EFFECT OF NUMBER OF SEEDLINGS PER HILL ON PERFORMANCE AND YIELD OF SPRING RICE (*Oryza sativa* L.) IN PANCHAKANYA, NUWAKOT

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF NUMBER OF SEEDLINGS PER HILL ON PERFORMANCE AND YIELD OF SPRING RICE IN PANCHAKANYA, NUWAKOT"** submitted in the partial fulfillment for the Bachelor of Science in Agriculture of Undergraduate Program, Agriculture and Forestry University, Rampur, Chitwan is a record of original research carried out by Mr. Rochak Niraula, Regd. No.: 1-1-114-2017, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

Prof. Dr. Arvind Srivastava
Chairman of the advisory committee
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The thesis attached hereto, entitled "**EFFECT OF NUMBER OF SEEDLINGS PER HILL ON PERFORMANCE AND YIELD OF SPRING RICE IN PANCHAKANYA, NUWAKOT**" prepared and submitted by Mr. **ROCHAK NIRAULA**, in partial fulfillment of the requirements for the degree of Bachelor of Science in Agriculture, is here by accepted.

Prof. Dr. Arvind Srivastava
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Rochak Niraula

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ACRONYMS AND ABBREVIATIONS

%	Percentage
^0C	Degree Celsius
AFU	Agriculture and Forestry University
AGDP	Agriculture Gross Domestic Product
ANOVA	Analysis of Variance
CBS	Central Bureau of Statistics
CDD	Crop Development Directorate
cm	Centimeter
CV	Coefficient of Variation
DADO	District Agriculture Development Office
DAP	Diammonium Phosphate
DAT	Days After Transplantation
FAO	Food and Agriculture Organization
FAOSTAT	Statistics of Food and Agriculture
GDP	Gross Domestic Product
ha	Hectare
HI	Harvest Index
INGO	International Non-Governmental Organization
Kcal	Kilo Calorie
kg	Kilogram
LSD	Least Significant Differences
m	Meter
m^2	Meter square
masl	Meter Above Sea Lev
MoALD	Ministry of Agriculture and Livestock Development

MOP	Muriate of Potash
Ms	Microsoft
mt/ha	Metric ton per Hectare
NGO	Non-Governmental Organization
No.	Number
NRs	Nepali Rupees
PIU	Program Implementation Unit
PMAMP	Prime Minister Agricultural Modernization Project
RCBD	Randomized Complete Block Design
sq.Km	Square Kilometer
TGW	Thousand Grain Weight
t/ha	Ton per Hectare
USDA	United States Department of Agriculture
WFP	World Food Program

ABSTRACT

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In spite of realization of spring rice's profitability over main season rice, farmers are quite unaware about the appropriate agronomic practices to gain maximum benefit. In this context, a field study was conducted to know the effect of number of seedlings hill^{-1} on performance and yield of spring rice from March to July 2022 at Panchakanya rural municipality, Nuwakot, Nepal. The experiment was conducted in randomized complete block design comprising four treatments viz., two, three, four and five seedlings hill^{-1} with five replications. Chaite-5 variety of rice was used for the experiment with individual plot size of 3m*2m (6m^2). Seedlings were grown in a wet seed bed and seedling thus prepared were transplanted as per the treatment at the spacing of 20cm*20cm on a well-prepared field. Observations on growth parameters like plant height, number of tillers per meter square and yield parameters like effective tillers per meter square, panicle length, filled grains per panicle, sterility percentage, thousand grain weight and grain yield, straw yield and Harvest Index were recorded. Data was entered and tabulated using MS-Excel while Analysis of variation and mean separation was done using R-Studio. The effect of number of seedlings hill^{-1} on yield and most of the yield attributing characters was found to be significant except for sterility percentage and thousand grain weight. Two seedlings hill^{-1} had the highest plant height (94.78 cm), highest tiller per meter square (358.75), effective tiller per meter square (303.75), panicle length (24.27 cm) and number of filled grains per panicle (120.43). Grain yield and straw yield (6.57 t/ha and 10.18 t/ha) were also highest at two seedlings per hill. Economic parameters like production cost, gross return, net return and B:C ratio varied significantly with number of seedlings hill^{-1}. Highest production cost (74.36 thousand NRs. ha^{-1}) incurred at five seedlings hill^{-1} and gross return (177.39 thousand NRs. ha^{-1}), net return (105.67 thousand NRs. ha^{-1}) and benefit:cost ratio (2.47) was highest at two seedlings hill^{-1}.

Prof. Arvind Srivastava, PhD
Major supervisor

Rochak Niraula
Author

1. INTRODUCTION

1.1 Background Information

Agriculture is the major sector of Nepalese economy and it contributes 26.5% to the national GDP (MoALD, 2021). Approximately 60% of the population is involved in agriculture for their livelihood (CBS, 2014). The total cultivated agricultural land in the present context is 30, 91,000 ha and total uncultivated agricultural land is 10, 30,000 ha representing 21% and 7% of total land area of Nepal respectively (MoALD, 2021). Due to the availability of diverse agro ecologies, Nepal has great potentiality to grow variety of commodities within different geographical locations. Nepalese agriculture is dominated by cereal crops. Rice, maize and wheat constitute more than 80% of cereal area coverage and production.

Rice (*Oryza sativa L.*) is annual self-pollinated and semiaquatic staple food grain crop for more than 60% of the world's population, of which 95% is produced and consumed in Asia (Alam, 2009). It is the most important food crop of the world and the staple food of more than half of the world's population (Muthayya, Sugimoto, Montgomery, & Maberly, 2014). Rice is the world's second most important cereal crop following only corn. Nearly 510 million metric tons of milled rice were produced in the last harvesting year worldwide (Statista, 2022). Traditionally, countries in Asia have the largest share in world rice production. In the fiscal year 2019/20, the total land under rice cultivation is 164 million ha with production of 757 million tons and productivity of 4.6 t/ha (FAOSTAT, 2020) globally. Over 90% of the world's rice is produced and consumed in Asia. Total global consumption of milled rice amounted to approximately 502.4 million metric tons in 2020/2021 (Statista,2022). The top rice producing countries are China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, Philippines and Japan. It accounts for 30-50% of agricultural income and provides about 50-80% of total calories consumed by Asian people (Hossain, 1995).

Rice occupies first place in terms of area coverage, production, productivity and preferences in Nepal and it covers about 50.56% of cultivated area (MoALD, 2021). In the fiscal year 2077/78, the total area coverage is 1,473,474 ha with production of 5,621,710 metric ton and productivity of 3.82 mt/ha (MoALD, 2021). More than 1,700 rice landraces are reported to be cultivated in Nepal from 60 m to 3,500 m altitude (Mallick, 1981). In Nepal, rice is grown almost in all the districts except the rain shadow area in Manang and Mustang and is cultivated from about only 67 masl (Kechanakawal, Jhapa) to Chhhumjul of Jumla, the world's highest place at an elevation of 3,050 masl (Paudel, 2013). Rice is cultivated for three seasons in Nepal, main season rice (*barkhe dhan),* boro rice or winter season rice and spring season rice (*chaite dhan).* Main season rice has broader coverage as compared to other rice because of availability of rainfall however the productivity of the crop is higher in spring season. In the fiscal year 2077/78, the productivity of spring rice is 4.66 mt/ha while that of main season rice is 3.74 mt/ha only (MoALD, 2021).

The productivity of rice in Nepal is 3.82 ton/ha which is lesser than the world average productivity of 4.6 ton/ha (FAOSTAT, 2020). It shows that there is immense potentiality to increase the rice productivity and total production in Nepal. Despite the importance of rice in national food security and economy, still it is grown under rain-fed conditions in more than 30% of total rice area. Due to lack of all year-round irrigation facilities, majority of rice area is still under rain-fed conditions (Tripathi, Mahato, Yadaw, Sah, & Adhikari, 2012). Success of paddy production depends upon monsoon rains in Nepal. Rice production is facing serious constraints including a declining rate of growth in yields, depletion of natural resources, labor shortages, fallow land, gender based conflicts, institutional limitations and environmental pollutions (Singh Basnet, 2017). Drought, flooding, and insect pests and diseases are major biotic and abiotic factors hindering the optimum rice production in Nepal (CDD, 2015). Still, most rice growers are unaware about proper cultivation practice of using appropriate seed rate and spacing, balanced fertilizer, proper plant density and so on. Generally, farmers use more than 60 kg of seeds/ha, transplant very old seedlings (30-45 days old), plant many seedlings, 8-10 $hill^{-1}$ and made unwise use of chemical fertilizer in conventional system of rice transplanting (Uprety, 2005).

Nuwakot district a part of Bagmati Province, is one of the agriculturally significant districts of Nepal. The district, with Bidur as its district headquarters, covers an area of 1,121 km^2 (433 sq mi) and had a population of 288,478 in 2001 and 277,471 in 2011. It is also a historically important district in Nepal. The altitude ranges from 457 masl to 5144 masl. Nuwakot comprises of total cultivated area of 45,242 ha with staggering 95.2% of the people involved in agriculture (PMAMP, 2078). In the fiscal year 2077/78, rice is grown over 17,098 ha area coverage and total production is 69,411 metric tons with yield of 4.06 mt/ha in the district (MoALD, 2021). Moreover, Panchankanya is one of the potential areas for high rice production of the district due to the varying altitudes and climates spread throughout the area contributing directly and indirectly for multiple varieties of rice production. This area is fully irrigated through Likhu River Irrigation Project. Spring rice is successfully adopted in this area in the last five years with the availability of irrigation.

