The Effect of Seedling Age on Growth and Yield of NERICA 4 Rice

Isaac Mupeta[1]*, Chifundo Susuwele[2], Ndille Claurence Nkumbe[3]

[1] Agricultural Officer, Ministry of Agriculture, Crops Section
Mwense, Zambia
Email: isaacmupeta [AT] gmail.com

[2] Technical Officer, Ministry of Agriculture, Department of Research
Lilongwe, Malawi
Email: susuwelechifundo [AT] gmail.com

[3]Institute of Agricultural Research for Development
Buea, Cameroon
Email: clarencendille [AT] yahoo.fr

**Corresponding author's email*: isaacmupeta [AT] gmail.com

ABSTRACT— Seedling *age at transplanting is a critical factor in determining the growth and yield of rice as it essentially affects tillering ability and grain yield of rice. We examined the influence of seedling age at transplanting on growth and yield parameters of NERICA 4 rice. Four seedling ages were transplanted 14 days (14DAS), 21 days (21DAS), 28 days (28DAS) and 35 days (35DAS) after sowing at the experiment field of Tsukuba International Centre (Field A-1-3) in Tsukuba city of Japan, in a randomized complete block design (RCBD) and replicated three times. Plant length, tiller number and leaf color were monitored from 20 days after transplanting until heading stage. Yield and yield components were analysed at physiological maturity.*

Seedling age at transplanting showed significant influence on plant length, tiller number and leaf color but failed to significantly affect yield and yield components. 14DAS had special ability to increase number of tillers (13), overall plant length at heading (106.9cm), number of panicles per m^2 (266.6) and harvest index (0.46). Along with 21DAS, 14DAS recorded a lower grain yield (4.9 ton/ha) than 35DAS (5.0 ton/ha) due to a lower ripening ratio (64.8% for 14DAS and 66.6% for 21DAS) and a lower 1,000 grain weight (19.0g and 20.5g respectively). 28DAS had the lowest yield (4.6 ton/ha) due to lowest number of panicles per m^2 (229.6), lowest spikelet number per panicle (105.7) and lowest ripening ratio (66.2%). In terms of panicle length, 35DAS obtained a higher value than 14DAS. It was observed that ripening ratio, 1,000 grain weight and panicle length tend to increase with age of seedlings, but the differences were statistically insignificant. The study showed that transplanting seedlings older than 14 days does not significantly increase paddy yield and its components. However, there is an opportunity of significantly increasing the yield and yield components of 14DAS by increasing nitrogen fertilizer application at panicle initiation.

Keywords— Seedling age, growth, yield, yield components

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for nearly 3.5 billion people globally (IRRI, 2013). Rice provides 50% of the dietary calories and is a significant portion of the protein intake for about 520 million people living in poverty in Asia where production and consumption are among the highest (Muthayya *et al*., 2014). Rice also plays a crucial role in the food security and nutrition of over half the world population in Asia, parts of Latin America, the Caribbean and, increasingly so, in Africa (FAO, 2006).

In sub-Saharan Africa, rice consumption among urban dwellers has progressively expanded with an increasing per capita consumption since the 1970s (IRRI, 2013). In Malawi and Zambia, Rice is becoming an important food and cash crop. In Zambia alone, national production averaged 29, 000 MT in milled rice as of 2015 whereas national consumption was at 39, 000 MT in milled rice with the deficit met by imports (IRRI, 2018). In Malawi, rice is the second main cereal crop from maize and an important cash crop, earning farmers as much as 80% in profits (African Institute of Corporate Citizenship, 2017).

Several studies have postulated the effect of seedling age at transplanting on growth and grain yield of rice. Ranamukhaarachchi & Ginigaddara (2011), observed that the age of seedlings at transplanting influences the number of productive tillers per hill, filled grains per panicle, panicle length, 1000-grain weight, grain yield and panicle setting rate. Pasuquin *et al*., (2008) also noted that tillering dynamics of rice depend on age of seedlings at transplanting. Liu *et al*.,

(2015) also observed that seedling age of more than 25 days after sowing can adversely affect rice growth and grain yield mainly due to poor tiller occurrence, shortened vegetative duration, and decreased dry matter accumulation. Furthermore, old rice seedlings result in delayed growth stages, poor tiller occurrence, limited dry matter accumulation and lower population growth rate, photosynthetic potential, and ultimately lower grain yield (Li *et al*., 2003). In this study, we investigated the effect of seedling age at transplanting on growth and yield of NERICA 4 rice.

