Original Paper

Response of three lowland rice (*Oryza sativa* L.) variety to seedling age under different plant populations in a derived savanna agro-ecology of Nigeria

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The field trials were conducted during rainy season of 2019 and 2020 at Teaching and Research Farms, Directorate of the Federal University of Agriculture, Abeokuta, Nigeria (Latitude 7° 12′ 54′′ N – 7° 9′ 17′′ N; Longitude 3° 20′ 24′′ E – 3° 27′ 68′′ E). The trials were laid out as a split-split plot arrangement in a Randomized Complete Block Design with three replicates. Main plot treatment was three lowland rice varieties (NERICA L-34, ARICA 3 and WITA-4), sub plot treatment (three plant populations: 250,000, 160,000 and 111,111) plants.ha^{-1} and the sub-sub plot treatment (three seedling ages: (7, 14 and 21 days). Data collected on growth, yield and yield components were subjected to analysis of variance (ANOVA) and treatment means separated using 5% least significant difference (LSD at $p \leq 0.05$). The results showed that there was 36% and 120% increase in hill count when rice was planted at 160,000 plants.ha^{-1} and 250,000 plants.ha^{-1}, respectively compared to 111,111 plants.ha^{-1} in both years. Planting 7 days old rice seedling resulted in lower hill count compared to planting 14 and 21 days olds seedling. In both years, NERICA L-34 produced longer rice grains, more number of grains per panicle and higher grain yield than ARICA 3. Our findings also revealed that rice grain yield increased with plant population with the highest yield recorded with 250,000 plants population. Also, highest grain yield was recorded with planting 21 days old rice seedling. Therefore for maximum rice yield, 21 days old seedling of NERICA L-34 should be planted at 250,000 plants.ha^{-1}.

Keywords: ARICA 3, NERICA L-34, populations, seedling, yield

1 Introduction

Rice is one of the most important cereal crops and a staple diet for more than half of the world's population. It offers up to 50% of the world's dietary calorie supply and a considerable share of their protein intake for a big number of individuals in various parts of the world. As a result, rice has become synonymous with food security (Khir et al., 2017, 2018). Ehrhartoideae, rice's sub-tribe, is divided into three tribes, each containing 17 genera and 120 species (Henry et al., 2009). Rice is one of the world's most valuable and dependable food crops, with many West African countries relying on it for stability, income generation, poverty alleviation, and social growth (Diagne et al., 2013). Rice is grown in over 100 countries, with Asian countries accounting for 90% of global production. Despite the fact that there are over 110,000 rice types, *Oryza sativa* is the most generally known and produced (Rice Association, 2018).

There are more than 40,000 rice varieties in the globe, with more than 15,000 being cultivated in China. Natural and human selection have resulted in significant genetic heterogeneity in Asian cultivated rice as a result of adaptation to various ecological environments. Rice has a great deal of genetic variation, such as indica and japonica ecotypes, because of this genetic divergence (Vaughan et al., 2008; Lu et al., 2009).

Rice cultivars responded differently when transplanted in the field at various seedling ages, Because of their genetic makeup and adaptability to certain environmental conditions (Aslam et al., 2015).

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Rice productivity can be improved by planting at the right time and using the right seedling age at transplanting. The age of seedlings when they are transplanted is significant because it influences the quantity of tillers produced per hill. It affected plant height, effective tiller number, panicle length, grains per panicle, and other yield-related parameters. Many above- and below-ground characteristics of rice plants (seedling vigour) vary with seedling age, growth habitat, and seeding rate before and after transplantation (Himeda, 1994; Sasaki, 2004).

Spacing during transplanting is one the most important factors that determine production (Uphoff, 2003). Optimal spacing guarantees that plants grow properly both above and below ground by utilizing solar radiation and nutrients in different ways. However, closer spacing, has been shown in multiple studies to promote mutual shadowing and intra-specific competition among crops, which can intensify problems such as lodging (Dunn et al., 2020). Plant features, growth period duration, planting time and methods, soil quality, plant size, available moisture, sun shine, planting pattern, and weed condition are all important factors in determining the optimal plant density (Shirtliffe & Johnston, 2002).

The present study hypothesized that matured rice seedlings at optimum population will enhance rice growth with higher grain yield. Therefore, the objective of the study is to identify appropriate seedling age and population for maximum rice grain yield.

2 Material and methods

The experimental field was conducted at the inland valley (FADAMA) of the Directorate of University farms (DUFARMS) at Federal University of Agriculture, Abeokuta, Ogun State, Nigeria (Latitude 7° 12′ 54′′ N – 7° 9′ 17′′ N and Longitude 3° 20′ 24′′ E – 3° 27′ 68′′ E) during 2019 and 2020 early wet cropping seasons. In 2019 and 2020 respectively, the site received a total rain fall of 1,413.2 mm and 1017.5mm (Table 1).

