

Research Article

Evaluating the Agronomic and Economic Yield of Rice: An Effective Way for Delivering Extension Service

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Abstract

Africa has experienced the fastest-growing demand for rice in the world over the past decade, making rice remarkable economic and social importance. However, compared to other rice-growing regions, Africa's rice yields are among the lowest, with imports meeting most of the demand. Yield improvement can be achieved by adjusting elements of the cropping system, such as planting date and density. Therefore, this experiment aims to determine the proper seedling age and optimum planting density of NERICA 10 for maximum grain and straw yields as well as high net profit. The experiment was conducted using a factorial randomized block design with three replications. Seedling age of 21 and 28 days after sowing (DAS) and planting density of 14.5, 20.0, and 25.6 hills/m² were used as factors. Plant length, stem number, leaf color, heading date, paddy yield, yield components, and straw yield were measured. Data were analyzed using Microsoft Excel and JMP (ver.14.0). There is no interaction effect between seedling age and planting density on growth, paddy yield and yield components, straw yield, and harvest index by ANOVA. However, seedling age had significant effect on plant length, stem number/m² and headings; while planting density had a significant effect on the number of stems/m², panicles/m², and spikelets/panicle. Number of panicles/m² had also a strong and significant relationship with paddy yield. In paddy yield estimated from yield components, A2D3 had a 5.4% advantage over A1D2. However, in Tsubo-Gari sampling, A1D2 outperformed in paddy and straw yield that reached up to 28.3% and 30.2%, respectively, and gave net benefit advantage between 978.35 to 2329.33 USD over alternatives. Applying A1D2 (14.5 hills/m²) decreased seedling cost/ha by 198.7 USD, increased milled rice by 0.98 ton/ha and net profit by 1982.05 USD over A2D3 (25.6 hills/m²). Therefore, treatment A1D2 confirmed as a better recommendation.

Keywords

Cost-benefit Analysis, Heading Date, NERICA 10, Planting Density, Seedling Age, Straw Yield, Tsubo-Gari Sampling

1. Introduction

Rice, a semi-aquatic plant, is the only crop that can grow well on fields with different levels of flooding [1]. It can be grown across a wide range of ecological systems, from rain-fed systems to deep water (submergence), where other crops can't grow well [2]. It is also known as a 'water loving

crop' because its water requirements for cultivation far exceed those of any other crops [3].

About 50% of the world's population consumes rice as a staple food, accounting for one-fifth of all calories consumed globally [4]. Asia, Sub-Saharan Africa (SSA), and South

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America are the largest consuming regions [5]. Due to regional population increase, urbanization, and shifting consumer habits, SSA's rice consumption is rising more quickly [6]. Its demand has increased at a rate of 6% per annum over the last decade giving it the fastest growth rate in the world [4].

Responding to the growing demand, efforts have been made and progress registered. Accordingly, over a last decade (from 2013 to 2022), area cultivated, total production and yield of rice have increased from 12.6 million to 16.5 million hectare, from 28.9 million tons to 39.8 million tons and from 2.29 t/ha to 2.41 t/ha respectively [7]. Despite a remarkable increase in production volume (tenfold since 1961), rice self-sufficiency level in SSA was only 48%, in 2020; enforces to relay on imports to fulfill the rest of the domestic demand [8].

A key obstacle in the regional rice development is the inability to increase yield to the anticipated level. The actual yield is less than half of the potential yield [8]. The farmer-based yield gaps (difference between actual and best farmers yields) are high; 3.1 t/ha for irrigated and rain-fed lowland; and 2.0 t/ha for rain-fed upland, respectively [9]. The inability to adopt well Good Agricultural Practices (GAPs) is one of the major drivers for the low and stagnant yield of rice in Africa.