2. MATERIALS AND METHODS

2.1 Study Site

The research was conducted at the experiment field of JICA’s Tsukuba International Centre (Field A-1-3) in Tsukuba city, Japan (located at 36º 12’ N Latitude, 140º 0559 longitude and at 33 m altitude), in Randomized Complete Block Design (RCBD) with 4 treatments (14 days, 21 days, 28 days and 35 days old seedlings) and 3 replications. Each plot size was 6m x 2.5m separated by 0.5m between plots and 1m between blocks. Table 1 shows treatment levels and their corresponding labels.

Table 1. Treatment levels of seedling age

Variety	Seedling Age	Label
NERICA 4	14DAS*	NER-14DAS
	21DAS	NER-21DAS
	28DAS	NER-28DAS
	35DAS	NER-35DAS

*DAS=Days after sowing

2.2 Seed Preparation and Sowing

Seeds were pre-cleaned, selected by saltwater method at specific gravity of 1.10, disinfected with Benlate-T (Thiaruam 20%, Benomyl 20%) as fungicide, rinsed, dried for 24 hours and thereafter pre-germinated by soaking in hot water for 24hrs at 33ºC. The pre-germinated seeds were then sown on nursery boxes (each nursery box measured 60cm x 30cm) at the rate of 50g per box at one week interval between treatments as shown in table 2. Seedlings were raised on the nursery boxes in the green house over a period of 35 days.

Table 2: Seedling age and their sowing dates

Seedling Age	Sowing Date
14 DAS	4^{th} week
21 DAS	3^{rd} week
28 DAS	2^{nd} week
35 DAS	1^{st} week

2.3 Fertilizer Application

All plots were applied with a uniform amount of Nitrogen, Phosphorus and Potassium fertilizer in form of Ammonium sulphate ($(NH4)_2SO_4$: 21%N), Single superphosphate (SSP: 18%P_20_5) and Potassium chloride (KCl: 60%K_20) respectively at basal and top dressing on split basis, i.e., before transplanting and at panicle initiation stage for each treatment respectively. Table 3 shows the rate and amount applied per plot.

Table 3: Fertilizer application rate and amounts

Nutrient Type	Basal (Kg/Ha)	Top Dress (Kg/Ha)	Total (Kg/Ha)
$(NH4)_2SO_4$ (21% N)	50	30	80
SSP (18% P_20_5)	100	0	100
KCl (60% K_20)	80	30	110

2.4 Field Preparation and Transplanting

The experimental field was plough up using a power tiller followed by harrowing and levelling. A day before transplanting, basal dressing fertilizer was applied and blended with soil by using a puddling machine. Seedlings were transplanted manually, two weeks after the last sowing date to ensure the youngest seedling age was exactly 14 days after sowing and the oldest seedling age was 35 days after sowing. The seedlings were transplanted at the spacing of 30cm x 15cm (22.2 hills/m^2) and at the planting density of 3 plants per hill. Table 4 shows leaf age of each treatment at transplanting.

Table 4: Seedling age at transplanting

Seedling Age	Leaf Age at Transplanting
14 DAS	**3.0**
21 DAS	**3.7**
28 DAS	**4.0**
35 DAS	**5.0**

2.5 Field Management.

After transplanting, irrigation was maintained at the optimum level required for each growth stage. First weeding was done at 2 weeks after transplanting by application of HOKUTO herbicide. This was followed by subsequent manual weeding to keep the field weed free.

2.6 Data Collection.

2.6.1 Growth Parameters

Growth data were collected on plant length, tiller number and leaf color. Growth data were recorded weekly on six (6) hills per plot marked for continuous observation for growth parameters from three weeks after transplanting until heading time.

2.6.2 Yield and Yield Components

At maturity stage, a total of 20 hills per plot were sampled and uprooted from each plot to establish the average number of panicles per hill in each plot. Three samples were further collected from the middle of each plot based on the average number of panicles per plot from which the spikelet number per panicle was determined. The number of spikelets per panicle were counted using an automatic counter. Filled grains were separated from unfilled grains by using water at specific gravity of 1.0 and counted to determine the ripening ratio. The 1,000-grain weight was obtained and adjusted to 14% moisture content. Panicle length and Harvest index at maturity were also investigated as yield related parameters on the 20 hills per plot samples.

2.7 Data Analysis

Microsoft Excel was used for data arrangement and analysis of variance (ANOVA) was used for statistical analyses. Mean separation was done according to Fisher`s LSD test and Tukey`s HSD Least Significance Difference test at 5% significance level. Microsoft Excel was used for generation of tables and graphs.