In both years, the trials were laid out as a split-split plot arrangement in a randomized complete block design with three replicates. Main plot treatment was lowland rice variety (NERICA L-34, ARICA-3 and WITA-4), sub plot treatment was planting population 250,000 plants.ha^{-1} (20 × 20 cm), 160,000 plants.ha^{-1} (25 × 25 cm) and 111,111 plants.ha^{-1} (30 × 30 cm) and the sub-sub plot treatment was seedling age (7 days, 14 days and 21 days). The area of the experimental site was 50 × 40 m (2,000 m^2). It consists of 81 plots. Each plot measured 5 × 4 m (20 m^2), separated by 0.5 m between plots and 1 m in-between the replicates. The experimental site was cleared manually, and after the removal of weed stumps and debris, field layout was done.

The seeds to be planted in the nursery were soaked in bucket for 24 hours and incubated for 48 hours (pre-germinated) and then broadcast on the bed, the bed size. The process was done every weed for three weeks to take care of the 7 days, 14 days and 21 days old seedling at transplanting.

Table 1 Monthly distribution and annual total rainfall, mean temperature and relative humidity to the experimental site

Month	2019			2020		
	total rainfall (mm)	mean temperature (°C)	relative humidity (%)	total rainfall (mm)	mean temperature (°C)	relative humidity (%)
January	9	28.9	64.1	0	27.9	75.4
February	79	29.9	57	0	29.4	68.3
March	59.6	29.1	79.2	145.1	30.1	73.7
April	157.6	27.7	78.1	120	28.5	73.4
May	150.4	27.7	80	110	28.4	78.7
June	264.5	27.1	83.1	149.1	26.2	81.3
July	108.7	26.2	87.4	109.5	25.7	82.5
August	65.8	26.4	83.4	2.9	26.2	80
September	96.3	26.6	85.7	246.3	26.1	79
October	310	26.4	84	127.6	27.1	71.8
November	112.3	28	86.9	7	29.5	69.1
December	0	28	81.2	0	0	0
Total	1,413.2			1,017.5		

Pre-emergence herbicide (Butaclor a.i.) at 2 L.ha^{-1} was applied just before transplanting and Vespanil as post-emergence herbicide for weed control. Data collected on hill count, number of leaves, plant dry matter production, yield and yield components were subjected to Analysis of Variance (ANOVA) according to the procedures of GENSTAT. Significant means were separated using lsd at 5% level probability.

3 Results and discussion

Across the years, plant population had significant effect (P ≤0.05) on the hill count throughout the period of observation. At 4 WAT in both years, hill count was highest with plant population of 250,000 plants.ha^{-1} and the lowest was recorded with 111,111 plants.ha^{-1}. Similarly, hill count on the plot having plant population of 160,000 plants.ha^{-1} was significantly higher than the hill count on the plot with 111,111 plants.ha^{-1} plant population (Table 2).

Seedling age had significant effect (P ≤0.05) on the hill count throughout the period of observation in which similar count was recorded with 14 and 21 day old seedlings and significantly higher than 7 days seedling (Table 2). The interaction of rice variety and seedling age is significant on hill count at 4 and 6 WAT in 2020. At 4 and 6 WAT, 7 days seedlings of ARICA 3 had significantly lower hill count compared to 14 and 21 days old seedling irrespective of rice varieties (Figures 1 and 2).

Plant populations had significant effect on number of leaves at 6 WAT in 2020 and both years at 10 WAT (Table 3). While 250,000 plants.ha^{-1} and 160,000 plants.ha^{-1} produced similar number of leaves at 6 WAT, 111,111 plants.ha^{-1} produced significantly higher number of leaves than 250,000 plants.ha^{-1} (Table 3). At 10 WAT in 2019, 250,000 plants.ha^{-1} produced significantly lower number of leaves than 160,000 and 111, 000 plants.ha^{-1}, while in 2020, 111,111 plants.ha^{-1} produced significantly higher number of leaves than 160,000 plants.ha^{-1} and 250,000 plants.ha^{-1} (Table 3). Seedling age had significant effect on number of leaves at 4 WAT in 2020, 6 WAT in 2019 and 10 WAT in 2019 (Table 3). At 4 WAT, the highest and lowest number of leaves were produced with 21 days old and 7 days old rice seedling, respectively, while the highest number of leaves at 6 WAT was produced by 14 days old seedling (Table 3). At 10 WAT, similar number of leaves was produced by 14 and 21 days old seedling which was significantly higher than 7 days old seedling.