Applying proper seedling age and optimum planting density are among the GAPs contributing to narrow down existing yield gaps. Planting density regulates utilization of radiation, water, and nutrients [10]. Narrowing the planting density leads to intra-specific competition, cultural operations, seed cost, while widening increases competition between crop and weeds, and weeding costs [11]. Using older age seedlings affects rice growth, tillering pattern, vegetative and reproductive period [12], while too young creates seedling establishment problem mainly in waterlogged condition [13]. Therefore, this experiment is motivated by three issues; first, as to the knowledge of the researchers information about interaction effect of seedling age and planting density on NERICA 10 is scant, second, emerging importance of rice straw as livestock feed and third, importance of looking economic yield in addition to agronomic yield for right decision. Henceforth, this experiment is designed to determine seedling age and planting density that provide optimum grain and straw yields and high net profit

2. Materials and Methods

2.1. Experiment Site

The experiment was conducted at JICA Tsukuba Center in Japan from May to August 2024. It is located between 36°14' 44' N latitude and 140°7' 40' E longitude. Before starting the experiment, the main property of the soil (0-30cm) was loamy clay with a Soil pH of 6.1, total Nitrogen of (N) 5.12g /kg Phosphorus (P) 415mg/ kg, Potassium (K) 0.44 cmolc/ kg.

The experiment was executed under rain-fed conditions, with supplemental irrigation provided as needed.

2.2. Experimental Design

The experiment consists of two factors, namely seedling age and planting density. The six treatments were arranged in a factorial randomized block design (RBD) with three replications, and each plot was 9 m². Table 1 illustrates factors and label of the treatments.

Table 1. Treatments.

Seedling age (DAS)	Planting density		Label
	Spacing (m)	(Hills/m ²)	
21	0.3x0.23	14.5	A1D1
	0.25 x 0.2	20.0	A1D2
	0.3 x 0.13	25.6	A1D3
28	0.3 x 0.23	14.5	A2D1
	0.25 x 0.2	20.0	A2D2
	0.3 x 0.13	25.6	A2D3

2.3. Seed Preparation and Sowing

Seeds of the NERICA 10 rice variety were winnowed to remove awns and rachis branches. Through using the water selection method, the immature grains were separated from the matured grains by using the floating method. After that hot water treatment and a chemical treatment were applied to control the bacterial seedling blight and leaf blight disease. The seeds were initially immersed in hot water (60 °C) for 10 minutes, cooled in cold tap water for 5 minutes, and air-dried for two days. After that, a chemical treatment was done on 15 April (-32 DAT) to disinfect the seed by using Sportak Starner SE applied at the rate of 100ml of fungicides to 20 liters of water, soaked seeds in fungicides for 24 hours, and air dried. The seeds underwent a pre-germination process, wherein they were soaked in an aqua bath at a temperature of 25 °C for two days on 17-April (-30DAT) and 23-April (-24DAT), for seedlings ages 28 and 21 DAS respectively. On 19-April (-26DAT), a total of 80 grams of seed was sown per nursery box, measuring 0.3m x 0.6m, and filled with commercial soil. At first, a total of nine nursery boxes were prepared for the seedling age of 28 DAS, and the seeds were transferred to a greenhouse. On 26 April (-19DAT), the second sowing for seedlings age 21 DAS was done, with 140 grams of seed sown per nursery box and filled with commercial soil. Tachigare ACE was applied as a recommended dose a week after germination to prevent fungal diseases.

2.4. Field Preparation and Fertilizer Application

The land was prepared for cultivation using a tractor for both plowing and puddling. The basal fertilizer was applied at the time of the puddling on 10-May (-7DAT). The fertilizers were applied according to the recommendations set forth by the Ibaraki prefecture, with an equal distribution across all plots. This included the application of 30 kg/ha of urea, 100 kg/ha of potassium chloride (K_2O), and 80 kg/ha of P_2O_5 (superphosphate) at the basal stage, along with the addition of 20 kg/ha of urea and 20 kg/ha of P_2O_5 as a top dressing on 5-July (48 DAT).

2.5. Transplanting

Ages of the seedling at the time of transplanting were 21 and 28 days or seedling leaf ages of 2.08 and 2.85 respectively. Seedlings were treated with V-Get Admine (2%) in nursery boxes prior to transplanting to control pests such as the plant hopper and stem borers and to prevent spread of diseases such as rice blast, sheath blight, and brown spot. A maximum of 50 g of chemical was applied on each nursery box. On 17-May (0 DAT), three seedlings per hills were transplanted manually with planting density of 14.5, 20 and 25.5 hills/m² based on the experimental plot design. Replacing the lost seedling (gap filling) were undertaken on 25-May (8 DAT).