3 RESULTS

3.1 Growth Parameters

3.1.1 Plant Length

The changes in plant length of NERICA 4 rice as influenced by age of seedlings is as shown in figure 1. Results showed that from transplanting to heading stage, plant length was significantly higher in 35DAS, intermediate in 21DAS and 28DAS but lower in 14DAS. Notably, 14DAS and 35DAS showed a significantly higher plant length than 21DAS and 28DAS from heading stage onwards. Nonetheless, no significant differences were observed between each set of treatments respectively.

3.1.2. Tiller Number

The tillering ability of NERICA 4 rice as influenced by age of seedlings is as shown in figure 2. We observed that, from transplanting to maximum tillering stage, the age of seedlings significantly increased number of tillers per hill in 14DAS than in 21DAS and 35DAS. The effect of seedling age on number of tillers per hill was however intermediate in 28DAS. Although tiller number was significantly higher in 14DAS than in other treatments, there was no significant difference observed between 28DAS and 35DAS during this period. Suffice to say that no significant differences were observed in tiller number between all the treatments after heading stage.

3.1.3 Leaf Color

The leaf color change in NERICA 4 rice as affected by seedling age is shown in figure 3. We found that seedling age had no consequential effect on leaf color in all treatments within the first 28 days after transplanting. Similarly, seedling age showed no substantial effect on leaf color in all treatments after panicle initiation stage. Although we noted a significant effect of seedling age on leaf color in 14DAS between active tillering stage and panicle initiation stage compared to other treatments, there were no significant differences observed among the other three treatments studied.

3.2 *Yield Components*

3.2.1 Panicle number

Our results (table 8) showed that 14DAS had the highest number of panicles per m^2 (266.7) followed by 21DAS and 35DAS (244.4) whereas the lowest number was observed in 28DAS (229.6) that also recorded the lowest number of spikelets per panicle. Nonetheless, our results suggested that seedling age had a marginal influence on panicle number in NERICA 4 rice across all treatments we studied.

3.2.2 Spikelet Number

The results of our study (table 8) revealed that spikelet number per panicle varied slightly across the four treatments of NERICA 4 rice we examined. Notable though was that young seedlings exhibited a higher spikelet number (110.2 in 21DAS and 108.9 in 14DAS) than older seedlings (105.7 in 28DAS and 107.9 in 35DAS). Notwithstanding these differences, our results were barely significant statistically (p=0.05).

3.2.3 Ripening Ratio

Our findings (table 8) revealed that the ripening ratio of NERICA 4 rice increased with the age of seedlings, with the highest percentage being observed in 35DAS (67.3%) and lowest in 14DAS (64.8%). Even though we noted some variations among the four treatments examined, the effect of seedling age on the ripening percentage of NERICA 4 rice was statistically inconsequential (p=0.05).

3.2.4 1000 Grain weight

We also observed that the one thousand grain weight of NERICA 4 rice was not considerably affected by age of seedlings. Hence, the results showed no significant variations (p=0.05) among the investigated treatments as treatment means varied marginally (table 8). It was further observed that the one thousand grain weight followed the pattern of ripening percentage, with the older seedlings recording higher grain weight and vice versa.

3.2.4 Paddy Yield

The highest paddy yield was obtained in 35DAS (5ton/ha), followed by 14DAS and 21DAS that recorded the same yield (4.9ton/ha) and lowest in 28DAS (4.6ton/ha). These results were however not significant statistically (p=0.05). We attributed the low yield in the young seedlings (14DAS) to its corresponding low ripening percentage resulting into lower filled grain number and lower thousand grain weight which ultimately affected the calculated yield.

RESULTS

Table 5: Effect of seedling age on plant length

Seedling Age	Plant Length 04-Jun	Plant Length 09-Jun	Plant Length 18-Jun	Plant Length 25-Jun	Plant Length 30-Jun	Plant Length 07-Jul	Plant Length 16-Jul	Plant Length 21-Jul	Plant Length 29-Jul
14DAS	37.2**b**	48.4**b**	58.2**b**	62.9**b**	64.3**b**	72.8**b**	97.7**a**	107.5**a**	106.9**a**
21DAS	41.4**ab**	50.8**ab**	59.4**b**	67.1**a**	68.6**ab**	70.9**bc**	92.3**b**	94.7**b**	95.2**b**
28DAS	41.8**ab**	50.4**ab**	59.6**b**	65.4**ab**	67.6**ab**	69.0**c**	89.1**b**	91.8**b**	91.6**b**
35DAS	45.6**a**	54.7**a**	65.3**a**	68.1**a**	71.7**a**	77.5**a**	99.5**a**	103.8**a**	104.1**a**
	Multiple comparisons by HSD 5%								