1.2 Statement of Problem

The development of nation is paced by agricultural development and rice is the most important sub-sector of agriculture in Nepal. Until early 1980s, Nepal used to export rice to India but with time the country has struggled for self-sufficiency. The country which used to export rice in the past, now imports about one million ton of milled rice every year (Tripathi, Bhandari, & Ladha, 2019). According to the Ministry of Agriculture and Livestock Development, the import of fine and aromatic rice makes up 70 percent in the import chart and high-class people and hotels are the users of these varieties of rice products. Data shows that Nepal imported 5, 89,056 tons of rice (milled only) worth 249 million US$ in the year 2020 (FAOSTAT, 2020). The population of Nepal is projected to be 33 million by 2031 A.D. The current domestic production rate is far lower than the demand. Rice productivity was forecasted to be increased in decreasing trend from 2018 to 2030 so, the productivity increment was found crucial to meet the ever-growing demand of rice (G.C & Yeo, 2020). Different future projections show a persistent shortfall in the domestic production of rice in Nepal to meet the total demand. Under the optimistic scenario, production deficit of 41% is forecasted by International Food Policy Research Institute (IFPRI) in the year 2030. Out of ten consecutive years, Nepal saw highest production of rice in the fiscal year 2020/21 at 5.621 million metric tons. Rice was planted across 1,473,478 hectares of land. But the same year Nepal has imported rice worth Rs 45 billion. The arable land and pocket areas for paddy cultivation have been continuously diminishing since the fiscal year 2003/04, the Ministry's data shows. Paddy cultivation done across 1,477,378 hectares land in 2003/04 shrunk to 82,058 hectares over 19 years. (MoALD, 2021). The national average yield of rice is less than its potential yield, for which poor agronomic management and changing climatic conditions have been reported to be critical factors. Spring rice possesses huge scope and potentiality for the substitution of import and fulfilling the increasing demand of rice. In the fiscal year 2077/78 spring rice was cultivated in 1,22,615 ha area with total production of 5,71,392 metric tons and productivity of 4.66 mt/ha in Nepal (MoALD, 2021). Despite having higher productivity than main season rice, spring rice cultivation is limited to small area due to unavailability of irrigation facility in Nepal. Along with main season rice, farmers of Panchakanya are attracted towards the cultivation of early season rice as well. The previous variety of spring rice Taichung Native which was widely cultivated here didn’t bear much economic returns as farmers would have wanted. Most of the growers are still unaware about the proper agronomic management practice for this newly introduced variety Chaite-5 (a fine aromatic rice variety), of which the seedling density per hill is a crucial factor. Excessive no. of seedlings per hill results higher tiller population but it increases the interplant competition and leads to mutual shading, lodging and production of more straw instead of grain. On the other hand, least no. of seedlings per hill may produce insufficient tiller, keeping space and nutrients unutilized resulting lower no. of panicles per unit area and ultimately the poor yield (Miah et al., 2004).

1.3 Rationale of study

Rice is a major base for economy of Nepal and it provides employment, income and food security to many rural households. Panchakanya rural municipality of Nuwakot district possess huge scope and opportunities not only for main season rice but also for spring rice production which has framed the economic base of this area. Spring rice is not new for this area and it has been widely used with variety like Taichung Native. But the economic returns that the farmers here have expected from spring rice hasn't been met by the older variety. Hence, the switch to newer variety has been even more essential from economic stand of view. The productivity of spring rice is reported to be higher than main season rice though the expected production is yet to be met. There is huge gap between the expected and actual production which can be minimized through proper agronomic management practice of farming. Rice growers of the study area are unknown about the appropriate seedling density per hill for optimum yield in their region. For promoting high grain production with proper utilization of resources, knowledge of seedling density per hill is must. Optimum seedlings hill^{-1} leads to the proper growth of plants both in aerial and underground parts by proper utilization of nutrients, solar energy, space and moisture and also reduce seedling costs to farmers (Azad, 2004). Seedling density hill^{-1} is an important factor affecting tiller population per unit area which ultimately influences the yield (Bhowmik, Sarkar, & Zaman, 2012). Generally, if single seedling per hill is used then there is chance of missing hills and if more than optimum seedlings hill^{-1} is used then there will be misuse of seedlings (Barua, Islam, Zahan, Paul, & Shamsunnaher, 2014). If fewer seedling hill^{-1} is used, the probable yield cannot be realized and if extra seedlings is used it might not be cost effective (Gurjar, Swami, & Meena, 2018). Plenty of researches have been already carried out to study rate of seedlings mainly focusing for rainy season rice. Since, the ecology and growing environment of spring season rice is completely different, a trial for evaluating number of seedlings per hill in case of spring rice is quite essential. Therefore, the present study was undertaken to evaluate effect of different seedling density $hill^{-1}$ on performance and yield of spring rice.

1.4 Objectives

1.4.1 Broad Objective

- To enhance the productivity of spring rice through proper management of seedling density $hill^{-1}$ at Panchakanya, Nuwakot, Nepal.

1.4.2 Specific Objectives

- To compare the effect of varying seedling density $hill^{-1}$ on the yield and yield attributing characters of spring rice Chaite-5.
- To compare the economics associated with different seedling density $hill^{-1}$ of spring rice

2. REVIEW OF LITERATURE

Rice is one of the important food crop cultivated worldwide. It is widely cultivated in Asian country and it contributes around 11.30% to AGDP of Nepal (MoALD, 2021). Rice is associated not only with national economy but also with cultural, religious and traditional values of the society. It forms an integral part in rituals of Hindu people from birth to death (CDD, 2015). Despite its importance in national economy, various factors are affecting its production and productivity. Poor agronomic management, change in climatic parameters, diseases and pests are some of the major constraints affecting the production and yield of rice in Nepal.

2.1 Rice: An important food crop

Rice (*Oryza sativa* L.) is an annual, self-pollinated and semi aquatic plant of Poaceae family. The plants are about 1m tall but certain deep water varieties can elongate up to 5m. Rice has a fibrous root system and the stem, known as culm, is hollow comprised of nodes and internodes. Each node bears a leaf and bud, which may grow into a shoot or tiller. Primary tillers grow out of the main culm. Panicles bearing tillers are known as fertile or productive tillers. Paddy is grown in wide range of soil but clayey loam soil is best with pH ranging from 5.0 to 8.0. The optimum temperature ranges from 20℃ to 27℃ whereas below 15℃ germination cannot take place. Paddy requires more water than any other crop and its cultivation is done in areas where minimum rainfall is 115 cm. Although region having average rainfall between 175-300 cm are most suitable.

Rice is the most important strategic crop for nutrition and food security in Nepal. It contributes more than 50% of the total calories required by Nepalese people. From nutritional point of view, it accounts for 715 kcal/capita/day, 27% of dietary energy and 20% of protein and 3% of dietary fat (FAO, 1999). Rice is a good source of B vitamins, thiamine, riboflavin and niacin but contains little to no vitamin C, D or beta-carotene. The nutrient content depends upon various factors like growing conditions, varieties, season, harvesting stage and post-harvest losses like milling, parboiling, storage, washing, cooking and so on. Along with main product bi-products straw, bran, husk etc. are also equally important for various purposes especially for livestock.

2.2 National scenario of rice production

Nepal is one of the major rice producing country in the world. Nepal ranks 17th in rice production and 64th in rice productivity in the world (FAOSTAT, 2020). The arable land and pocket areas for paddy cultivation have been continuously diminishing since the fiscal year 2003/04, the Ministry's data shows. Paddy cultivation done across 1,477,378 hectares land in 2003/04 shrunk to 82,058 hectares over 19 years (MoALD, 2021).

Table 1: Area, Production and Productivity of Rice in Nepal

S. N	Fiscal Year	Area (ha)	Production (mt)	Productivity (mt/ha)
1	2009/10	14,81,289	40,23,823	2.72
2	2010/11	14,96,476	44,60,278	2.98
3	2011/12	15,31,493	50,72,248	3.31
4	2012/13	14,20,570	45,04,503	3.17
5	2013/14	14,86,951	50,47,047	3.39
6	2014/15	14,25,346	47,88,612	3.36
7	2015/16	13,62,908	42,99,079	3.15
8	2016/17	15,52,469	52,30,327	3.37
9	2017/18	14,69,545	51,51,925	3.51
10	2018/19	14,91,744	56,10,011	3.76
11	2019/20	14,58,915	55,50,878	3.80
12	2020/21	14,73,474	56,21,710	3.82

Source: (MoALD, 2021)

2.3 Rice production scenario in Nuwakot

Nuwakot is one of the major districts regarding rice production in Nepal. The following table shows the area, production and productivity of rice in Nuwakot:

Table 2**:** Area, Production and Productivity of Rice in Nuwakot

S.N	Fiscal Year	Area (ha)	Production (mt)	Productivity (mt/ha)
1	2014/15	15,692	73,762	4.70
2	2015/16	15,695	62,627	3.99
3	2016/17	17,892	73,668	4.12
4	2017/18	16,936	72,564	4.28
5	2018/19	16,678	72,049	4.32
6	2019/20	16,129	70,535	4.37
7	2020/21	17,098	69,411	4.06

Source: (MoALD, 2021)

2.4 Spring rice trend in Nuwakot

Nuwakot is an important district in terms of spring rice production. The initiation of Rice zone from this year (2020/21) onwards will prove to be a huge boost in overall rice production in the district. The area covered by, production and productivity of spring rice over Nuwakot are presented in a table below:

Table 3: Area, Production and Productivity of Spring Rice in Nuwakot

S. N	Fiscal Year	Area(ha)	Production(ton)	Productivity(t/ha)
1	2075/76	5066	22,696	4.48
2	2076/77	4865	21,987	4.12
3	2077/78	5486	22,383	4.08

Source: (PMAMP, 2078)

2.5 Seedlings hill^{-1} and its effect on growth and yield parameters

No. of seedling hill^{-1} is an important agronomic factor that has significant effect upon growth pattern of rice. It influences crop geometry and ultimate yield of transplanted rice. Number of productive tillers and their proper growth both quantitative and qualitative are influenced by no. of seedling per hill. Therefore, it is important to transplant appropriate no. of seedlings hill^{-1} to get optimum yield. The various researches conducted on effect of seedling density hill^{-1} on growth and yield attributing characters of transplanted rice have been discussed in this sub-section.