2.6. Field Management

On 20-June (33 DAT), the herbicide Priority was applied at the recommended application rate. After herbicide application, the water level was maintained at a depth of 5 cm for 7 days. To control stink bugs and Caterpillars pesticides such as Mr Jocker EW and Sumichion were applied respectively a week after heading. Besides, manual weeding was conducted three weeks before the harvesting period.

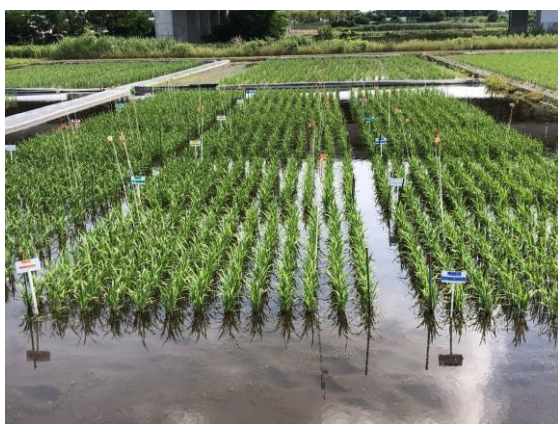


Figure 1. Applying herbicide and maintaining water at 5cm depth.



Figure 2. Performance of the experiment; picture taken by drone on 10 June, 2024.

2.7. Data Collection and Analysis

The growth stages of the rice plant were monitored regularly, and data pertaining to the growth parameters were duly collected. The parameters considered in growth observation includes plant length, stem number, and leaf color. Plant length and leaf color were measured by ruler and leaf color chart (Fujihira Industry Co. Ltd) respectively. Data were collected almost at two-week intervals from a total of six sample plants per plot. To estimate yield from yield components, five sample hills were randomly selected from five middle rows of the plots. The number of panicles was counted separately for each sample, followed by counting the number of spikelets using a seed counter machine. Then after, mature grains were separated using tap water, air-dried for one day, and counted; that help to know the ripening ratio. The weight of the filled grains was measured to determine the 1000-grain weight, adjusted to a moisture content of 14%. Tsubo-Gari unit area sampling (1m² quadrat sampling) was also implemented to collect data used for measuring grain, straw yield, and harvest index. Data were analyzed using Microsoft Excel and JMP (ver.14.0).



Figure 3. Sample collection to determine yield components.

3. Results and Discussion

3.1. Plant Length

As shown in Table 2 and Figure 4, all treatments demonstrated a steady increase in plant length from the active tillering stage up to the ripening stage. The highest mean length of 112.3 cm was recorded in the seedling age of 21 DAS and planting density of 14.5 hills/m² (A1D1), while the lowest mean plant length of 106.9 cm was observed in the treatment with seedling age of 28 DAS and planting density of 20 hills/m² (A2D2). Almost after the heading stage, plant length showed minimal increases up to harvest, which were not statistically significant, the higher plant length scored at lower planting densities (wider plant spacing). This could be attributed to the improved utilization of nutrient resources and solar radiation, which provides a favorable growth advantage compared to higher planting densities.

Plant length was not significantly affected either by interaction or individual factors from the active tillering stage up to the ripening stage. However, significant treatment effect dif-

ferences on plant length by seedling age were observed before the active tillering stage, specifically 16 DAT (Table 2). The 28 DAS seedlings scored a higher mean plant length, likely due to their more advanced growth stage and greater initial vigor, which helped to minimize transplanting shock.