Table 2 Effects of variety, plant population and seedling age on hill count of lowland rice at 4 WAT, 6 WAT and harvest

Treatment	4 WAT		6 WAT		Maturity	
	2019	2020	2019	2020	2019	2020
Rice varieties (V)						
NERICA L-34	146.9	159.7	161.8	161.3	134.3	150.4
ARICA 3	143	153.2	156.3	154.7	130.7	145.3
WITA-4	153.3	163.7	166.3	165.3	139.2	154.8
LSD 5%	ns	ns	ns	ns	ns	ns
Plant population (P)						
250,000 plants.ha^{-1}	216.1	232.3	236.1	234.5	195.1	217.6
160,000 plants.ha^{-1}	137.7	146.5	150.8	148	120.6	134.6
111,111 plants.ha^{-1}	89.3	97.8	97.5	98.8	88.5	98.3b
LSD 5%	4.44	10.24	3.43	10.21	5.62	13.34
Seedling age (S)						
7 days	140.4	150	153.8	151.5	125.6	139.7
14 days	151.1	164	165.6	165.5	139.2	155.4
21 days	151	162.7	165	164.3	139.4	155.4
LSD 5%	3.07	6.77	3.22	6.86	3.34	7.88
Interactions						
V × P	ns	ns	ns	ns	ns	ns
V × S	ns	*	ns	*	ns	ns
P × S	ns	ns	ns	ns	ns	ns
V × P × S	ns	ns	ns	ns	ns	ns

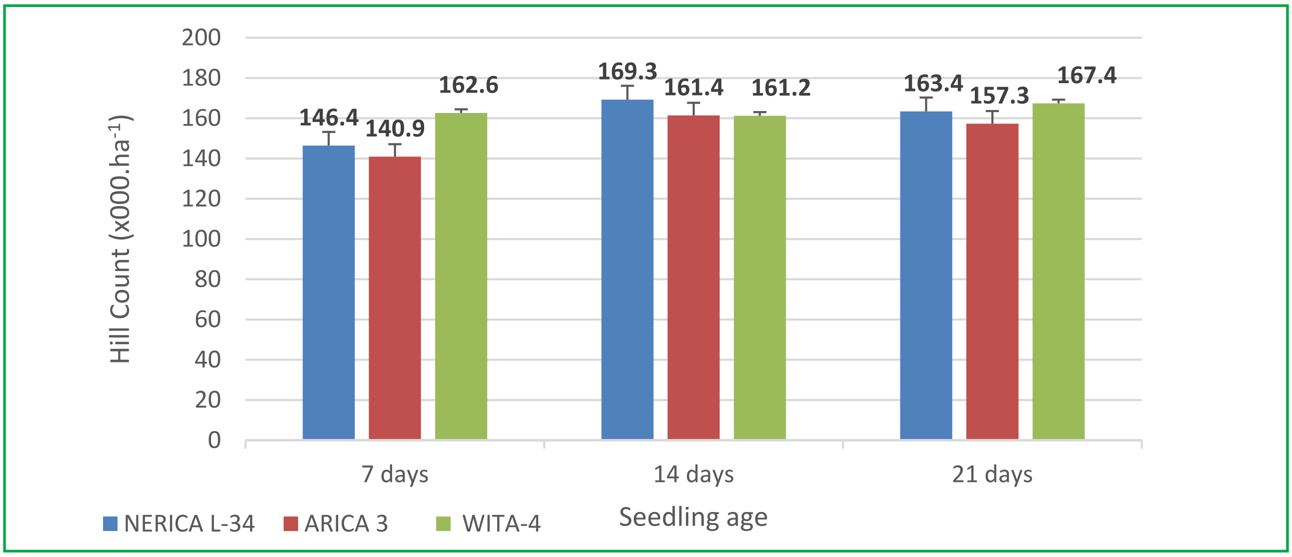

Figure 1 Variety × seedling age interaction effect on hill count at 4 weeks after transplanting in 2020