Table 6: Effect of seedling age on tiller number

Seedling Age	Tiller No, 04-Jun	Tiller No, 09-Jun	Tiller No, 18-Jun	Tiller No, 25-Jun	Tiller No, 30-Jun	Tiller No, 07-Jul	Tiller No, 16-Jul	Tiller No, 21-Jul	Tiller No, 29-Jul
14DAS	10.4**a**	14.6**a**	14.7**a**	14.9**a**	14.1**a**	13.6**a**	11.7**a**	11.7**a**	11.4**a**
21DAS	8.0**b**	11.1**b**	12.3**b**	12.4**b**	12.1**a**	11.9**a**	10.3**a**	10.2**a**	10.1**a**
28DAS	8.6**ab**	12.1**b**	12.9**ab**	13.4**ab**	12.7**a**	12.6**a**	11.2**a**	11.2**a**	11.2**a**
35DAS	8.8**ab**	11.4**b**	13.3**ab**	13.4**ab**	13.2**a**	12.4**a**	11.4**a**	11.9**a**	11.7**a**
	Multiple comparisons by HSD 5%								

Table 7: Effect of seedling age on leaf color

Seedling Age	Leaf color 04-Jun	Leaf color 09-Jun	Leaf color 18-Jun	Leaf color 25-Jun	Leaf color 30-Jun	Leaf color 07-Jul	Leaf color 16-Jul	Leaf color 21-Jul	Leaf color 29-Jul
14DAS	5.7**a**	5.9**a**	4.1**c**	4.0**b**	4.0**b**	5.6**a**	5.6**a**	5.8**a**	5.1**a**
21DAS	6.1**a**	6.2**a**	5.3**b**	5.7**a**	5.6**a**	5.5**a**	5.5**a**	5.8**a**	5.5**a**
28DAS	5.8**a**	5.6**a**	4.9**b**	5.3**a**	5.3**a**	5.6**a**	5.6**a**	5.9**a**	5.7**a**
35DAS	5.9**a**	6.0**a**	5.9**a**	5.9**a**	5.7**a**	5.9**a**	6.0**a**	5.9**a**	5.8**a**
	Multiple comparisons by HSD 5%								

Note: Means in a column with the same letter are not significantly different at 5% level by HSD