2.5.1 Effect on plant height

It was evident that the no. of seedling hill^{-1} affects the plant height and it was highest (91.60 cm) for one seedling hill^{-1} and lowest (88.0 cm) for four seedlings hill^{-1} in a field experiment conducted in Bangladesh. The decrease in plant height with increase in no. of seedlings was due to interplant competition for space, nutrients and light (Islam, Akhter, Rahman, Banu, & Khalequzzaman, 2008). Pariyani and Naik (2004) reported from Jabalpur in their experiment that planting of 1 or 2 seedlings hill^{-1} did not show any signifiant differences in plant height in hybrid rice 'PA 6201' and 'PAC 801'. Ashraf, Khalid and Ali (1999) reported transplanting of two or three seedlings hill^{-1} resulted taller plants compared to those of one and four seedlings hill^{-1}. Channabasappa (1998) reported from Karnataka that the tallest plants were obtained from 4 to 5 seedlings hill^{-1} compared to those of 2 to 3 and 6 to 7 seedlings hill^{-1}. Zhang and Hung (1990) reported from China, that there was significant increase in the plant height due to increase in number of seedlings from one to five. Five seedlings hill^{-1} recorded significantly more plant height (84.4cm) than the 1 seedling hill^{-1} (79.0cm), 2 seedlings hill^{-1} (82.2cm), 3 seedlings hill^{-1} (81.8 cm) and 4 seedlings hill^{-1} (80.4cm).

2.5.2 Effect on tillers m^{-2}

Transplanting of 5 seedlings hill^{-1} produced significantly more tillers m^{-2} followed by 3 seedlings hill^{-1} and 1 seedling hill^{-1}. The greater number of tillers m^{-2} in high density might be due to high number of plants m^{-2} (Vijayalaxmi, Sreenivas, Leela, & Madhavi, 2016). However, in less density planting total tillers per plant increased but the tillers m^{-2} is less due to lower initial plant population (Yadav, 2007). Molla (2001) conducted a field experiment at West Bengal with rice hybrids 'PA 6201' and 'CNRH 3' reported that 2 seedlings hill^{-1} produced significantly higher number of tillers per m^{-2} as compared to 1 seedlings hill^{-1}. Siddhu, Agrawal and Singh (1988) found that rice crop transplanted with 2 seedlings hill^{-1} produced higher number of tillers as compared to 1 seedling hill^{-1}. Similarly, the number of tillers m^{-2} increased with number of seedlings hill^{-1} and found to be highest for 5 seedlings hill^{-1} and lowest for 2 seedlings hill^{-1} (Bhowmik, Sarkar, & Zaman, 2012). In contrast, Reddy and Mitra (1984) observed that tiller number m^{-2} decreased with more than 2 seedlings hill^{-1} when planted.

2.5.3 Effect on yield and yield attributing characters

Srivastav and Tripathi (1998) reported that crop transplanted with 2 seedlings hill^{-1} produced significantly more effective tillers per m^{-2} (316) as compared to 1 seedlings hill^{-1} (308) and 3 seedlings hill^{-1} (309). In an experiment conducted in Bangladesh, the effective tiller per hill was found to be increased up to three seedlings per hill and then it decreased. The length of panicle was not affected whereas the no. of grains per panicle increased with increase in no. of seedlings up to three seedlings hill^{-1}. Further, the experiment concluded that the grain yield increased up to three seedlings hill^{-1} (4.07 t/ha) which was similar with four seedlings hill^{-1} (Islam, Akhter, Rahman, Banu, & Khalequzzaman, 2008).

Ashraf, Khalid and Ali (1999) reported transplanting of two or three seedlings per hill gave more convincing results compared to those of one and four seedlings per hill. Specifically, the experiment showed that maximum increase in plant height, grain and straw yield with two seedlings per whereas more no. of productive tillers were reported with three seedlings per hill.

Bhowmik, Sarkar and Zaman (2012) conducted an experiment to study the effect of spacing and no. of seedling per hill on cv. rice NERICA in Bangladesh. A substantial difference in yield and performance was noted between different no. of seedlings viz. two, three, four and five per hill. The height of plant was noted to be decreased with increase in no. of seedlings per hill and was shortest for five seedlings per hill. In was reported that the total no. of tillers per m^2, effective tillers per m^2 and grains per panicle were highest for five seedlings per hill and lowest for two seedlings per hill. The highest grain yield (3.05 t/ha) was obtained from five seedlings per hill which was due to highest no. of effective tillers per unit area and highest no. of grains per panicle. Lowest grain yield (2.19 t/ha) was obtained with two seedlings per hill because of lowest number of effective tillers per unit area and lowest no. of grains per panicle. The highest biological yield (6.63 t/ha) and harvest index (45.93%) were obtained with five seedlings per hill. The thousand grain weight was not significantly affected by no. of seedlings per hill.

In an experiment conducted at University of Rajshahi, Bangladesh during kharif season to study the effect of variety, spacing and no. of seedling per hill on the yield potential of transplanted aman rice, effect of no. of seedling per hill was found to be signifcant on almost all the yield attributing parameters. Out of four levels of seedlings per hill viz. two, three, four and five, the tallest plant (111.91 cm) was obtained from two seedlings per hill and shortest one (108.13 cm) was obtained from five seedlimgs per hill which was statistically identical with four seedlings per hill. The no. of total tillers increased with increase in no. of seedlings per hill and was highest (12.13) for five seedlings per hill and lowest (9.79) with two seedlings per hill. There was no significant difference in effective tillers per hill while panicle length was significantly affected with no. of seedlings per hill and was highest (24.40 cm) with two seedlings per hill and lowest (22.76 cm) with five seedlings per hill. Grain yield was maximum (5.78 t/ha) for two seedlings per hill and minimum (5.26 t/ha) was obtained with five seedlings per hill (Alam, Baki, Sultana, Ali, & Islam, 2012).

A field experiment was carried out to study the effect of age and density of seedling per hill on yield of short duration aman rice with three levels of no. of seedlings (one, two and three) per hill. The tallest plant (115.4 cm) was observed from two seedlings per hill and shortest (114.8 cm) from three seedlings per hill.The experiment showed highest no. of effective tillers per hill (9.86) from two seedlings per hill and lowest one (7.04) from one seedling per hill. The highest no. of grains per panicle (114.4) was obtained with two seedlings per hill and lowest one (109.6) with one seedling per hill. Grain yield was highest (3.91 t/ha) with two seedlings per hil and lowest (3.63 t/ha) with one seedling per hill. All the yield parameters except thousand grain weight and panicle length was influenced by no. of seedlings per hill (Faruk, Rahman, & Hasan, 2009).

A study conducted at Lahijan, Iran revealed that highest grain yield (3526 kg/ha) was recorded with three seedlings per hill out of three levels of seedling per hill viz. one, three and five. Comparision of mean between no. of seedlings per hill showed highest grains per panicle (87.67) with three seedlings per hill and lowest one (80.89) with one seedling per hill. The maximum amount of straw yield (4837 kg/ha), biological yield (8163 kg/ha) and no. of tillers per m^2 (276.7) was recorded from five seedligs per hill wherease minimum values of these traits respectively with 4408kg/ha, 7533kg/ha and 217.4 was recorded from one seedling per hill (Bozorgi, Farajit, Danesh, Keshavaraj, Azarpour, & Tarighi, 2011).

In trials conducted on different boro rice varieties to find the effect of seedling density, significant results were obtained for almost all the yield attributing characters and yield. Out of four levels of seedlings per hill viz. one, two, three and four; the maximum effective tillers per hill (13.2) obtained from two seedlings per hill while minimum (9.0) was obtained from four seedlings per hill. The highest grain yield (6.63 t/ha) and biological yield (14.34 t/ha) was obtained from two seedlings oer hill and minimum grain yield (5.15 t/ha) and biological yield (13.01 t/ha) were obtained from four seedlings per hill (Masum, Ali, Hasanuzzaman, Chowdhury, Mandal, & Jerin, 2014).

In an experiment consisting of six levels of seedlings per hill i.e. one, three, five, seven, nine and eleven to study the performance of rice in a saline-sodic soil, it was revealed that plant biomass increased from one to seven seedlings per hill and was invariable from nine to eleven seedlings per hill during the growing season. The experiment showed increased grain yield from one to nine seedlings per hill and then levelled off (Wang, Liang, Yang, Ma, Huang, & Liu, 2010).

An experiment was carried out to find out the effect of three plant densities (1, 3 and 5 seedlings per hill) on the yield of different aged seedlings. The results revealed that five seedlings per hill produced highest grain yield (5817 kg/ha) and straw yield (7140 kg/ha) over one and three seedlings per hill (Vijayalaxmi, Sreenivas, Leela, & Madhavi, 2016). Mahamud, Haque, & Hasanuzzaman (2013), in their experiment revealed that single seedling per hill produced highest grain yield (4.20 t/ha) over two and three seedlings per hill.