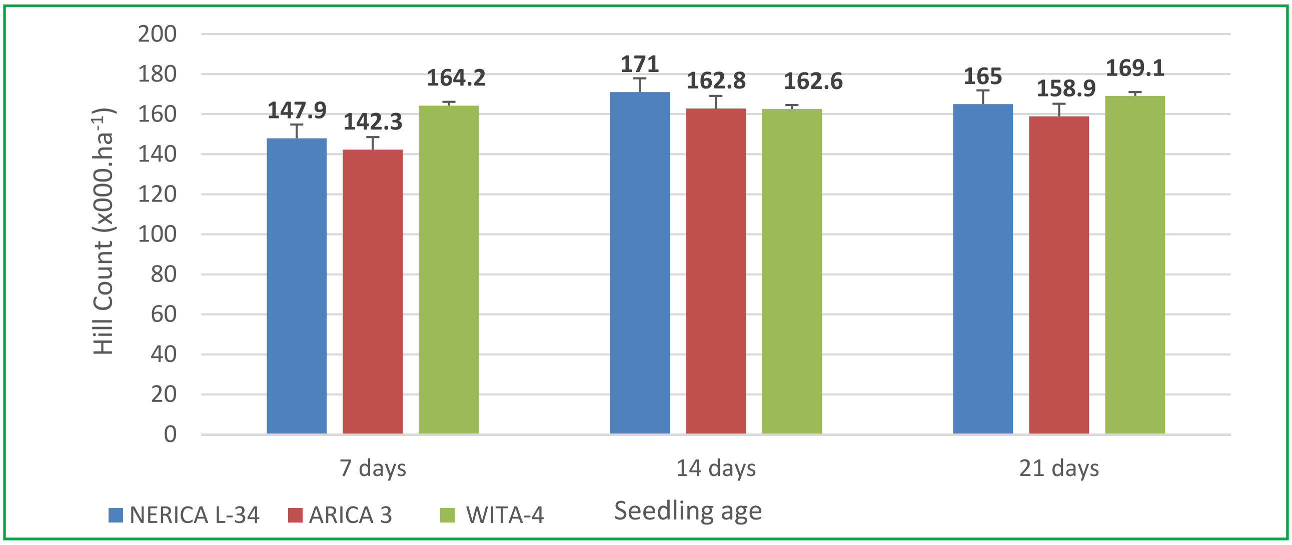

Figure 2 Variety × seedling age interaction effect on hill count at 6 weeks after transplanting in 2020

Plant population had significant effect on plant dry matter production in 2019 at 6 WAT and at 10 WAT in both years, while seedling age had significant effect throughout the period of observation (Table 4). At 6 WAT in 2019 and 10 WAT in both years, planting rice at 160,000 plants.ha^{-1} and 111,111 plants.ha^{-1} resulted in significantly higher plant dry production than when rice is planted at 250,000 plants.ha^{-1} (Table 4).

Throughout the period of observation, the highest and lowest plant dry matter was recorded with the use of 21 days old seedling and 7 days old seedling, respectively (Table 4). Also at 4, 6 and 10 WAT in 2019, the use of 14 days old pepper seedling resulted in significantly higher plant dry matter than 7 days old seedling (Table 4).

Rice variety had significant effect on panicle length, number of grains per panicle in both years and grain yield in 2020. Plant population had significant effect on panicle length in 2020 and grain yield in both years, while seedling age had significant effect on panicle length, number of grains per panicle and grain yield in both years (Table 5). In both years, planting NERICA L-34 resulted in longer panicle, more number of grains per panicle and grain yield in 2020 than ARICA 3 and WITA 4 (Table 5).

Planting rice at 160,000 plants.ha^{-1} and 111,111 plants.ha^{-1} resulted in longer panicle than when rice is planted 250,000 plants.ha^{-1} (Table 5). In both years, grain yield increased with increase in plant population with the highest value recorded when rice was planted at 250,000 plants.ha^{-1} (Table 5). In both years, 14 days and 21 days old seedlings produced longer panicle compared to

Table 3 Effects of varieties, plant population and seedling age on number of leaves of lowland rice

Treatment	Number of leaves					
	4 WAT		6 WAT		10 WAT	
	2019	2020	2019	2020	2019	2020
Rice varieties						
NERICA L-34	21.8	27.2	34.9	52.3	66.5	80.7
ARICA 3	22.2	23.3	31.1	45.6	63.8	68.9
WITA-4	20.1	27.5	31.5	46.9	54	74.1
LSD 5%	ns	ns	ns	ns	ns	ns
Plant population (P)						
250,000 plants.ha^{-1}	20.73	24.1	29.6	37.7	53.6	59.4
160,000 plants.ha^{-1}	21.95	24.5	33.3	46.5	64.7	72.6
111,111 plants.ha^{-1}	21.44	29.4	34.6	60.6	66.1	91.9
LSD 5%	ns	ns	ns	14.54	9.29	14.77
Seedling age (S)						
7 days	19.56	21.9	30	44.9	53.9	73.1
14 days	22.94	25.9	34.7	49.7	63.9	74.9
21 days	21.61	30.1	32.8	50.2	66.5	75.8
LSD 5%	ns	4.89	3.62	ns	7.33	ns
Interaction						
V × P	ns	ns	ns	ns	ns	ns
V × S	ns	ns	ns	ns	ns	ns
P × S	ns	ns	ns	ns	ns	ns
V × P × S	ns	ns	ns	ns	ns	*