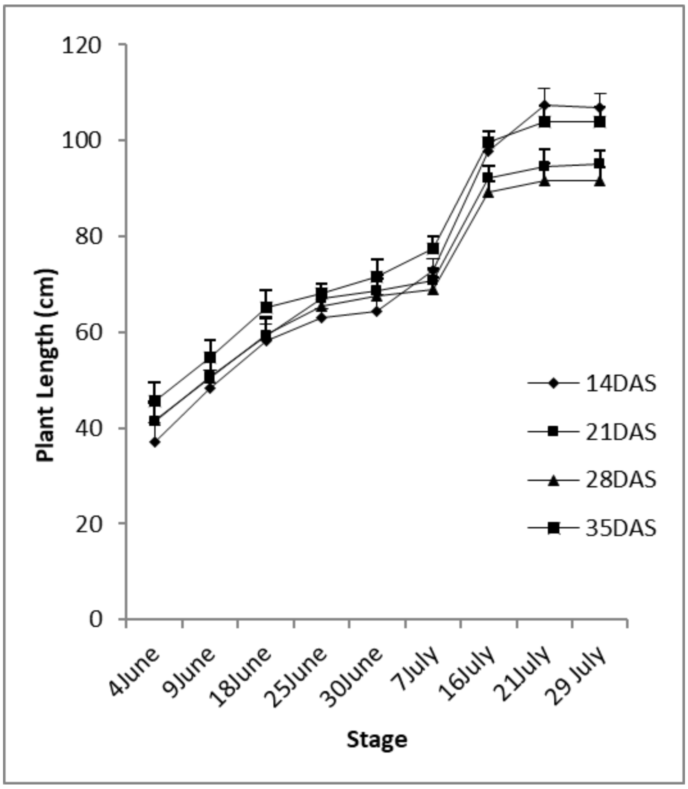

Figure 1: Effect of seedling age on plant length

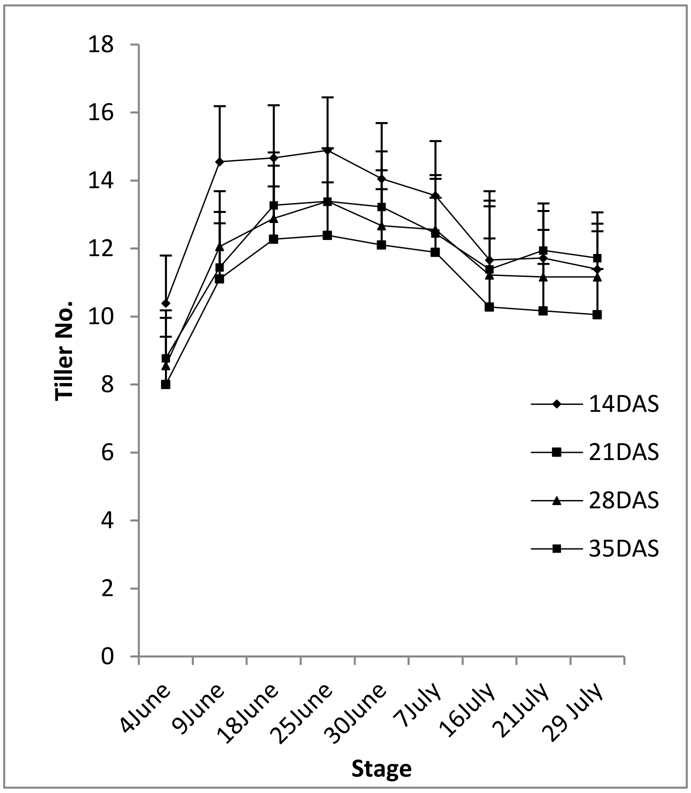

Figure 2: Effect of seedling age on tiller number

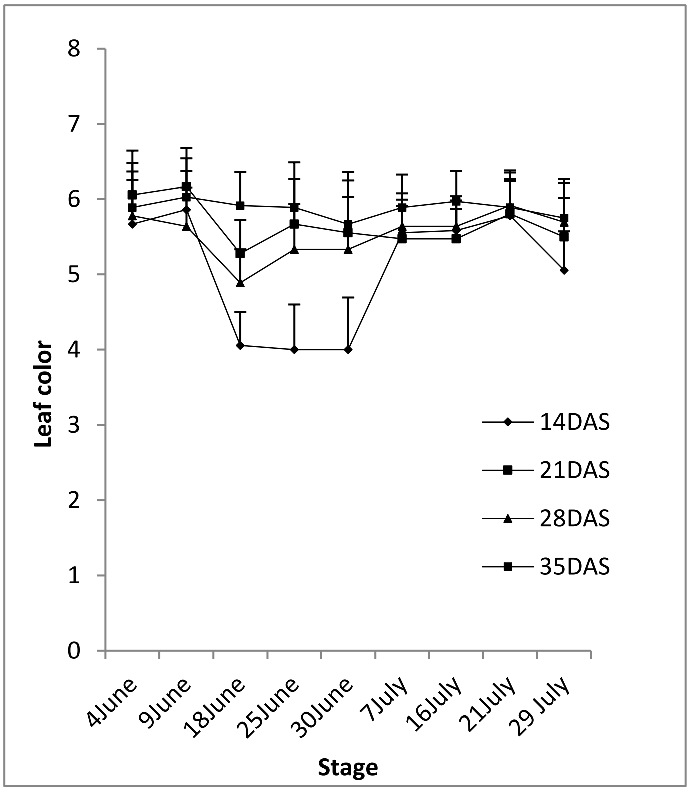

Figure 3: Effect of seedling age on leaf color

Table 8: Effect of seedling age on yield and yield components

Seedling Age	No. of Panicles/m^2	No. of Spikelet/ panicle	Ripening ratio	1000 Grain weight (g) at 14% Moist.	Calculated Yield (ton/ha)	Panicle Length	Harvest Index
14DAS	266.7a	108.9a	64.8a	26.9a	4.9a	19.0a	0.5a
21DAS	244.4a	110.2a	66.6a	27.5a	4.9a	20.5a	0.4a
28DAS	229.6a	105.7a	66.2a	28.6a	4.6a	21.1a	0.4a
35DAS	244.4a	107.9a	67.3a	28.3a	5.0a	21.3a	0.4a