Ninad, Bahadur, Hasan, Alam and Rana (2017) in their experiment reported higher effective tillers hill^{-1} (21.87), longest paniicle length (24.40 cm), higher grains per panicle (117.38), TGW (24.2 gm), grain yield (2.98 t/ha), straw yield (3.61 t/ha) and HI (47.12%) all at four seedlings hill^{-1} over one seedling and two seedlings hill^{-1}. Thawait, Patel, Kar, Sharma and Meshram (2014) reported from Raipur, India that the treatment combination having 2-3 seedlings per hill recorded highest yield attributing parameters along with highest grain yield (38.20 quintal ha^{-1}) and straw yield (77.91 quintal ha^{-1}). Ehsanullah, Jabran, Asghar, Hussain and Rafiq (2012) from Faisalabad, Pakishtan reported that rice transplanted at the treatment combinations having two seedlings hill^{-1} resulted maximum grain yield. Mamun, Sarkar and Uddin (2010) in an experiment reported highest number of effective tillers hill^{-1} (12.41), weight of 1000 grains (11.83 gm), grain yield (3.30 t/ha), biological yield (6.35 t/ha) and harvest index (51.79%) in 4 seedlings hill^{-1} over two and six seedlings hill^{-1}. Ahmad and Hasanuzzaman (2012) reported that the highest grain yield (497 gm m^{-2}) was in the treatment combination of two seedlings hill^{-1}.

A field experiment was conducted to investigate the effects of cultivation density and seedling age on agronomic traits and grain yield of mechanically transplanted rice in China. Its result suggested that the increase in cultivation density could effectively compensate for rice grain yield loss resulting from delayed transplantation. Additionally, it was found that with increasing seedling age or cultivation density, the significant reduction in grain number per panicle was primarily attributable to the marked decrease in the number of secondary branches per panicle and ultimate reduction in grain yield. (Liu et al., 2017).

3. MATERIALS AND METHODS

3.1 Site Selection

Research was conducted in ward number 2, Kabilas of Panchakanya, Nuwakot, Nepal in the farmers field of Mrs. Sulochana Gajurel which is under the command of Rice zone. Kabilas is geographically located between latitude 27°52'35.8''N and longitude 85°17'01.3''E. The field area is approximately 7630 m^2 but only a small part of it will be used for my research purpose.

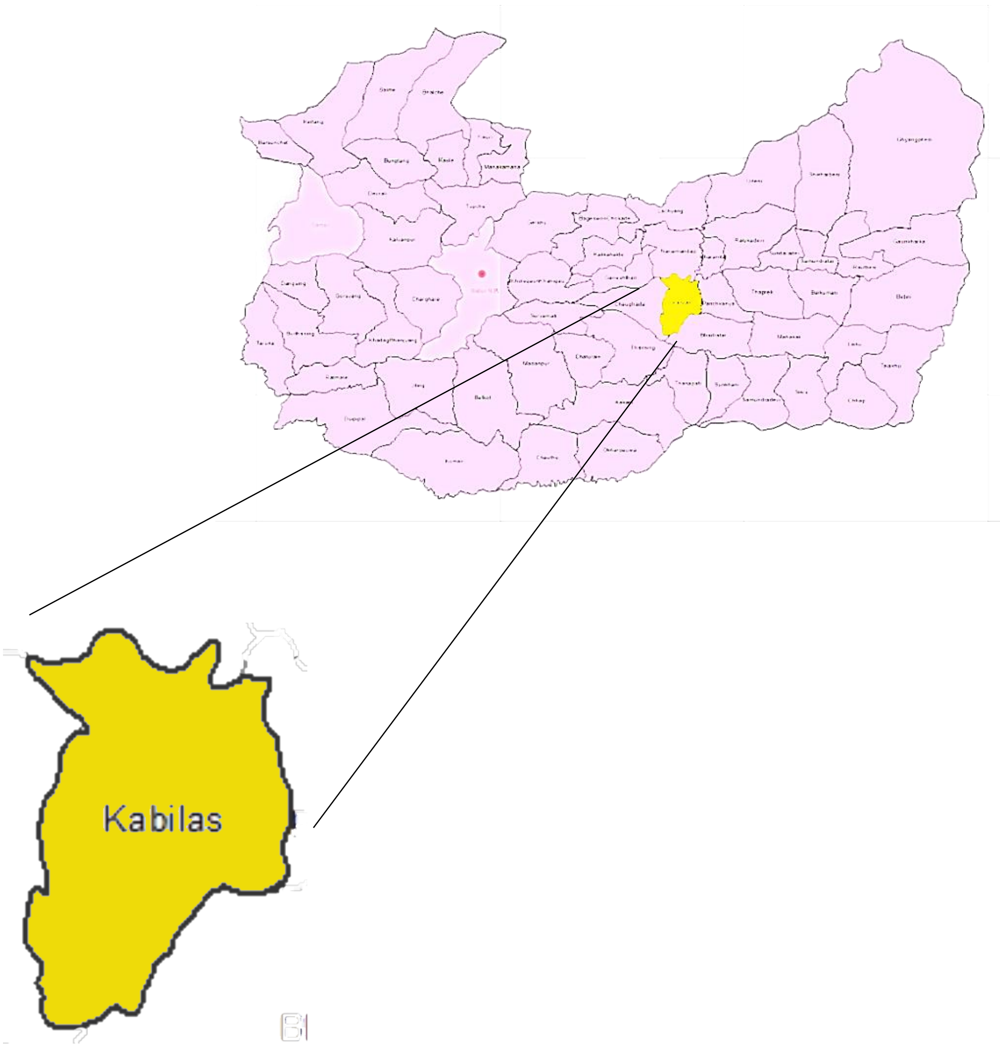

Figure 1: Map showing Nuwakot district and research site

3.2 Weather Condition

The research site lies in the sub-tropical climatic region. The research site is characterized with three distinctive seasons i.e., spring summer (March-May), rainy (June- September) and winter

(November- February). The research was conducted during spring season and the weather-related data were retrieved from online weather website.

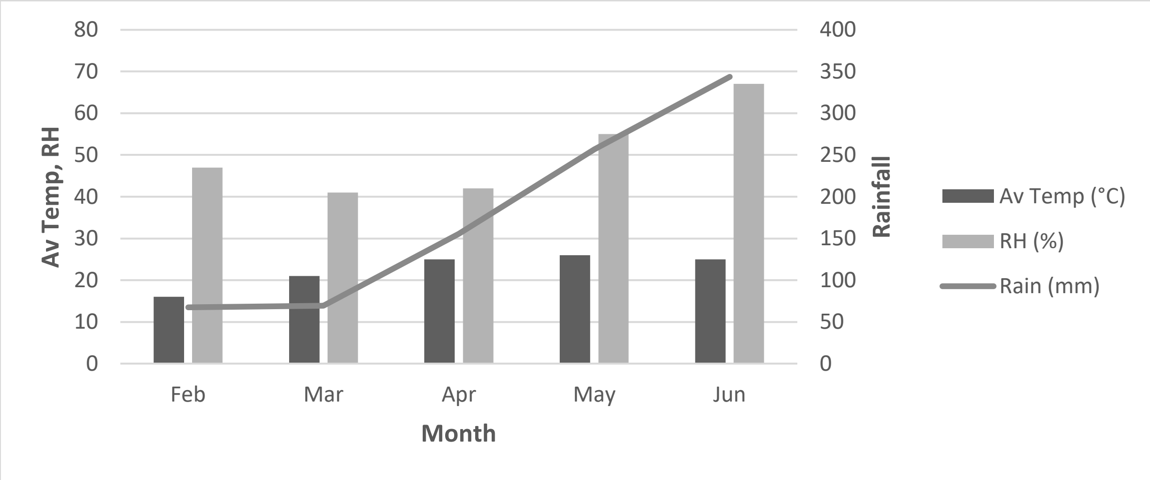

Figure 2: Diagram showing monthly mean temp, RH and rainfall of Nuwakot during research period (month), 2022 Source: worldweatheronline.com

3.3 Crop Variety

Chaite-5 variety of rice was planted in research field. It was released in Nepal by NARC in 2018. It is spring season rice with crop duration of 120-125 days and yield potential of 4.6 t/ha. The domain of this variety is terai, inner terai and river basin up to 700 masl.

3.4 Experimental details

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four treatments and five replications. Four different seedling densities viz. two, three, four and five per hill were tested in the field.

Table 4: Different treatments and their symbols

No. of seedling per hill	Treatment Symbols
1	T1
2	T2
3	T3
4	T4

Table 5: Experimental details

Variety	Chaite-5
Design	RCBD
Treatment	4
Replication	5
Border	1m
Spacing between plot	1m
Spacing between replication	1m
Plot size	3m × 2m

R1	T3	T4	T2	T1
R2	T2	T4	T1	T3
R3	T1	T2	T3	T4
R4	T2	T3	T4	T1
R5	T4	T2	T1	T3

Figure 3: Layout of experimental field

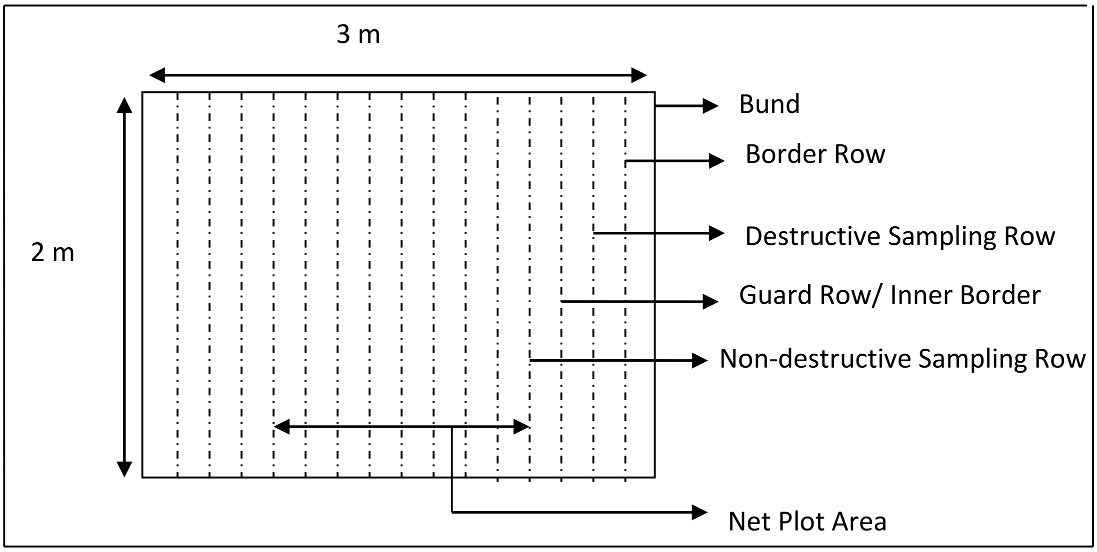

Figure 4: Layout of individual plot

3.5 Agronomic practices

Following agronomic practices were carried out for the proposed research:

3.5.1 Nursery raising

The seedlings were raised on wet bed which was prepared by thorough puddling and ploughing using local plough. The seeds were kept on jute sac for pre germination. The pre germinated seeds were sowed uniformly over the prepared seed bed. The seed bed was kept saturated with water for the first five days and then the water level was gradually increased as seedlings started to grow. Application of urea 50 g per square meter was done to account for nitrogen defieciency symptoms. Irrigation was done from nearby river.