7 days old ones. The use of 14 days old seedling in 2019 and 21 days old in 2020 resulted in significantly higher number of grains per panicle than 7 days old seedlings. In both years, the highest and lowest grain yield was recorded with the use of 21 days old seedling and 7 days old seedlings, respectively (Table 5). In 2019, NERICA L-34 transplanted at 14 and 21 days resulted in longer panicle compared to ARICA 3 and WITA-4 irrespective of seedling age, and NERICA L-34 transplanted at 7 days (Figure 3). NERICA L-34 irrespective of plant population produced significantly higher number of grains per panicle compared to WITA-4 irrespective of plant populations (Figure 4). In 2020, NERICA L-34 transplanted at 21 days resulted in the highest grain yield (Figure 5). Also, NERICA L-34 transplanted at 14 days resulted in significantly

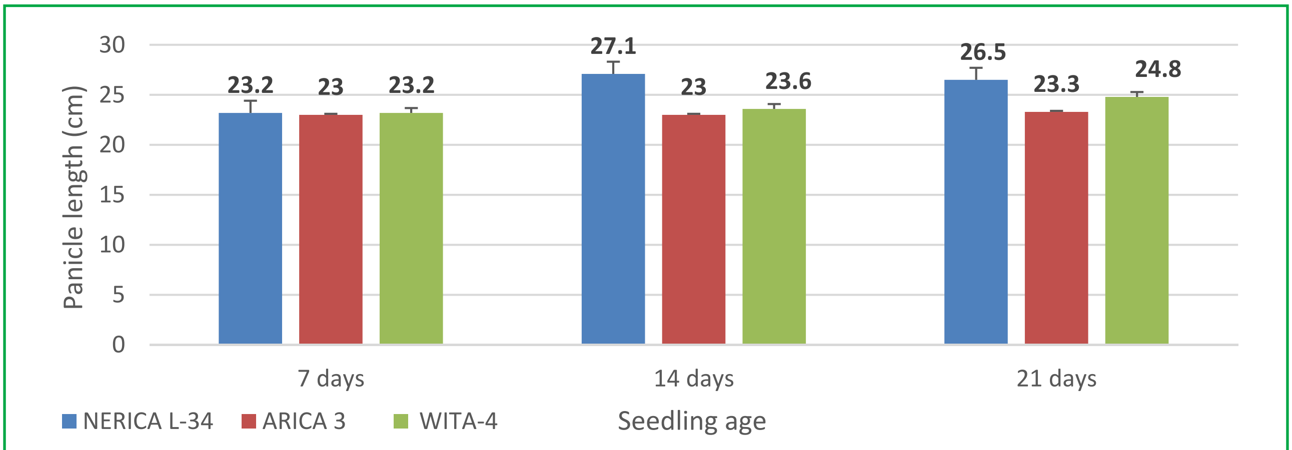

Figure 3 Variety × seedling age interaction effects on panicle length in 2019

Table 4 Effects of varieties, plant population and seedling age on plant dry matter production of lowland rice

Treatment	Plant dry matter production (g)					
	4 WAT		6 WAT		10 WAT	
	2019	2020	2019	2020	2019	2020
Rice varieties						
NERICA L-34	8.9	5.3	27.8	11.7	43.6	45
ARICA 3	8.3	5.1	25.8	10.7	41.2	44.9
WITA-4	7.4	4.8	23.5	7.4	36.6	38.2
LSD 5%	Ns	ns	ns	ns	ns	ns
Plant population (P)						
250,000 plants.ha^{-1}	7.2	5	19.7	9.4	31.6	34
160,000 plants.ha^{-1}	8.6	4.6	28.2	9.2	42.9	46.3
111,111 plants.ha^{-1}	8.8	5.6	29.2	11.1	46.9	47.8
LSD 5%	Ns	ns	7.95	ns	12.25	7.58
Seedling age (S)						
7 days	6	3.9	16.8	6.9	29.8	33.3
14 days	8.9	4.9	27.9	8.9	43.3	41.6
21 days	9.7	6.5	32.4	13.9	48.2	53.3
LSD 5%	2.45	1.3	7.64	4.16	12.03	10.59
Interaction						
V × P	Ns	ns	ns	ns	ns	ns
V × S	Ns	ns	ns	ns	ns	ns
P × S	Ns	ns	ns	ns	ns	ns
V x P x S	Ns	ns	ns	ns	ns	ns

higher grain yield compared to WITA-4 irrespective of seedling age (Figure 5).

The higher hill count with 250,000 plants.ha^{-1} compared to other populations is as a result of higher number of seedlings transplanted which directly translate to higher hill count. The higher hill count recorded with the older seedlings could be attributed to the fact that, the older seedlings are more matured before transplanting with more matured root systems which helps them withstand the transplanting shook compared to the 7 day old seedlings.

