386	0.1478145
Eb	18	4.4725	0.2485	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 12. Mean square from ANOVA for the effect of the treatments on the effective tillers per hill of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum Square	Mean Square	F value	Pr(>F)
Replication	2	0.134	0.067	NaN	NaN
Spacing	2	68.967	34.484	234.6711	7.141e-05 ***
Ea	4	0.588	0.147	NaN	NaN
Age	3	51.214	17.071	63.4231	9.105e-10 ***
Spacing:Age	6	4.488	0.748	2.7792	0.04307 *
Eb	18	4.845	0.269	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 13.Mean square from ANOVA for the effect of the treatments on the filled grains per panicle of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	184.2	92.1	NaN	NaN
Spacing	2	7842.7	3921.4	24.9592	0.005504 **
Ea	4	628.4	157.1	NaN	NaN
Age	3	7330.3	2443.4	30.6139	2.773e-07 ***
Spacing: Age	6	1927.5	321.2	4.0249	0.009887 **
Eb	18	1436.7	79.8	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 14. Mean square from ANOVA for the effect of the treatments on the sterility percentage of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	1.21	0.604	NaN	NaN
Spacing	2	393.74	196.868	47.6095	0.001625 **
Ea	4	16.54	4.135	NaN	NaN
Age	3	128.00	42.668	14.0482	5.801e-05 ***
Spacing:Age	6	71.18	11.863	3.9058	0.011287 *
Eb	18	54.67	3.037	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance and * indicates 10% level of significance

Appendix 15.Mean square from ANOVA for the effect of the treatments on the thousand-grain weight of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	0.326	0.1632	NaN	NaN
Spacing	2	44.842	22.4209	62.7549	0.0009539 ***
Ea	4	1.429	0.3573	NaN	NaN
Age	3	9.278	3.0927	4.6614	0.0140015 *
Spacing:Age	6	6.583	1.0972	1.6537	0.1899819
Eb	18	11.943	0.6635	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance

Appendix 16. Mean square from ANOVA for the effect of the treatments on the grain yield of Chaite-5 at Bardiya, Nepal, 2022

Source	Df	Sum of Square	Mean Square	F value	Pr(>F)
Replication	2	2522	1261	NaN	NaN
Spacing	2	511375	255688	130.0106	0.0002295 ***
Ea	4	7867	1967	NaN	NaN
Age	3	370746	123582	37.5491	5.9e-08 ***
Spacing:Age	6	144288	24048	7.3067	0.0004499 ***
Eb	18	59242	3291	NaN	NaN

Note: Ea means Error of factor a and Eb means Error of factor b, NaN means No any Number *** indicates 1 % level of significance ** indicates 5% level of significance, and * indicates 10% level of significance