3.5.2 Main field preparation

The field was ploughed two times before sowing using tractor drawn disc plough to make soil loose and friable followed by planking. Weeds and stubbles were removed manually.

3.5.3 Fertilizer application

The recommended dose of nutrient (100:30:30 Kg NPK ha^{-1}) was supplied through the application of urea (46% N), DAP (18% N and 46% P_2O_5) and MOP (60% K_2O). One third of nitrogen and full dose of phosphorus and potash was applied as basal dose at the time of final land preparation. Remaining two-third dose of nitrogen was applied at tillering stage and panicle initiation stage in equal splits.

3.5.4 Seedling transplantation

The seedlings were transplanted manually with the spacing of 20cm × 20cm with no. of seedlings varying from two to five per hill.

3.5.5 Irrigation

The field was irrigated through the canal of nearby Likhu River as per needed.

3.5.6 Weed management

Application of Pretilachlor EC 0.75kg/ha at 8 DAT followed by manual weedings at 40 DAT and 60 DAT were done to maintain the weed population below economic threshold level.

3.5.7 Plant Protection

Appropriate and possible manual and cultural measures were employed through regular field visit and no any chemicals, pesticides were employed during the experiment.

3.5.8 Harvesting and threshing

In experimental field, crops were harvested manually with sickles. The harvested crops were then sun dried for one day and weighted to take biological yield. Threshing was done manually and grains were cleaned by winnowing which were then weighted to get economic yield.

3.6 Observations recorded

The following data related to crop growth and yield parameters were recorded:

3.6.1 Plant height

Plant height of randomly selected ten plants was measured from non-destructive sampling rows (4^{th} row) at an interval of 15 days starting from 30 DAT to 90 DAT. The vertical distance from the base of the main tiller of the selected plants to its top was taken as height and expressed in cm.

3.6.2 Number of tillers per meter square

One-meter row length in 4^{th} row of each plot ($1*100*20=2000$ cm^2) was marked and total no of tillers were counted in that row length. The number of tillers obtained from counting was converted into number of tillers per meter square. The data was collected at an interval of 15 days starting from 30 DAT to 90 DAT.

3.6.3 Number of effective tillers per meter square

The panicle bearing tillers were counted from one-meter row length (4^{th} row) of each plot ($1*100*20=2000cm^2$) just before harvesting and worked out as effective tillers per meter square.

3.6.4 Length of panicle

Length of 20 randomly selected panicles from each plot was recorded. The selection of panicles was done just before harvesting and mean was calculated and average length was expressed in cm.

3.6.5 Total grains per panicle and sterility percentage

The total filled grains were counted from randomly selected 20 panicles (panicle used for determining length). Total unfilled grains per panicle were also counted and sterility percentage was calculated using following formula:

Sterility percent = (Total no. of unfilled grains/ Total no. of grains) × 100

3.6.6 Thousand grain weight

Thousand grains were separated from the bulk of grains of the net plot from each plot and weighed with the help of portable electronic balance to get thousand grain weight.

3.6.7 Grain and straw yield

The crops from net plot area of each plot were harvested for grain and straw yield. The harvested crops were then sun dried for one day and tied as bundles. Then, the harvested crops were threshed manually and cleaned by winnowing. Cleaned grains of each plot were weighed by electronic balance. The moisture percentage of grains of each plot was measured by portable automated moisture meter and finally grain yield was adjusted at 14% moisture level by using formula:

$$\text{Grain yield (kg/ha) at 14\% moisture} = \frac{(100-MC) \times \text{plot yield (kg)} \times 10000\ (m^2)}{(100-14) \times \text{net plot area } (m^2)}$$

Where, MC is the moisture content in percentage of the grains.

The straw yield was obtained by subtracting grain yield from total biomass yield of the net plot.

3.6.8 Harvest Index

Harvest index (HI) was computed by dividing grain yield with the total dry matter yield as per the following formula. To obtain harvest index, grain and straw yield was calculated at same moisture level.

$$\text{HI} = \frac{\text{Grain Yield (Economic Yield)}}{\text{Total biomass yield (grain yield+straw yield)}}$$

3.7 Economic analysis

3.7.1 Production cost

Cost of cultivation was calculated on the basis of local charges for different agro-inputs viz. labor, fertilizer, seeds and other necessary materials.

3.7.2 Gross return

Economic yield (grain + straw) of rice was converted into gross returns (NRs.ha^{-1}) on the basis of local market price.

3.7.3 Net return

It was calculated by subtracting the cost of cultivation from the gross return. In formula:

Net return = gross return (NRs.ha^{-1}) - cost of cultivation (NRs.ha^{-1})

3.7.4 B: C ratio

It was calculated by following formula:

$$\text{B: C ratio} = \frac{\text{Gross return (NRs.per ha)}}{\text{Cost of cultivation (NRs.per ha)}}$$

3.8 Data entry and analysis

All the observed data were properly arranged treatment wise under four replications. After each observation data were properly recorded in MS excel spreadsheet and for further analysis MS excel, analysis of variance, R-studio software were used. Word processing was done through MS word. For graphs, tables, charts and simple statistical analysis MS excel was used. The LSD values were calculated at 5% level of significance.

4. RESULTS AND DISCUSSION

The results obtained during the experiment are analyzed and presented in this section with the help of the tables and figures wherever necessary. The results obtained are discussed with possible reasons and literature support.

4.1 Biometric observations

4.1.1 Plant Height

Table 6: Plant height of spring rice at different DAT as influenced by number of seedlings hill^{-1} in Nuwakot, Nepal, 2022

Treatments	Plant Height (cm)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Two seedlings hill^{-1}	59.22^{a}	74.23^{a}	92.82^{a}	100.82^{a}	104.7^{a}
Three seedling hill^{-1}	60.32^{a}	73.07^{a}	90.00^{b}	97.74^{b}	102^{b}
Four seedlings hill^{-1}	57.76^{a}	71.68^{ab}	88.48^{b}	94.98^{c}	100.84^{b}
Five seedlings hill^{-1}	54.76^{b}	69.26^{b}	86.4^{c}	94.78^{c}	99.01^{c}
SEM (±)	1.01	1.03	0.585	0.53	0.56
LSD (0.05)	2.94***	3.00*	1.70***	1.56***	1.63***
CV (%)	3.68	3.02	1.38	1.16	1.16
Grand Mean	58.01	72.06	89.42	97.08	101.63

Note: DAT, days after transplantation; NS, non-significant; LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test and columns represented with same letter(s) are not significantly different among each other at 5% level of significance. "***": significant at 0.001P level, "**" significant at 0.01P level, "*" significant at 0.05P level

The study revealed that plant height was significantly influenced by number of seedlings hill^{-1}. The average plant height varied from 58.01 cm at 30 DAT to 101.63 cm at 90 DAT. Two seedlings hill^{-1} had highest plant height and five seedlings hill^{-1} had lowest plant height as compared to other in each date of observations.

At 30 DAT, the highest plant height was obtained from three seedlings hill^{-1} (60.32 cm) which was statistically similar with two seedling hill^{-1} (59.22 cm) and four seedlings hill^{-1} (57.76 cm). Lowest plant height was obtained at five seedlings hill^{-1} (54.76 cm).
At 45 DAT, the highest plant height was obtained from two seedlings hill^{-1} (74.23 cm) which was statistically similar with three seedlings hill^{-1} (73.07 cm). Lowest plant height was obtained at five seedlings hill^{-1} (69.26 cm) followed by four seedlings hill^{-1} (71.68 cm).

At 60 DAT, two seedlings hill^{-1} resulted highest plant height (92.82 cm) whereas shortest plant was obtained at five seedlings hill^{-1} (86.4 cm). Plant heights obtained from three seedlings hill^{-1} (90.00 cm) and four seedlings hill^{-1} (88.48 cm) were found to be statistically similar. Similarly, at 75 DAT, highest plant height was obtained on two seedlings hill^{-1} (100.82 cm) and lowest plant height was obtained on five seedlings hill^{-1} (94.78 cm) which was statistically similar with four seedlings hill^{-1} (94.98 cm). At 90 DAT, highest plant height was obtained on two seedlings hill^{-1} (104.7 cm) while lowest height was obtained on five seedlings hill^{-1} (99.01 cm). Plant heights obtained from three seedlings hill^{-1} (102 cm) was found to be statistically similar to four seedlings hill^{-1} (100.84 cm). The data revealed that fewer seedlings number; i.e., two, produced highest plant height and it starts to decrease from three seedlings hill^{-1} and became the shortest one at five seedlings hill^{-1}.