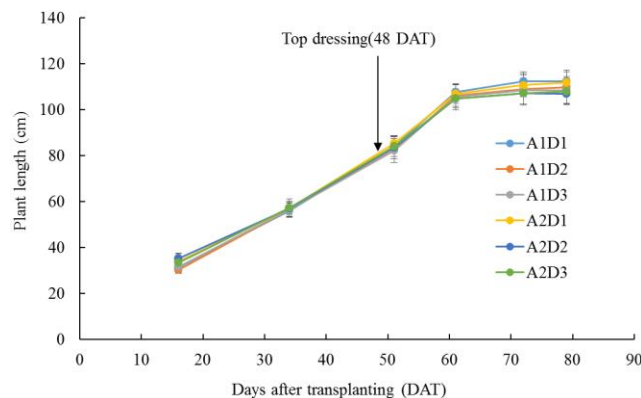


Figure 4. Plant length.

Table 2. Effect of treatment on plant length.

Seedling age (DAS)	Planting density (hills/m ²)	Days after transplanting (DAT)					
		16	34	51	61	72	79
21	14.5	31.2	55.9	83.9	107.6	112.2	112.3
	20.0	30.2	56.4	82.4	106.1	109.0	109.6
	25.6	31.6	56.5	82.3	105.5	108.4	108.3
28	14.5	33.9	57.1	85.3	106.8	110.6	111.9
	20.0	35.1	56.9	83.6	104.8	107.2	106.9
	25.6	33.4	57.2	84.0	104.8	107.1	108.0
21		31.6 b	56.4	82.9	106.3	109.6	109.7
28		36.0 a	57.3	85.3	106.8	108.9	109.4
	14.5	33.0	57.2	83.0	105.8	108.5	109.4
	20.0	31.1	56.5	82.1	104.7	108.1	108.5
	25.6	32.4	56.3	82.7	104.9	109.1	109.6
P value							
ANOVA	Age	0.0093	0.0558	0.1543	0.3437	0.0558	0.4238
	Density	0.9908	0.7459	0.3160	0.2036	0.7459	0.0674
	Age x Density	0.4287	0.7895	0.9481	0.9661	0.7895	0.7227
	Block	0.2088	0.1151	0.2854	0.0803	0.1151	0.2398

3.2. Stem Number

All treatments showed a rapid increase in stem number/m² up to the maximum tiller number stage, when rice plants actively produce more stems to maximize grain-bearing potential. After the maximum tiller number, a steady decline in stem number/m² was observed in all treatments until the heading stage, attributed to the die-off of nonproductive tillers as the plants redirected energy from tiller production to panicle development and grain filling. The rate of decline varied among the treatments, with some maintaining higher stem numbers/m² than others. Treatment A2D3 consistently had a relatively highest stem number/m², while A2D1 showed the lowest. From the heading stage onwards, the stem number stabilized across all treatments, indicating that no new tillers were produced and all nonproductive tillers had been eliminated. Overall, treatment A2D3 maintained a consistently higher stem number compared to the other treatments.

On the other side, the ANOVA results indicated that the interaction had no statistically significant effect on stem number/m². However, seedling age had a significant effect on stem number at an early stage while planting density signifi-

cantly influenced stem number/m² from maximum tiller number to maturity, with the highest stem number/m² of 333 observed in treatment A2D3 (Table 3).

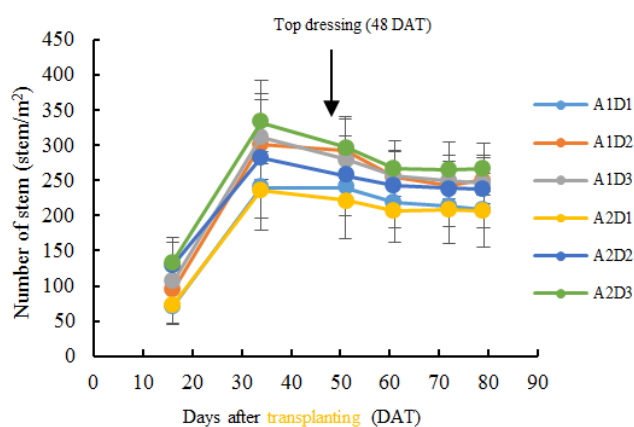


Figure 5. Stem number per meter square.

Table 3. Effect of treatment on stem number/m².