The higher number of leaves with 111,111 plants.ha^{-1} compared to the higher plant population could be attributed to less plant population on the plots which

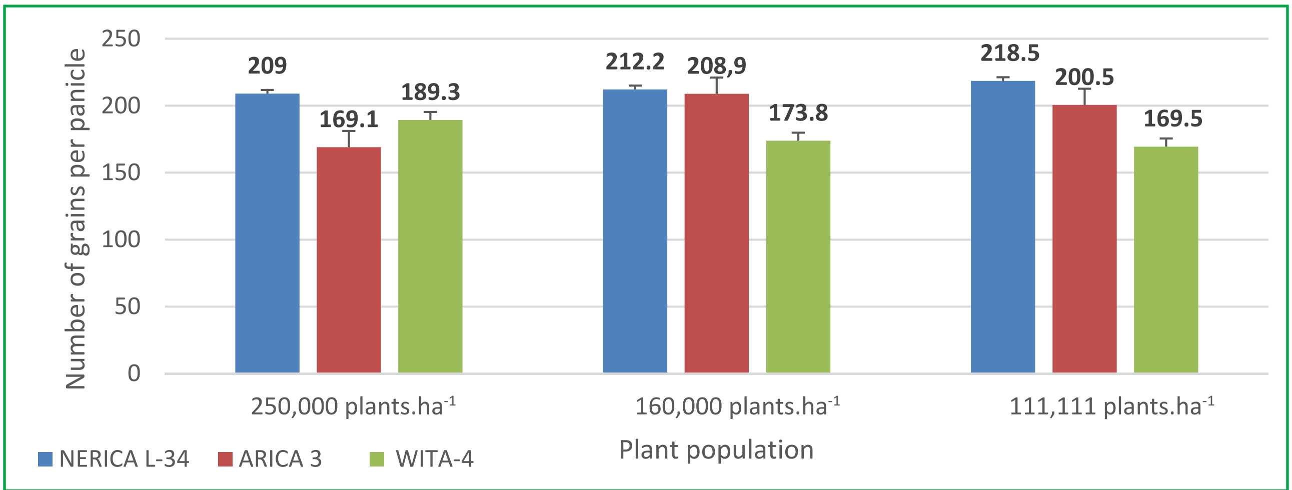

Figure 4 Variety × plant population interaction effects on number of grain/panicle in 2020

Table 5 Effects of carieties, plant population and aeedling age on yield and yield components of lowland rice

Treatment	Panicle length (cm)		Number of grains per panicle		Grain yield (kg.m^{-2})	
	2019	2020	2019	2020	2019	2020
Rice varieties						
NERICA L-34	25.6	26.9	190.7	213.2	0.58	0.69
ARICA 3	23.1	25.7	174.2	192.8	0.54	0.58
WITA-4	23.8	24.9	160.4	177.6	0.49	0.57
LSD 5%	1.51	0.8	20.72	18.33	ns	0.089
Plant population (P)						
250,000 plants.ha^{-1}	24.2	25.1	175.5	189.2	0.66	0.73
160,000 plants.ha^{-1}	24.1	26	169.7	198.3	0.52	0.61
111,111 plants.ha^{-1}	24.3	26.3	180.1	196.1	0.43	0.5
LSD 5%	Ns	0.9	ns	ns	0.104	0.063
Seedling age (S)						
7 days	23.1	25	162.8	181.1	0.45	0.56
14 days	24.6	26.4	187.4	195.1	0.5	0.63
21 days	24.9	26	175	207.4	0.66	0.65
LSD 5%	0.77	0.58	18.35	14.73	0.088	0.071
Interaction						
V × P	ns	ns	ns	*	ns	*
V × S	**	ns	ns	ns	ns	ns
P × S	ns	ns	ns	ns	ns	ns
V × P × S	ns	**	ns	ns	ns	ns

reduced competition for soil nutrient and environmental resources. The higher number of leaves on the 21 day old seeding could be attributed to the fact that 21 days old seedling are more physically matured at transplant than the 7 day old with more leaves and better root system. The better root system with 21 day old seedling would have help the crop to tap more soil nutrients and this will consequently help general crop growth and increase cell division and elongation. This confirms the report of Raut et al. (2019) who reported the highest number of leafs and tillers when 20 day old seedling was planted. Osunleti et al. (2021) had earlier reported higher number of leaves with older seedlings compared to the younger ones.