The result is in agreement with the results obtained by Alam et al (2012), who also reported highest plant height on transplanting two seedlings hill^{-1} and lowest with five seedlings hill^{-1}, statistically identical to four seedlings hill^{-1}. Similarly, Bhowmik, Sarkar, & Zaman (2012) also reported similar result with tallest plant at two seedlings hill^{-1} and shortest at five seedlings hill^{-1}. The decrease in plant height with increased number of seedlings hill^{-1} was due to the interplant competition for space, light and nutrients which might acts for attaining lowest plant height at higher seedling density hill^{-1} (Islam, Akhter, Rahman, Banu, & Khalequzzaman, 2008).

4.1.2 Tillers per meter square

Table 7: Tillers per meter square of spring rice at different DAT as influenced by number of seedlings hill^{-1} in Nuwakot, Nepal, 2022

Treatments	Number of tillers per meter square				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Two seedlings hill^{-1}	305.28^{c}	431.28^{a}	528.48^{a}	410.4^{a}	377.28^{a}
Three seedling hill^{-1}	292.89^{d}	379.44^{b}	433.44^{c}	353.52^{c}	318.24^{c}
Four seedlings hill^{-1}	316.28^{b}	385.64^{b}	451.47^{b}	358.74^{c}	311.36^{c}
Five seedlings hill^{-1}	361.54^{a}	436.72^{a}	535.34^{a}	383.75^{b}	333.74^{b}
SEM (±)	3.14	2.92	3.32	2.25	3.02
LSD (0.05)	9.17***	8.51***	9.69***	6.56***	8.80***
CV (%)	2.08	1.51	1.44	1.26	1.90
Grand Mean	319.28	408.24	486.54	375.84	335.7

Note: DAT, days after transplantation; LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test and columns represented with same letter(s) are not significantly different among each other at 5% level of significance. "***": significant at 0.001P level, "**" significant at 0.01P level, "*" significant at 0.05P level

In the study, it was found that the number of tillers per meter square was significantly influenced by number of seedlings hill^{-1} at each observation dates. Number of tillers per meter square increased continuously up to 60 DAT and after that it decreased in all the treatments. This was due to tiller mortality. The mean number of tillers was found to be lowest (319.28) at 30 DAT which increased to maximum (486.54) at 60 DAT and decreased to (335.7) at 90 DAT. Initially, five seedlings hill^{-1} produced higher tillers per unit area (361.54) at 30 DAT, reached maximum (535.34) at 60 DAT and then decreased later. After maximum tillering stage, two seedlings hill^{-1} exceed five seedlings hill^{-1} and produced higher tillers per meter square which might be due to more intra competition in case of five seedlings hill^{-1}.

At 30 DAT, the number of tillers per meter square was highest for five seedlings hill^{-1} (361.54) significantly higher than other treatments followed by four seedlings hill^{-1} (316.28) and two seedlings hill^{-1} (305.28). The lowest number of tillers per meter square was for three seedling hill^{-1} (292.89). At 45 DAT and 60 DAT, highest number of tillers per meter square was for five seedlings hill^{-1} (436.72 and 535.34) which was statistically similar to two seedlings hill^{-1} (431.28 and 528.48) whereas lowest was for three seedlings per hill (379.44 and 433.44) which was statistically similar to four seedlings hill^{-1} (385.64 and 451.47). Similarly, at 75 DAT and 90 DAT, two seedlings hill^{-1} produced highest tillers per meter square (410.4 and 377.28) followed by five seedlings hill^{-1} (383.75 and 333.74) whereas three seedling hill^{-1} produced lowest tillers per meter square (353.52) at 75 DAT which was statistically similar to four seedlings hill^{-1} (358.74). However, at 90 DAT lowest tillers per meter square was obtained from four seedlings hill^{-1} (311.36) which was also statistically similar to three seedlings hill^{-1} (318.24).

4.2 Yield attributing parameters

Table 8: Yield attributes of spring rice as influenced by number of seedlings hill^{-1} in Nuwakot, Nepal, 2022

Treatments	Effective tillers m^{-2}	Panicle length (cm)	Filled grains panicle^{-1}	Sterility %	TGW
Two seedlings hill^{-1}	319.12^{a}	24.312^{a}	120.42^{a}	24.86	21.60
Three seedlings hill^{-1}	278.86^{b}	23.668^{a}	118.64^{a}	26.50	22.36
Four seedlings hill^{-1}	237.52^{d}	22.662^{b}	104.60^{c}	28.52	24.98
Five seedlings hill^{-1}	253.68^{c}	21.456^{c}	112.60^{b}	27.62	23.14
SEM (±)	3.632	0.328	1.587	0.096	0.448
LSD (0.05)	10.58***	0.95***	4.62***	NS	NS
CV (%)	2.82	3.01	2.94	0.79	10.31
Grand Mean	272.29	23.024	114.06	26.87	21.40

Note: TGW: thousand grain weight, NS, non-significant; LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test and columns represented with same letter(s) are not significantly different among each other at 5% level of significance. "***": significant at 0.001P level, "**" significant at 0.01P level, "*" significant at 0.05P level

4.2.1 Effective tillers per meter square

The effect of number of seedlings hill^{-1} on effective tillers m^{-2} was found to be significantly different. The highest number of effective tillers m^{-2} (319.12) was found at two seedlings hill^{-1} followed by three seedlings hill^{-1} (278.86). Higher number of seedlings hill^{-1} viz., four and five, resulted lower effective tillers (237.52 and 253.68). The result is in close conformity with Masum et al (2014) who also reported highest effective tillers with two seedlings hill^{-1} and lowest with four seedlings hill^{-1}. Similar result was obtained by Ehsanullah, Jabran, Asghar, Hussain and Rafiq (2012) in which highest effective tillers was produced from treatment combination having two seedlings hill^{-1}. Transplanting more seedlings hill^{-1} results more non effective tillers production and did not contribute to the yield (Hasanuzzaman, Nahar, Roy, Rahman, Hossain, & Ahmed, 2009).

The correlation between number effective tillers m^{-2} and grain yield was highly significant (r = 0.850***). The coefficient of determination was (R^2 = 0.723) reflecting that 72.3% contribution to the total grain yield was due to number of effective tillers m^{-2} and rest was governed by other factors governing grain yield. (Figure 5).

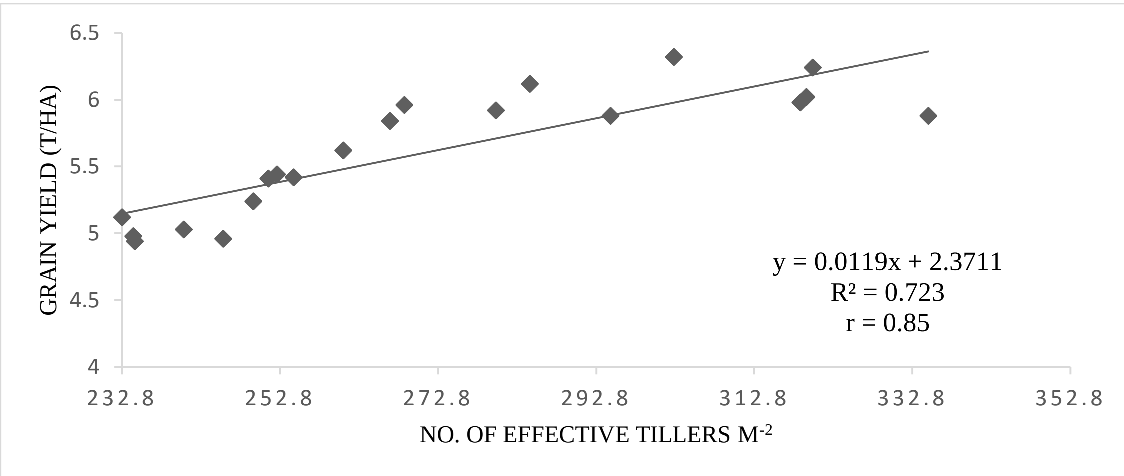

Figure 5: Relationship between effective tillers m^{-2} and grain yield as influenced by number of seedlings hill^{-1} at Panchakanya, Nuwakot, 2022

4.2.2 Panicle length

Panicle length was significantly influenced by the number of seedlings hill^{-1}. The highest panicle length was recorded for two seedlings hill^{-1} (24.31 cm) followed by three seedlings hill^{-1} (23.66 cm), both of which were statistically similar. Similarly, the higher number of seedlings (four and five) hill^{-1} recorded shortest panicle length (22.66 cm and 21.45 cm). Similar results were also observed by Alam, Baki, Sultana, Ali and Islam (2012) and Mamun, Sarkar and Uddin (2010). They also reported the highest panicle length from two seedlings hill^{-1} and decreased thereafter with increased seedlings hill^{-1}.

There was positive correlation (r = 0.62**) between panicle length and grain yield (Figure 6). The coefficient of determination was (R^2 = 0.384) reflecting that 38.4% contribution to the total grain yield was due to panicle length and rest was governed by other factors governing grain yield. (Figure 6).