Seedling age (DAS)	Planting density (hills/m ²)	Days after transplanting (DAT)					
		16	34	51	61	72	79
21	14.5	70	240	240	219	214	208
	20.0	93	301	292	254	243	251
	25.6	105	312	280	256	249	246
28	14.5	73	235	222	207	208	207
	20.0	129	282	257	243	239	237
	25.6	134	333	297	266	265	266
21		90b	284	271	243	236	235
28		111a	283	259	239	237	237
	14.5	71	238 b	231 c	213 c	211 c	207 c
	20.0	111	292 ab	274 b	249 b	241 b	243 b
	25.6	120	322 a	289 a	261 a	256 a	256 a
P value							
ANOVA	Age	0.0058	0.8623	0.1895	0.5452	1.000	1.000
	Density	0.0987	0.0037	0.0002	0.0001	0.0001	0.0001
	Age x Density	0.1411	0.602	0.2301	0.6017	0.6283	0.2578
	Block	0.0005	0.0615	0.5123	0.0973	0.6895	0.4409

3.3. Leaf Color

Leaf color is a morphological trait that reveals the photosynthetic activity and nutrient content of the rice plant [14]. As shown in Figure 6 below, the leaf color increased steady from transplanting up to maximum tillering stage. Following top-dressing fertilizer application, there was a consistent increase in leaf color across the treatments, with treatment A1D2 showing a greater increase compared to others. However, almost at the heading stage, all treatments, showed a marked decrease in leaf color, indicating a reduction in nitrogen levels as the rice crop approached the harvesting period. This also indicates the source organ (leaf) start supplying photosynthetic products to sink (panicles). Moreover, neither the interaction nor individual factors had a statistically significant effect on leaf color (Table 4).

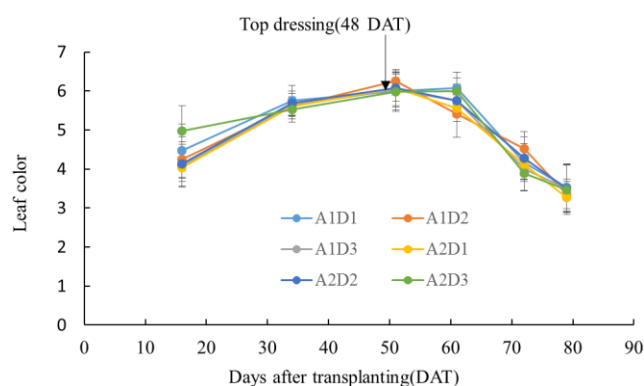


Figure 6. Leaf color.

Table 4. Effect of treatment on leaf color.

Seedling age (DAS)	Planting density (hills/m ²)	Days after transplanting (DAT)					
		16	34	51	61	72	79
21	14.5	4.5	5.8	6.0	6.1	4.2	3.5
	20.0	4.3	5.6	6.3	5.4	4.5	3.4
	25.6	4.1	5.6	6.0	5.8	4.0	3.5
28	14.5	4.0	5.6	6.1	5.6	4.1	3.3
	20.0	4.1	5.7	6.1	5.8	4.3	3.5
	25.6	5.0	5.5	6.0	6.0	3.9	3.5
21		4.3	5.7	6.1	5.8	4.2	3.5
28		4.4	5.6	6.0	5.8	4.1	3.4
	14.5	4.3	5.7	6.0	5.8	4.1	3.4
	20.0	4.2	5.7	6.2	5.6	4.4	3.4
	25.6	4.5	5.6	6.0	5.9	3.9	3.5
ANOVA		P value					
	Age	0.0937	0.8867	0.7121	0.5138	0.3367	0.0910
	Density	0.4781	0.1435	0.3517	0.9173	0.3366	0.9884
	Age x Density	0.7011	0.4800	0.4469	0.9685	0.3958	0.4295
	Block	0.8012	0.4889	0.1353	0.1057	0.0285	0.1900

3.4. Heading

Seedling age had significant effect on the 10%, 50%, and 90% heading of rice plant. The 28 DAS seedlings headed earlier than the 21 DAS seedlings; that might be because of its

vigor advantage (Table 5). This phenomena implied that panicle initiation and fertilizers top dressing time of the two seedling ages was different. Moreover, this Phenological characteristic of rice is an indicator to make a decision so as to keep adequate water in the field for better development of pollen grains.