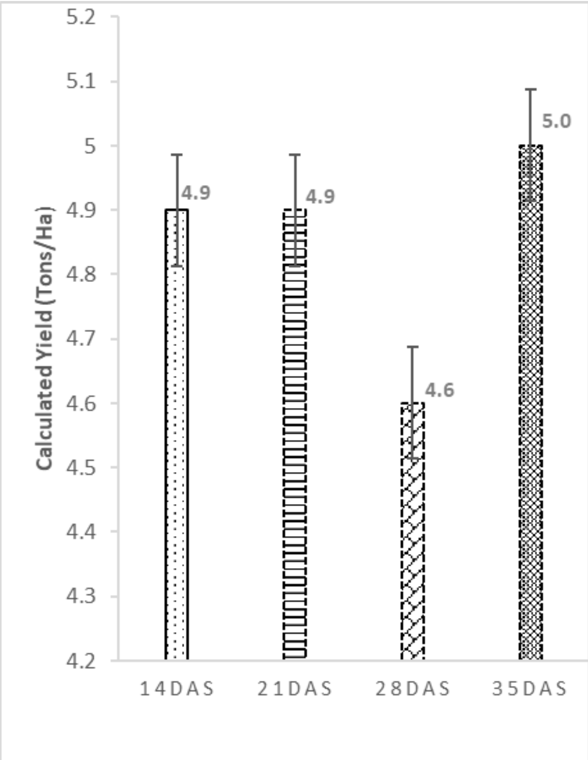

Figure 4: Effect of seedling age on calculated of yield of NERICA 4 Rice

3.2.6 Panicle Length and Harvest Index

Panicle length was lower in young seedlings (19cm in 14DAS and 20.5 in 21DAS) but higher in old seedlings (21.1cm and 21.3cm in 28DAS and 35DAS respectively). A higher harvest index of 0.5 was recorded in 14DAS. The rest of the treatments recorded a harvest index of 0.4.

4. DISCUSSION

4.1 *Growth Parameters*

The age of seedling is a critical consideration in determining the development and yield of rice as it essentially affects the tillering ability of rice (Ranamukhaarachchi & Ginigaddara, 2011). In this study, seedling age at transplanting showed significant effect on plant length (Table 5), tiller number (Table 6) and leaf color (Table 7) during the active growth stage of NERICA 4 rice.

4.1.1 Plant Length

Plant length aside plant age by leaf number, is an important morphological character in measuring plant growth rate that largely eliminate weed competition in rice (Nyarko & De Datta, 1991). In this study, 35DAS showed significantly higher plant length during early growth stage (Figure 1) but after Heading (HD), 14DAS showed a significantly higher plant length than other treatments. This is in line with what Shukla *et al*., (2014) observed that transplanting of younger age seedlings (10 days) recorded significantly higher growth attributes, vis-à-vis plant length, leaf number and dry matter accumulation. Gani *et al*., (2002) also reported that rice transplanted with 7 and 14-days old seedlings had greater plant length compared to those of 21-days. Grist (2002), in examining 4 levels of seedling ages (30, 45, 60 and 70 days) also reported that the length of the cluster will reduce with the increasing age of seedlings such that the highest cluster length was produced in 30 days old seedlings and its minimum length in 70 days old seedlings. In this study, we observed that 14DAS reached the panicle initiation (PI) and heading stage much earlier than other treatments. After PI stage, growth of 14DAS was so rapid that it reached maturity much earlier than other treatments, but experienced lodging and high shattering at harvest time.

4.1.2 Tiller Number

Tillering in rice is an important factor because the final yield is mainly a function of the number of panicle-bearing tillers per unit area (Mohammad *et al*., 2006). From results obtained, seedling age had a significant effect on tiller number with 14 DAS showing the highest number of tillers and ultimately number of productive panicles m^2 (Figure 2). It was noted that 14DAS showed special tillering activity during active tillering stage compared to other treatments. A similar observation was made by Makarim, *et al*., (2002), who reported that 14-days old seedlings performed better than transplanting 21 to 23-days old seedlings. On the other hand, tiller number tend to decrease in older seedlings due to degradation of primary tiller buds on the lower nodes of the main culm when seedlings overstay on the nursery (Mobasser *et al*., 2007).

4.1.3 Leaf color

Leaf color is an important morphological characteristic in rice that is indicative of the photosynthetic activity and nutrient content of the rice plant (Khakwani *et al*,. 2005). This study showed that 20 days after transplanting (DAT), leaf color was not influenced by the age of seedlings, but during active tillering stage, the effect was significant on 14DAS which recorded a significantly lower leaf color score. Our plausible explanation of this result is that the surge in number of tillers consequently decreased leaf color due to competition for nutrients because of high population of tillers per m^2. This is in line with Matsuzaki *et al*., (1980), who observed that a relationship exists between the spikelet number, leaf color and the number of tillers. After top dressing, there was a sharp rise in the score of leaf color observed in 14 DAS, indicating the effectiveness of applying nitrogen fertilizer at panicle initiation stage. However, we observed that leaf color continued to decrease significantly after heading until maturity due to nutrient depletion because of high competition among plants and senescence due to maturity.