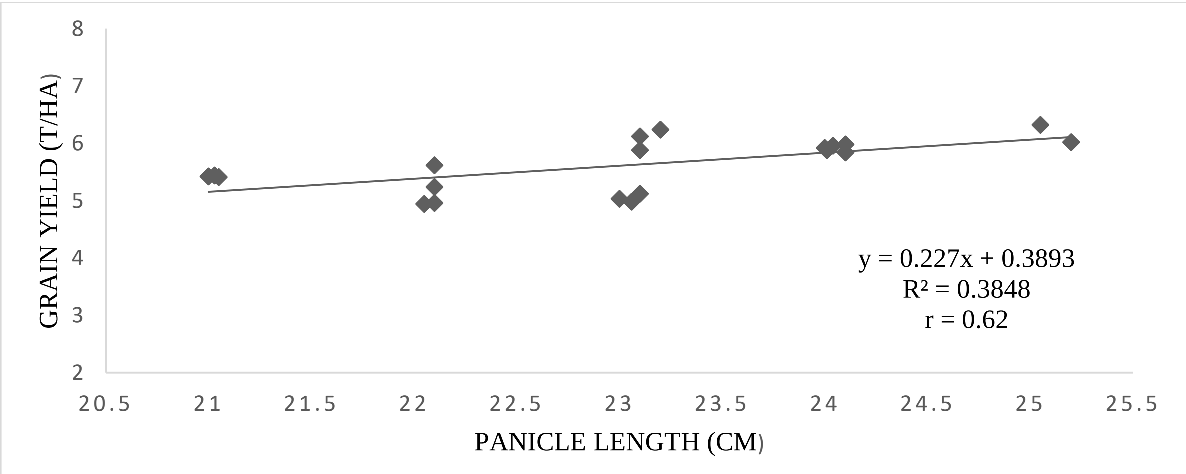

Figure 6: Relationship between panicle length and grain yield as influenced by number of seedlings hill^{-1} at Panchakanya, Nuwakot, 2022

4.2.3 Filled grains per panicle

The number of seedlings hill^{-1} significantly influenced the number of filled grains per panicle. Highest number of filled grains per panicle was obtained for two seedlings hill^{-1} (120.42) at par with three seedlings hill^{-1} (118.64). Similarly, the lowest number of filled grains per panicle was reported for four seedlings hill^{-1} (104.60). Five seedlings hill^{-1} produced moderate number of filled grains per panicle (112.60). Highest number of grains per panicle in case of two seedlings hill^{-1} might be due to longest length of panicle. The data revealed that filled grains per panicle increased up to two seedlings hill^{-1} and decreased thereafter with increased number of seedlings. Faruk, Rahman and Hasan (2009) also reported similar results with highest number of filled grains per panicle at two seedlings hill^{-1}. Inaba and Kitano (2005) also reported that the number of grains per panicle decreased with increased seedling density.

. There was positive correlation (r = 0.718**) between filled grains per panicle and grain yield (Figure 7). The coefficient of determination was (R^2 = 0.516) reflecting that 51.6% contribution to the total grain yield was due to filled grains per panicle and rest was governed by other factors governing grain yield.

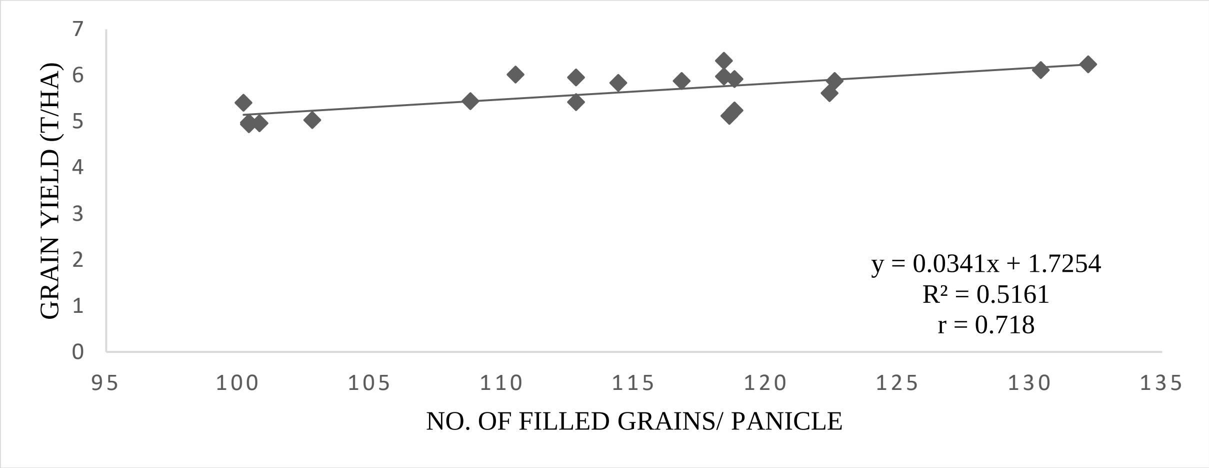

Figure 7: Relationship between filled grains per panicle and grain yield as influenced by number of seedlings hill^{-1} at Panchakanya, Nuwakot, 2022

4.2.4 Sterility percentage

Sterility percentage was found to be non-significant at different number of seedlings used. However, the lower values were obtained for lower seedlings number as compared to higher seedlings number. The average sterility percentage during the experiment was observed to be 26.87% ranging from 24.86% at two seedlings to 28.52% at four seedlings hill^{-1}.

4.2.5 Thousand grain weight

The average weight of thousand grains was found to be non-significant at different number of seedlings used. The result is in conformity with Rasool, Habib and Bhat (2012) and Ashraf, Khalid and Ali (1999) who also reported no any significant effect on thousand grains weight at different number of seedlings hill^{-1}.

4.3 Yield

Table 9: Grain yield, straw yield and harvest index of spring rice as influenced by number of seedlings hil^{-1} in Panchakanya, Nuwakot, 2022

Treatments	Grain yield(t/ha)	Straw yield(t/ha)	HI
Two seedlings hill^{-1}	6.08^{a}	9.71^{a}	0.40
Three seedlings hill^{-1}	5.94^{b}	7.56^{b}	0.40
Four seedlings hill^{-1}	5.02^{d}	6.86^{c}	0.41
Five seedlings hill^{-1}	5.42^{c}	9.62^{a}	0.39
SEM (±)	0.041	0.136	0.004
LSD (0.05)	0.12***	0.39***	NS
CV (%)	1.56	3.42	2.29
Grand Mean	5.61	8.43	0.40

Note: HI: harvest index, NS, non-significant; LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test and columns represented with same letter(s) are not significantly different among each other at 5% level of significance. "***": significant at 0.001P level, "**" significant at 0.01P level, "*" significant at 0.05P level

4.3.1 Grain yield

Grain yield was significantly affected by number of seedlings hill^{-1}. Grain yield is the function of parameters like effective tillers per unit area, panicle length, thousand grain weight, filled grains per panicle etc. The mean grain yield was observed to be 5.61 t/ha in the experiment. The highest yield (6.08 t/ha) was observed at two seedlings hill^{-1}. The higher seedling densities recorded fewer grain yield which was lowest, 5.02 t/ha at four seedlings hill^{-1} and 5.42 t/ha at five seedlings hill^{-1}. The highest yield in case of two seedlings hill^{-1} might be due to highest number of productive tillers and more interception of light. Also, grain filling is the process of remobilization from stored reserves so the effectiveness of grain filling is decided by the condition of particular tiller. Grain yield increased up to two seedlings hill^{-1} and further increase in number of seedlings showed decreasing trend. This might be due to less effective tillers m^{-2} and less assimilation rates at higher seedling numbers (Rasool, Habib, & Bhat, 2012). So, planting fewer seedlings results higher grain yield. Faruk, Rahman and Hasan (2009), Sarkar, Paul, & Hossain (2011) and Masum et al (2014) also reported similar results with the highest grain yield at two seedlings hill^{-1}.

4.3.2 Straw yield

Significant differences among the number of seedlings hill^{-1} used in the experiment were observed in straw yield with mean straw yield of 8.43 t/ha. The highest straw yield (9.71 t/ha) was recorded at two seedlings hill^{-1} at par with five seedlings hill^{-1} (9.62 t/h). Similarly, the lowest straw yield (6.86 t/ha) was recorded at four seedlings hill^{-1} at par with three seedlings hill^{-1} (7.56 t/ha). Two seedlings hill^{-1} produced maximum straw which is mainly contributed due to highest total tillers. Ashraf, Khalid, and Ali (1999) also reported highest straw yield at two seedlings hill^{-1}.

4.3.3 Harvest Index (HI)

The average harvest index in the experiment was 0.40. No significant effect of number of seedlings per hill was observed in case of Harvest Index. Dejen (2018) also reported non-significant differences on harvesting index to the number of seedlings hill^{-1}.

4.4 Economic analysis

Table 10: Economic parameters of spring rice as influenced by number of seedlings hill^{-1} in Nuwakot, Nepal, 2022

Treatments	Economic parameters			
	Production cost (NRs. '000ha^{-1})	Gross return (NRs. '000ha^{-1})	Net return (NRs. '000ha^{-1})	B:C ratio
Two seedlings hill^{-1}	71.72	177.39^{a}	105.67^{a}	2.47^{a}
Three seedlings hill^{-1}	72.60	169.02^{ab}	96.42^{ab}	2.32^{ab}
Four seedlings hill^{-1}	73.48	140.33^{d}	66.85^{d}	1.91^{c}
Five seedlings hill^{-1}	74.36	146.61^{cd}	72.25^{cd}	1.97^{c}
SEM (±)		4.07	3.66	0.06
LSD (0.05)		15.15***	15.15***	0.21
CV (%)		6.22	11.50	6.23
Grand Mean		158.15	85.55	2.18

Note: LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test and columns represented with same letter(s) are not significantly different among each other at 5% level of significance. "***": significant at 0.001P level, "**" significant at 0.01P level, "*" significant at 0.05P level

4.4.1 Production cost

Production cost varied with different number of seedlings hill^{-1}from NRs. 65.25 thousand ha^{-1} to NRs. 61.73 thousand ha^{-1}. Variation in production cost was only due to the seedling numbers which affect the purchasing cost of seed required ha^{-1}. So, highest production cost (NRs. 65.25 thousand ha^{-1}) recurred in five seedlings hill^{-1} and lowest (NRs. 61.73 thousand ha^{-1}) in one seedling hill^{-1}.

4.4.2 Gross return

Gross return was significantly influenced by number of seedlings $hill^{-1}$. The average gross return of NRs. 175.73 thousand ha^{-1} was obtained in the experiment. Higher gross return was obtained in two seedlings $hill^{-1}$ (NRs. 177.39 thousand ha^{-1}) followed by three seedlings $hill^{-1}$ (NRs. 169.02 thousand ha^{-1}). Similarly, lowest gross return was obtained from four seedlings $hill^{-1}$ (NRs. 140.33 thousand ha^{-1}) followed by five seedlings $hill^{-1}$ (NRs. 146.61 thousand ha^{-1}). Higher gross return in two seedlings $hill^{-1}$ was attributed to its higher grain yield.