Table 5. Effect of treatment on heading.

Seedling age (DAS)	Planting density (hills/m ²)	10% heading	50% heading	90% heading
21	14.5	55.7	59.3	62.7
	20.0	55.7	60.0	63.0
	25.6	54.3	58.0	62.3
28	14.5	54.3	58.0	59.7
	20.0	54.0	57.3	59.3
	25.6	54.0	57.0	59.3
21		55.2b	59.1b	62.7b
28		54.1a	57.4a	59.4a
	14.5	55.0	58.7	61.2
	20.0	54.8	58.7	61.2
	25.6	54.2	57.5	60.8
ANOVA		<i>P</i> value		
	Age	0.0050	0.0428	0.0062
	Density	0.1160	0.3488	0.9452
	Age x Density	0.2373	0.6196	0.9452
	Block	0.1160	0.1226	0.1498

Note 1: Figures followed by the same letter are not significantly different by t test ($p = 0.05$)

3.5. Treatment Effect on Grain Yield and Yield Components

The ANOVA results showed that the interaction effect yield components was not significant. However, planting density showed significant differences in spikelets number and panicles number/m², but not in ripening ratio (%) and 1000 grain weight (g) (Table 6). The highest mean panicle number/m², 255, was observed at a planting density 25.6 hills/m², while the lowest, 196,

was recorded at 14.5 hills/m². The highest mean spikelet number, 140, occurred at a planting density 20 hills/m², whereas the lowest, 116, was found at a planting density of 25.6 hills/m². In terms of paddy yield, there were no significant differences across treatments, both in the interaction and individual factors. The highest mean yield, 5.71 t/ha, was achieved at A2D3, while the lowest mean paddy yield, 4.97 t/ha, occurred at A1D1, and treatment A2D3 showed a 5.4% (0.29 ton) yield advantage over the control, A1D2, despite the difference was not statistically significant.

Table 6. Effect of treatment on grain yield and yield components.

Seedling age (DAS)	Planting density (hills/m ²)	Panicle number/ m ²	Spicklet number/Panicle	Ripening ratio (%)	1000 grain weight (g)	Grain yield (t/ha) (%)	
21	14.5	189	137	67.2	28.6	4.97	(91.7)
	20.0	238	122	64.5	28.8	5.42	(100)
	25.6	259	113	63.7	28.7	5.35	(98.7)
28	14.5	203	143	64.1	28.3	5.25	(96.9)
	20.0	228	130	66.7	28.9	5.66	(104.4)
	25.6	251	119	66.9	28.6	5.71	(105.4)
21		229	124	65.1	28.7	5.25	(100)

Seedling age (DAS)	Planting density (hills/m ²)	Panicle number/ m ²	Spicklet number/Panicle	Ripening ratio (%)	1000 grain weight (g)	Grain yield (t/ha) (%)
28		227	131	65.9	28.6	5.54 (105.5)
	14.5	196 b	140 a	65.7a	28.4a	5.11 (92.2)
	20.0	233 a	126 ab	65.6a	28.9a	5.54 (100)
	25.6	255 a	116 b	65.3a	28.7a	5.53 (99.8)
ANOVA		<i>P</i> value				
	Age	0.8748	0.2019	0.6545	0.0885	0.2944
	Density	0.0011	0.0077	0.9812	0.1926	0.3511
	Age x Density	0.59.63	0.9912	0.2970	0.6238	0.9851
	Block	0.9609	0.1902	0.5488	0.2341	0.5441

Note 1: Figures followed by the same letter are not significantly different by Tukey's HSD test ($p = 0.05$)

Note 2: Grain yield (t/ha) is a paddy yield adjusted to a moisture content of 14%

3.6. Relationship Between Grain Yield and Yield Components

In the tests for relationship between grain yield and yield components, with the exception of the number of panicles/m², all the three yield components have p values greater than 0.05, indicates that there isn't a linear relationship (Table 7). The P value of the number of panicles/m², 0.0122 is less than the specified value ($\alpha = 0.05$), indicated that the number of panicles/ m² has a linear relationship with grain yield. Besides, the r value (Pearson correlation coefficient) tells how strong the linear relationship is. Therefore, the r value of 0.57 revealed as there is a fairly strong relationship between numbers of panicles/ m² and grain yield.