The higher plant dry matter production with lower plant population compared to 250,000 plants.ha^{-1} was as

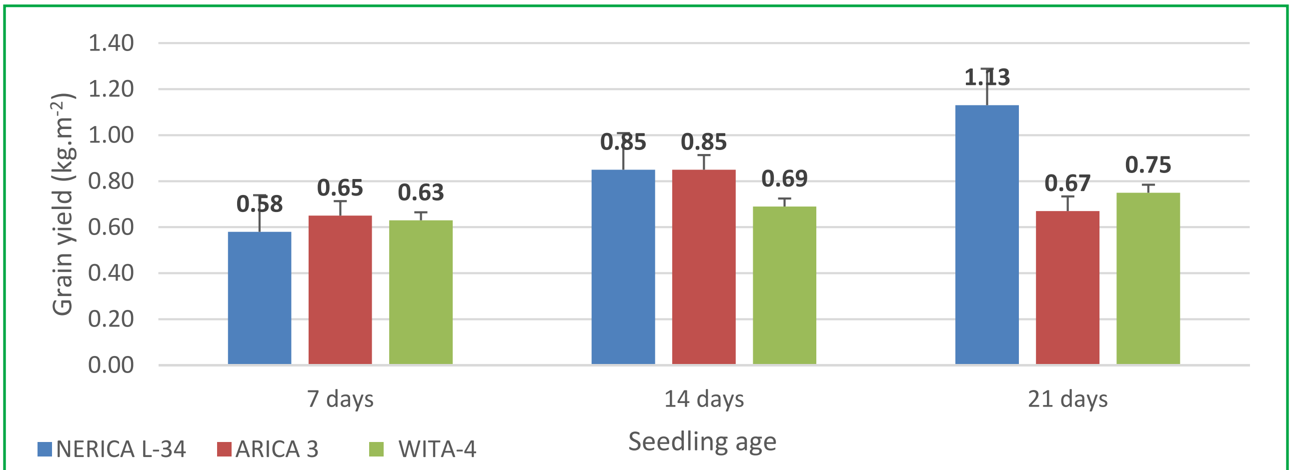

Figure 5 Variety × seedling age interaction effects on grain yield in 2020

results of less competition on the plots. Plants generally competes for soil and environmental resources. There was less competition with 111,111 plants.ha^{-1} compared to 250,000 plants.ha^{-1}, this lead to more even distribution of resources, adequate use and proper translocation leading to more dry matter production. This results corroborates earlier report of Marie-Noel et al. (2021) who reported that the tightest spacing gave short plants with a very small number of tillers whereas the larger spacing produce tall plants with a high number of tillers for all varieties used. Marie-Noel et al. (2021) attributed the results to nutrient availability of the soil for the most spaced plants and the competition among them. Better root system associated with 21 days old seedling compared to the younger seedlings could be responsible for the higher dry matter production. The more developed root system will enhanced nutrient uptake by the seedlings and thereby better and healthier growth. This result corroborates the earlier findings of Uphoff (2005), who reported that a well-developed and healthy root system plays an essential role in the uptake and translocation of nutrients from the soil.

Also, more leaves with the 21 day old seedlings enhanced the ability of the seedling to trap more light for photosynthesis compared with the younger ones thereby increased food manufactured by plants and consequently increased dry matter. Sarker et al. (2012) had earlier reported higher straw yield with 30 day old rice seedling, and further reported the lowest straw yield with 10 days old seedling.

The higher yield with NERICA L-34 could be attributed to the genetic make-up and its compatibility of the environment in which it is grown. Roy et al. (2014) had earlier observed that variety itself is a genetic factor which contributes much in producing yield and yield components of a particular crop. Yield components are directly related to a variety and its environment in which it grows. The increase in yield with 250,000 plants.ha^{-1} compared to other lower population is as a result of higher rice stands at harvest which lead to higher net yield. Our study showed that the planting density of 250,000 plants.ha^{-1} produced the highest grain yield of rice. This confirms the findings of Shi et al. (2016) that increasing plant density is a common technique for enhancing higher grain yield, as it increases the potential capacity of the crop canopy to capture solar radiation, water, and nutrients (Shi et al., 2016). This result is consistent with the results of Bahadur et al. (2000) and Osunleti et al. (2022) who observed significant increase in yield under closer spacing and attributed this to higher plant density per unit area of land.

The findings obtained from the present study during the two years of investigation showed that seedlings transplanted at 14 or 21 days increased hill count in the two years compared to 7 days, regardless of planting density and variety used. This indicates that rice seedling age is vital in determining rice productivity. Transplanting seedlings at appropriate age can provide reasonable ground for achieving potential production by reducing the death of tillers and providing the optimum period for completion of the growing cycle of paddy (Li et al., 2003). This finding was in agreement with the results of Vijayalaxmi et al. (2016) who reported better performance of rice when transplanted between 15 to 25 days. Sudharani et al. (2018) also reported higher rice grain yield with 20 days old seedling than younger ones.