4.4.3 Net return

Net return varied significantly with the number of seedlings $hill^{-1}$. Higher net return was obtained in two seedlings $hill^{-1}$ (105.67 thousand NRs ha^{-1}.) followed by three seedlings $hill^{-1}$ (96.42 thousand NRs. ha^{-1}). Lower net return was obtained in four and five seedlings $hill^{-1}$ (66.85 thousand NRs. ha^{-1} and 72.25 thousand NRs. ha^{-1}) due to their higher production cost and lower gross return.

4.4.4 B:C ratio

Significant differences among the number of seedlings $hill^{-1}$ used in the experiment were observed in B:C ratio with mean B:C ratio of 2.18. The highest B:C ratio was obtained in two seedlings $hill^{-1}$ (2.47) which was due to reduced production cost and increased yield of crop which ultimately increased gross and net return.

5 SUMMARY AND CONCLUSION

5.1 Summary

A field experiment was conducted to evaluate the effect of number of seedlings hill^{-1} on performance and yield of spring rice. The experiment was carried out at LEE site, Rice Zone, Nuwakot, Nepal. The research experiment was carried out in completely randomized block design (RCBD) with four treatments and five replications. The treatments consisted of different number of seedlings hill^{-1} viz., two, three, four and five. The variety tested was Chaite-5 and the plots were of dimension 3m*2m. The seeds were pre-germinated in a jute sac. The sprouting seeds were then sowed uniformly in a wet bed prepared by thorough puddling and ploughing. The nursery seedlings were protected from nutrient deficiency and irrigated as per needed. Main field was prepared by power tiller and puddling was done a day before transplantation. Seedlings were transplanted with spacing of 20cm*20cm with seedling rates varying from two to five seedlings per hill as per treatment. The biometric data (plant height and number of tillers m^{-2}) was taken in the research field at every fortnight interval from 30 DAT to 90 DAT. Data on various yield attributing parameters viz., effective tillers per m^2, panicle length, filled grains per panicle, sterility percentage, thousand grain weight were recorded at harvesting time and grain yield, straw yield and HI was recorded. The maximum, minimum, average temperature and humidity data observations were recorded on the monthly basis. The total rainfall received in experimental site (Nuwakot district) was 892.5 mm with the minimum temperature ranging from 10℃ to 22℃ and maximum temperature ranging from 22℃ to 32℃ during the experiment period i.e., February, 2022 to June, 2022. The result obtained is summarized as:

5.1.1 Biometric Observations

Highest plant height (104.78 cm) and number of tillers per m^2 (377.28) were observed at two seedlings hill^{-1} while lowest plant height (99.01 cm) observed at five seedlings hill^{-1} and number of tillers per m^2 (311.36) at four seedlings hill^{-1}.

5.1.2 Yield attributing parameters

The yield attributing parameters including effective tillers per m^2 (319.12), panicle length (24.31 cm), filled grains per panicle (120.42) were observed to be highest in case of two seedlings hill^{-1}. The minimum value of parameters: effective tillers per m^2 and filled grains per panicle respectively (237.52) and (104.60) were observed in case of four seedlings hill^{-1}. The minimum value for panicle length was observed in case of five seedlings per hill. Regression analysis shows that the yield attributing parameters like number of effective tillers per m^2, panicle length and number of filled grains per panicle have positive linear relation with the grain yield.

Thousand grain weight and sterility percentage were observed to be non-significant with various treatments used.

5.1.3 Yield

The highest grain yield (6.08 t/ha) and straw yield (9.71 t/ha) observed at two seedlings $hill^{-1}$ whereas the lowest grain yield (5.02 t/ha) and straw yield (6.86 t/ha) observed at four seedlings $hill^{-1}$. However, HI was found to be non-significant to the number of seedlings $hill^{-1}$ used.

5.1.4 Economic analysis

Economic parameters like production cost, gross return, net return and B:C ratio varied significantly with number of seedlings $hill^{-1}$. Highest production cost (74.36 thousand NRs. ha^{-1}) incurred at five seedlings $hill^{-1}$ and gross return (177.39 thousand NRs. ha^{-1}), net return (105.67 thousand NRs. ha^{-1}) and B:C ratio (2.47) were highest at two seedlings $hill^{-1}$.

5.2 Conclusion

Number of seedlings $hill^{-1}$ has significant effect on most of the yield attributing parameters except thousand grain weight and sterility percentage. The yield was also significantly different among the number of seedlings $hill^{-1}$ used. Planting fewer number of seedlings like 2 and 3 seedlings $hill^{-1}$ during the experiment enabled the plant to produce healthy tillers with healthy panicles and a greater number of grains per panicle thus resulting in higher grain yield. Production of spring rice at two seedlings $hill^{-1}$ was found to be economical due to its highest gross and net return and B:C ratio than other seedling numbers used $hill^{-1}$. The experiment showed that two seedlings $hill^{-1}$ gave maximum benefit in spring rice variety Chaite-5 based on its yield and yield attributing parameters in Panchakanya, Nuwakot.

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LIST OF APPENDICES

Appendix 1 : Monthly weather data of experimental field from February to June 2022 at Nuwakot district, Nepal

Months	Av Temp (°C)	RH (%)	Rain (mm)
Feb	16	47	67.5
Mar	21	41	69.3
Apr	25	42	155.7
May	26	55	256.5
Jun	25	67	343.5

Appendix 2 : Mean squares from ANOVA of plant height as influenced by number of seedlings hill-1 at Panchakanya, Nuwakot, Nepal, 2022

Source of Variance	df	Plant height(cm)				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	4	7.262	13.758	2.641	1.842	0.7357
Treatment	3	59.702	22.856	36.501	40.205	28.5045
Error	12	4.392	4.747	1.534	1.281	1.4107

Appendix 3 : Mean squares from ANOVA of tillers per m^2 as influenced by number of seedlings hill-1 at Panchakanya, Nuwakot, Nepal, 2022

Source of Variance	df	Tillers per m^2				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	4	63.7	18.8	44.7	12.3	35.6
Treatment	3	4563.02	4534.3	13447.9	3361.0	4289.5
Error	12	44.3	38.2	49.5	22.7	40.8

Appendix 4 : Mean squares from ANOVA of yield attributes as influenced by number of seedlings hill-1 at Panchakanya, Nuwakot, Nepal, 2022

Source of Variance	df	Yield attributes		
		Effective tiller per m^2	Panicle length	Filled grains per panicle
Replication	4	135.6	0.1322	215.092
Treatment	3	6319.2	7.7722	255.082
Error	12	59.0	0.4830	11.266

Appendix 5 : Mean squares from ANOVA of yield as influenced by number of seedlings hill-1 at Panchakanya, Nuwakot, Nepal, 2022

Source of Variance	df	Yield	
		Grain Yield	Straw Yield
Replication	4	0.04586	0.1679
Treatment	3	1.23095	10.4845
Error	12	0.00777	0.0835

Appendix 6 : Mean squares from ANOVA of economic parameters as influenced by number of seedlings hill-1 at Panchakanya, Nuwakot, Nepal, 2022

Source of Variance	df	Economic parameters		
		Gross return	Net return	B:C ratio
Replication	4	21.25	9.57	0.00567
Treatment	3	1564.86	1748.83	0.36679
Error	12	9.04	4.46	0.00432

Appendix 7: Details of cultural operations of rice at the experimental site during February to June 2022 at farmer's field, Nuwakot, Nepal

SN	Particular Operations	Date (D-M-Y)
1	Nursery bed preparation	09-02-2022
2	Main field preparation	22-02-2022
3	Fertilizer application as basal dose	23-02-2022
4	Transplanting	26-02-2022
5	Weeding	
	Application of pre-emergence herbicide pretilachlor 50EC	03-03-2022
	Hand weedings at 40DAT and 60DAT	16-03-2022 06-04-2022
6	Irrigation	27-02-2022
7	Nitrogen top dressing	
	First top dressing	23-03-2022
	Second top dressing	17-04-2022
8	Cypermethrin 25% spray	26-03-2022
9	Harvesting	26-06-2022
10	Threshing, cleaning and weighing	27-06-2022

Appendix 8: General cost of spring rice production (Rs. /ha) during experiment at Panchakanya, Nuwakot, Nepal, 2022.

SN	Particulars	Unit	Quantity	Rate (Rs)	Total
I	**Variable cost**				
A	**Nursery raising (100m^2)**				
1	Land preparation through disc harrow	minute	5	20	100
2	Nursery bed preparation	labour	1	400	400
3	Bavistin	packet	1 packet (50gm)	65	65
4	Annapurna (micronutrients)	kg	1	100	100
B	**Field preparation and transplanting (1ha)**				
1	Ploughing and puddling	minute	120	20	2400
2	Bund making and digging	labour	8	500	4000
3	Well decomposed FYM	trailer	8	500	4000
4	Fertilizer@100:45:45 NPK kg/ha				
	Urea		179	36	6444
	DAP		97.42	30	2922.42
	MOP		75	40	3000
5	Application of fertilizer	labour	8	500	4000
6	Cypermethrin 25%	litre	1	550	550
7	Transplanting	labour	8	700	5600
8	Harvesting	labour	8	700	5600
9	Threshing	labour	4	500	2000
10	Cleaning, drying and storage	labour	4	500	2000
11	Miscellanous	-	-	-	2000
	Sub total				45181.42
12	**Interest at variable cost**	month	6	12%/year	2710.86
	Total variable cost				47892.28
II	**Fixed cost: government land tax**	month	6	500/ha/year	250
III	**Total cost**				48142.28