Table 7. Regression coefficient for grain yield and yield components.

Parameters	r	p value
Number of panicles /m ²	0.577	0.0122
Number of spikelets/ panicle	0.141	0.5761

Parameters	r	p value
Ripening ratio (%)	0.114	0.6529
1000 grain weight (g)	0.059	0.8161

3.7. Treatment Effects on Yield and Harvest Index

The data for dry straw was recorded only at the ripening stage. As shown in Table 8, neither the interaction nor individual factors have a significant effect on grain and dry straw yields and harvest index. The highest total grain and dry straw were obtained at 21 seedling ages and 20 hills/m² (7.01 t/ha and 5.26 t/ha), while the lowest figure was recorded at 28 seedling ages and 14.5 hills/m² (5.03 t/ha and 3.67 t/ha), respectively. In relation to harvest index, A1D1 received the highest score, 0.45 followed by A2D2, 0.44. Though, A2D3 had a 5.4% (0.29 ton) grain yield advantage over A1D2 in the yield components estimated yield, A1D2 had the highest grain and straw yield than alternatives with the difference ranged from 13.1 to 28.2% (0.92 to 1.98 tones), and 4.2 to 30.3% (0.22 to 1.59 tones) respectively in Tsubo-Gari unit area sampling.

Table 8. Effect of treatment on yield and harvest index.

Seedling age (DAS)	Planting density (hills/m ²)	Grain yield (t/ha) (%)	Straw yield (t/ha) (%)	Harvest Index
21	14.5	6.09 (86.9)	5.04 (95.8)	0.45
	20.0	7.01 (100)	5.26 (100)	0.42
	25.6	5.81 (82.9)	3.80 (72.2)	0.40
28	14.5	5.03 (71.8)	3.67 (69.8)	0.42

Seedling age (DAS)	Planting density (hills/m ²)	Grain yield (t/ha) (%)		Straw yield (t/ha) (%)		Harvest Index
21 28	20.0	5.95	(84.9)	4.77	(90.7)	0.44
	25.6	5.61	(80.0)	4.11	(78.1)	0.42
		6.30	(100)	4.70	(100)	0.42
		5.53	(87.8)	4.18	(88.9)	0.43
	14.5	5.56	(85.8)	4.35	(86.8)	0.43
	20.0	6.48	(100)	5.01	(100)	0.43
ANOVA	25.6	5.71	(88.1)	3.95	(78.8)	0.41
				<i>P</i> value		
	Age	0.096		0.406		0.735
	Density	0.228		0.362		0.696
	Age x Density	0.651		0.550		0.561
	Block	0.284		0.130		0.063

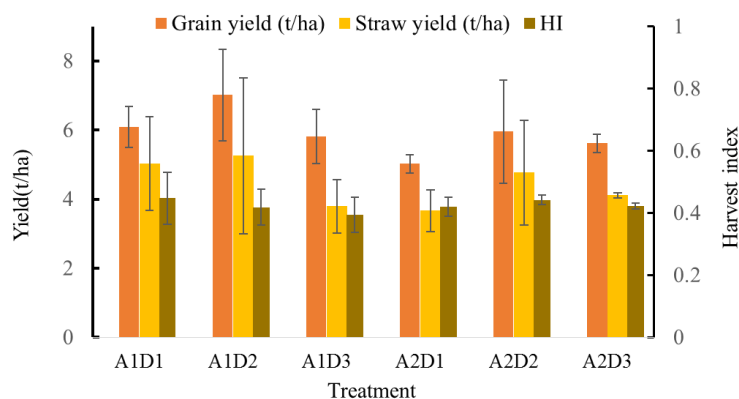


Figure 7. Grain and straw yield and harvest index by treatment.