4 Conclusions

The study showed that NERICA L-34 produced the highest yield and yield components and therefore, recommended for rice cultivation especially in the environment. In both years, planting rice at 250,000 plants.ha^{-1} produced the highest rice grain yield resulting into 21.4% and 49.7% yield increase compared to planting 111,111 plants.ha^{-1} and 160,000 plants.ha^{-1}, respectively. Therefore, rice should be planted at 250,000 plants.ha^{-1} for maximum rice yield. Also, use of 21 days old rice seedling produced the highest rice yield in both years and therefore recommended for rice cultivation.

References

Aslam, M.M. et al. (2015). Influence of seedling age and nitrogen rates on productivity of rice (*Oryza sativa* L.): A review. *American Journal of Plant Sciences*, 6(9), 1361–1369. https://doi.org/10.4236/ajps.2015.69135

Bahadur, M.M. et al. (2000). Effect of different spacing and potassium levels on the growth and yield of turmeric. *Pakistan Journal of Biological Sciences,* 3(4), 593–595. https://doi.org/10.3923/pjbs.2000.593.595

Diagne, A. et al. (2013). Estimation of cultivated area, number of farming households and yield for major rice-growing environments in Africa. Realizing Africa's rice promise. Seedling age on the yield of rice. *Pakistan Journal of Biological Sciences* 5, 40–42.

Henry, R.J. et al. (2009). Australian oryza: utility and conservation. *Rice*, 3, 235–241.

Himeda, M. (2013). Cultivation technique of rice nursing seed-lings: review of research papers and its future implementation. *Agriculture and Horticulture*, 69, 679–683.

Khir, R., Ventitasamy, C., & Pan, Z. (2017). Infrared heating for improved drying efficiency, food safety and quality of rice. In J. Shi, & D. Liu (Eds), *Food Physical Processing Science Advances and Prospects*. Zhejiang University Press(pp. 167–192).

Khir, R., Ventitasamy, C., & Pan, Z. (2018), Rice fotifications. In Z. Pan, & R. Khir (Eds), *Advances in Science and Engineering of Rice*. DEStech Publications.

Li, X. Q. et al. (2003). Control of tillering in rice. *Nature*, 422(6932), 618–621.

Lu, Y. et al. (2008). A study on the high yielding mechanism of different rice cultivars under different planting density conditions. *Jiangsu Journal of Agricultural Science*, 1, 18–20.

Marie-Noel, M.F. et al. (2011). Effect of plant spacing on the growth and yield of rainfed rice (*Oryza sativa*) in the Bimodal rain forest zone of Cameroon. *Journal of Agriculture and Crops*, 7(2), 48–59.

Osunleti, S.O. et al. (2021). Influence of period of weed interference and age of pepper (*Capsicum annuum* L. cv. *Cayenne pepper*) seedlings on pepper fruit quality and marketability. *International Journal of Pest Management*. https://doi.org/10.1080/09670874.2021.1995794

Raut, S.D. et al. (2019). Effect of age of seedling, levels and methods of fertilizer application on growth, yield attributes and yield of rice (*Oryza sativa* L.). *International Journal of Chemical Studies*, 7(5), 1641–1647.

Roy, S.K. et al. (2014) Evaluation of growth and yield attributing characteristics of indigenous Boro rice varieties. *Life Science Journal*, 11(4), 122–126.

Sarker, T.K. et al. (2012). Effect of seedling age and method of transplanting on the yield of aman rice. *Progressive Agriculture*, 24(1–2), 9–16. https://doi.org/10.3329/pa.v24i1-2.19092

Shi, D.Y. et al. (2016). Increased plant density and reduced N rate lead to more grain yield and higher resource utilization in summer maize. *Journal of Integrative Agriculture*, 15, 2515–2528.

Shirtliffe, S.J., & Johnston, A.M. (2002). Yield density relationships and optimum plant populations in two cultivars of solid-seeding dry bean grown in Saskatchewan. *Canada Journal Plant Science*, 82, 521–529.

Sudharani, J.S. et al. (2018). Effect of age of seedling, spacing and fertilizer frequencies on extra early rice variety: Pradhyumna (JGL-17004) under late season condition in northern Telangana agroclimatic zone of Telangana state India. *Journal of Pharmacognosy and Phytochemistry*, 7(6), 2665–2668.

Uphoff, N. (2003). Higher yields with fewer external inputs? The system of rice intensification and potential contributions to agricultural sustainability. *International Journal of Agricultural Sustainability*, 1(1), 38–50.

Vaughan D.A., Lu, B.R., & Tomooka, N. (2008). The evolving story of rice evolution. *Journal of Plant Science*, 174 394–408.

Vijayalami, G. et al. (2016). Influence of plant densities and age of seedlings on dry matter partitioning and grain yield potential of transplanted rice (*Oryza sativa* L.). *International Journal Current Research Bioscience Plant Biology*, 3(4), 51–55.