4.2 Yield and Yield Components

In this study, we could not observe any significant effect of the age of seedings at transplanting on the panicle number, spikelet number per panicle, ripening ratio, the 1,000-grain weight, calculated yield, panicle length and harvest index. (Table 8).

The 1,000 grain-weight is a critical factor of rice yield as it is an effective indicator of more allocation of photosynthesis material to the grain. Some studies have shown that the 1,000 seed-weight of rice is not affected by seedling age (Rahimpour *et al*., 2013). This is because the 1,000-grain weight in rice is one of the most stable qualities of the cultivar and is higher than the other components of yield due to genetic Stability (Rahimpour *et al*., 2013). In this study, the 1,000-grain weight was observed to be high in 28DAS and 35DAS and lowest in 14DAS but showed no significant difference statistically.

In terms of panicle number, 14DAS recorded highest in terms of panicle number per m^2 whereas 28DAS recorded the lowest figure. This is related to the high tiller number recorded in 14DAS during active tillering stage. However, spikelet number per panicle was highest in 21DAS and lowest in 28DAS where as 14DAS and 35DAS were intermediate (Table 8). Notwithstanding the variations among treatments, it was observed that ripening ratio, 1,000-grain weight, and panicle length tend to increase with age of seedlings. Thus, 14DAS had the shortest panicle, lowest ripening ratio and lowest grain weight. This was attributed to possible competition for photosynthates, nutrients and other growth factors because of high panicle number per square meter.

The highest paddy yield was obtained in 35DAS (5ton/ha), followed by 14DAS and 21DAS (4.9ton/ha), and lowest in 28DAS (4.6ton/ha). Low yield in 28DAS could be attributable to the lowest panicle number per square meter (229.6) as well as panicle spikelet number (105.7). Some studies have asserted that seedling age does not significantly affect seed yield of rice and that 25 days old seedlings gave higher yields than that of 35 days (Rahimpour *et al*., 2013). In this study, seedling age could not show any significant effect on yield obtained from the treatments. The authors of this study are of the view that yield of NERICA 4 rice is a product of various factors, and that transplanting young seedlings such as 14-day old seedling can contribute significantly to increased paddy yield. This is because of the observed effect of the investigated factor (seedling age) on yield components of rice as shown in this study.

5. CONCLUSIONS

This study has shown that transplanting old seedlings (21DAS, 28DAS and 35DAS) does not significantly increase paddy yield and its components. Noteworthy this observation, 14DAS has special ability to increase number of tillers and panicle number of NERICA 4 rice. With proper N-fertilizer application timing and amount and other management practices, the ripening ratio, panicle spikelet number, the 1,000-grain weight and ultimately the yield of 14DAS can be significantly increased.

We further hold the view that since transplanting seedlings older than 14DAS does not significantly affect paddy yield and its components, farmers can transplant within the age range investigated in this study. However, from the economic point of view, 14DAS is a better option for farmers to reduce on time, labour, cost and risk of pests, diseases and adverse weather conditions that may affect raising seedlings and management of rice in the field over an extended period.

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7. REFERENCES

African Institute of Corporate Citizenship. (2017). Geographical Distribution of Rice Profits in Malawi. African Institute of Corporate Citizenship:Lilongwe, Malawi. Retrieved on September 14, 2018 from http://www.aiccafrica.org/index.php?option=com_content&view=article&id=63&Itemid=140&jsmallfib=1&dir=JSROOT/Analysis&download_file=JSROOT/Analysis/GEOGRAPHICAL+DISTRIBUTION+OF+RICE+PROFITS+IN+MALAWI.pdf

FAO. (2006). Rice International Commodity Profile. Food and Agriculture Organization of the United Nations Markets and Trade Division, December 2006. Food and Agricultural Organization (FAO). http://www.fao.org/fileadmin/templates/est/COMM_MARKETS_MONITORING/Rice/Documents/Rice_Profile_Dec-06.pdf

Gani, A., Rahman, A., Dahono, R., & Hengsdi, H. (2002). Synopsis of water management experiments in Indonesia. In B. A. Bouman, A. Hengsdijk, B. Hardy, P. Bindraban, T. Tuong, & J. Ladha, *Water-wise rice production.* Philipines: IRRI.

Grist D, H. (2002). Rice. *Los Banos*, 377.