3.8. Partial Budget Analysis

Evaluating and recommending GAPs based solely on grain yield may not effectively support extension services or encourage widespread adoption, particularly in crop-livestock mixed farming systems. A more holistic approach should consider additional factors such as straw yield and overall economic returns. Using partial budget analysis offers a clear understanding of the financial impact by assessing both costs and benefits beyond grain yield. This method enhances extension efforts by demonstrating the profitability of GAP, making adoption more appealing to farmers and increasing

the likelihood of long-term success.

The cost and return analysis under different treatments is presented in Table 9. Accordingly, the standard treatment (A1D2) showed a maximum net profit of 5921.59 USD, while treatment A2D1 showed a minimum net profit, 3592.26 USD. Likewise, A1D2 provided relative net profit advantages ranged from 978.35 USD to 2329.33 USD over alternatives. Moreover, the cost and return analysis indicated that applying A1D2 (14.5 hills/m²) reduced seedling costs by 198.7 USD per hectare, increased milled rice yield by 0.98 tons per hectare, and boosted net profit by 1,982.05 USD compared to A2D3 (25.6 hills/m²), which ranked second among the six treatments.

Table 9. Cost and return analysis by treatment.

Treatments	Grain yield (t/ha)	Milled yield (t/ha)	Gross Income (USD)	Production cost (USD)	Net Income (USD)
A1D1	6.09	4.26	8358.82	3415.58	4943.24

Treatments	Grain yield (t/ha)	Milled yield (t/ha)	Gross Income (USD)	Production cost (USD)	Net Income (USD)
A1D2	7.01	4.91	9621.57	3699.98	5921.59
A1D3	5.81	4.07	7974.51	3780.06	4194.45
A2D1	5.03	3.52	6903.92	3311.66	3592.26
A2D2	5.95	4.17	8166.67	3596.06	4570.61
A2D3	5.61	3.93	7700.00	3760.46	3939.54

Note 1: Milled rice is calculated from paddy yield with assumption of getting a maximum of 70% milling recovery
Note 2: Exchange rates of yen to dollar is at November 2nd, 2024
Note 3: Selling price of 1kg milled rice in Japan is about 1.97 USD

4. Conclusion

The aim of this experiment is to determine proper seedling age and planting density for maximum grain and straw yields and a high net profit. The ANOVA results showed that the interaction effects of seedling age and planting density on growth, yield and yield components of NERICA 10 were not statistically significant. However, it was confirmed that seedling age had significant effects on plant length, number of stems/m² at the early growth stage, and 10%, 50% and 100% headings of the rice plant; while planting density had significant effects on the number of stems/m², the number of panicles/m², and the number of spikelets/ panicle. Among the yield components, number of panicles/m² had a strong and significant relationship with paddy yield. On the yield computed from yield components, A2D3 had a 5.5% (0.29 ton/ha) advantage over A1D2, while, in Tsubo-Gari unit area sampling, A1D2 had the highest grain and straw yield than alternatives, that reached up to 28.2% (1.98 ton/ha) and 30.3% (1.59 ton/ha) respectively. In harvest index, A1D2, 0.42 competed with A1D1, 0.45. Moreover, on top of straw yield benefit, from grain yield, A1D2 gave net benefit advantage in between 978.35 to 2329.33 USD over alternatives. Applying A1D2 (14.5 hills/m²) decreased seedling cost/ha by 198.7 USD, increased milled rice by 0.98 ton/ha and net profit by 1982.05 USD over A2D3 (25.6 hills/m²). Therefore, taking into account differences in yield, required amount of seedlings, and related transplanting cost, treatment A1D2 confirmed as a better agronomic recommendation.

Abbreviations

ANOVA	Analysis of Variance
DAS	Days After Sowing
DAT	Days After Transplanting
GAPs	Good Agricultural Practices
RBD	Randomized Block Design
SSA	Sub-Saharan Africa
USD	United State Dollar

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Author Contributions

Adane Melak Beyene: Conceptualization, Data curation, Formal Analysis, Methodology,, Software, Supervision, Writing – original draft, Writing – review & editing

Conflicts of Interest

The author declare no conflicts of interest.

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