IRRI. (2018, September 14). *World Rice Statistics*. Retrieved from International Rice Research Institute: http://ricestat.irri.org:8080/wrsv3/entrypoint.htm

International Rice Research Institute. 2013. World Rice Statistics 2013. Los Baños, the Philippines: IRRI. June 29, 2013. http://irri.org/index.php?option=com_k2&view=item&id=9081&Itemid=100481&lang=en

Khakwani, A. A., Shiraishi, M., Zubair, M., Baloch, M. S., Naveed, K., & Awan, I. (2005). Effect of seedling age and water depth on morphological and physiological aspects of transplanted rice under high temperature. *Journal of Zhejiang University-science B, 6*(5), 389-395. Retrieved September 14, 2018, from https://ncbi.nlm.nih.gov/pmc/articles/pmc1389756

Li, X., Qian, Q., Fu, Z., Wang, Y., Xiong, G., Zeng, D., Li, J. (2003). Control of tillering in rice. *Nature*, *422*(6932), 618-621. Retrieved October 9, 2018, from http://ncgr.ac.cn/articles/control of tillering in rice.pdf

Liu Q, Wu X, Ma J, Chen B, Xin C. (2015). Effects of Delaying Transplanting on Agronomic Traits and Grain Yield of Rice under Mechanical Transplantation Pattern. PLoS ONE 10(4): e0123330. https://doi.org/10.1371/journal.pone.0123330

Makarim, A. K., Balasubramanian, V., Zaini, Z., Syamsiah, I., Diratmadja, G. P., & Handoko. (2002). Systems of rice intensification (SRI): Evaluation of seedling age and selected components in Indonesia. In B. A. Bouman, A. Hengsdijk, B. Hardy, P. Bindraban, T. Tuong, & J. Ladha, *Water-wise Rice Production* (pp. 129-139). Philipines: IRRI.

Matsuzaki, A., Kariya, K., Machida, H., & Tsunoda, K. (1980). Studies on the Growth Control and the Nutritional Diagnosis in Rice Plants: The nutritional diagnosis based on the leaf color and the estimation of the number of spikelets per unit area. *Japanese Journal of Crop Science*, *49*(3), 439-455. Retrieved 10 9, 2018, from https://cabdirect.org/cabdirect/abstract/19800714689

Mobasser, H. R., Tari, D. B., Vojdani, M., Vojdani, M., Abadi, R. S., & Eftekhari, A. (2007). Effect of Seedling Age and Planting Space on Yield and Yield Components of Rice (Neda Variety). Asian Journal of Plant Sciences, 6: 438-440. https://scialert.net/abstract/?doi=ajps.2007.438.440

Mohammad, S. B., Inayat, N. A., & Gul, H. (2006). Growth and yield of rice as affected by transplanting dates and seedlings per hill under high temperature of Dera Ismail Khan, Pakistan. *Journal of Zhejiang University Science B, 7*(7), 572–579. Retrieved October 10, 2018, from http://europepmc.org/articles/PMC1500883

Muthayya, S., Sugimoto, J. D., Montgomery, S., & Maberly, G. F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences*, 1324(1), 7-14. DOI: https://doi-org.hvhl.idm.oclc.org/10.1111/nyas.12540

Nyarko, K. A., & De Datta, S. K. (1991). Weed control in irrigated rice. In IRRI, *Hand book for weed control in Rice* (pp. 73-80). Manila,Phillpines: IRRI.

Pasuquin, E. M., Lafarge, T., & Tubana, B. (2008). Transplanting young seedlings in irrigated rice fields: Early and high tiller production enhanced grain yield. *Field Crops Research*, *105*, (1-2) 141-155. Retrieved 9 14, 2018, from https://sciencedirect.com/science/article/pii/s0378429007001943

Rahimpour, L., Daliri, M. S., & Mousavi, A. A. (2013). Effect of seedling age on yield and yield component of rice cultivars (Oryza sativa L.). *Annals of Biological Research*, *4*(1), 72-74. Retrieved 10 9, 2018, from http://scholarsresearchlibrary.com/articles/effect-of-seedling-age-on-yield-and-yield-component-of-rice-cultivarsoryza-sativa-l.pdf

Ranamukhaarachchi, S. L., and Ginigaddara, G. A. S. (2011) Study of Age of Seedlings at Transplanting on Growth Dynamics and Yield of Rice under Alternating Flooding and Suspension of Irrigation of Water Management, *Recent Research in Science and Technology*, 3(3). (Accessed: 10 October 2018). Available at: https://updatepublishing.com/journal/index.php/rrst/article/view/637

Shukla, U. N., Srivastava, V., Singh, S., Sen, A., & Kumar, V. (2014). Growth, yield and economic potential of rice (Oryza sativa) as influenced by different age of seedlings, cultivars and weed management under system of rice intensification. *Indian Journal of Agricultural Sciences*, *84*(5). Retrieved 10 10, 2018, from http://epubs.icar.org.in/ejournal/index.php/ijags/article/view/40489