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Effect of Plant Spacing and Number of Seedlings per Hill toTransplanted Rice (*Oryza Sativa X Oryza Glaberrima*) under Irrigation in Middle Awash, Ethiopia

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Aims: The scientific information available with regards to the response of transplanted rice to plant spacing and number of seedling per hill for its optimum production is very limited. Hence, a field experiment was carried out to assess the effect of plant spacing and a number of seedlings per hill on yield components and yield of transplanted rice under irrigation at Werer, Middle Awash.
Methodology: Factorial combinations of six plant spacing (20 x 10 cm, 20 x 15 cm, 20 x 20 cm, 30 x 10 cm, 30 x 15 cm and 30 x 20 cm) and three seedlings (2, 3 and 4) were laid out in randomized complete block design with three replications.
Results: Number of days to 50% heading, days to 90% physiological maturity, Number of total tiller per hill, Number of effective tiller per hill, plant height (cm), panicle length (cm), Number of grain per panicle, 1000 seed weight and straw yield were significantly affected by the main effect of spacing. Moreover, a number of days to 50% emergence, Number of total tiller per hill, Number of effective tiller per hill, plant height (cm) and straw yield were affected by a number of seedling per hill. Grain yield and above ground biomass yield were also affected significantly by the interaction effects of

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spacing and number of seedling per hill. The highest grain yield (5327 kg ha^{-1}) and biomass yield (14348 kg ha^{-1}) were obtained from 20 x 20 cm spacing and 3 seedlings per hill the lowest grain yield (2957 kg ha^{-1}) and biomass yield (7181 kg ha^{-1}) obtained from 20 x 10 cm spacing and 2 seedlings per hill. Optimum plant spacing and a number of seedlings per hill were important management practice.

Conclusion: Therefore, it can be concluded that spacing 20 x 20 cm with 3 seedlings per hill appears as the best combination to obtain maximum grain yield of NERICA-4 under a transplanted system of the irrigated condition.

Keywords: Rice; seedling per hill; spacing; main effect; transplanting.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a plant belonging to the family of Poaceae. It is one of the three major food crops of the world and forms the staple food for over half of the world's population. It provides 27% of dietary energy and 20% of the dietary protein in the developing world (FAO, 2004).

Ethiopia has a huge potential in both rain fed and irrigated areas for rice production, which is, estimated about thirty million ha [1] of this 30 million ha, more than half of the area is found in the irrigated lowland of the country. However, rice is a recent introduction in the irrigated areas where research and development on rice have been started by introducing commercial rice varieties and germplasm from abroad. So far, some improved varieties and agronomic practices have been developed and promoted in the irrigated areas of the country.

The importance of the crop in the irrigated area is increasing as the area covered by rice is increasing year after year. As indicated in the National Rice Research and Development Strategy, irrigated rice will increase on average by 10.2 thousand ha every year in the first five years and by about 18 thousand ha per year in the second five years [2]. The existence of several rivers and fertile lands in the lowland areas, high yield potential, high economic and food value and its suitability to people food habits are some of the opportunities for its expansion. Under the current situation of the rice sector in Ethiopia, the research and development gaps and priorities in rice production inputs, agronomic practices, pre and post-harvest handling, marketing, utilization and overall investment are identified (NRDSE, 2009).

Transplanting is the practice of raising seedlings in a nursery and planting them into a separate field [3]. Spacing and number of seedlings per hill during transplanting are among the major factors that determine the production [4]. Optimum plant spacing ensures plants to grow properly both in their above and underground parts through different utilization of solar radiation and nutrients. However, numerous studies reveal that closer planting may cause mutual shading and may lead to intra-specific competition that intensifies various problems like lodging [5]. [6] Reported that plant population and number of seedlings per hill may influence stand geometry and ultimate yield of transplanted rice and further concluded that narrow plant spacing and number of seedlings per hill has been found most effective to compensate the yield loss because of high planting density and tiller population per unit area. It is, therefore, necessary to determine the optimum density of plants population per unit area for obtaining higher yields [7].

Therefore, to improve the yield and quality of rice, seedlings need to be transplanted at their optimum spacing and seedling per hill. Keeping this in view, the present research work was undertaking to assess the effect of plant spacing and a number of seedlings per hill on yield components and yield of transplanted rice under irrigation.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

An experiment was conducted at Werer Agricultural Research Center (WARC) in 2016 cropping season under irrigation from June to November 2016. The site is located in the Afar National Regional State, in Rift Valley of Amibara Woreda at Melka Werer town, which is 280 km in the north east of Addis Ababa. It is located at 9° 60' N latitude and 40° 9' E longitude. The altitude of Werer is 740 m.a.s.l. The area is characterized by low and erratic rainfall with total annual rainfall of 568.6 mm which is less than the total annual average evapotranspiration of 2846.7 mm. Thus, crop production is mainly dependent on irrigation from Awash River. Light textured alluvial and black soils with a pH of 8.4 are the dominant soil types of the center. The mean annual temperature is 27.14°C with a minimum of 19.5°C and maximum of 34.8°C, respectively [8].

2.2 Treatments and Experimental Design

The treatments consists of factorial combinations of spacing (20 x 10 cm, 20 x 15 cm, 20 x 20 cm, 30 x 10 cm, 30 x 15 cm and 30 x 20 cm) and number of seedlings per hill of (2, 3 and 4) in randomized complete block design with three replications. There were 18 and 12 rows in plots having 20 and 30 inter-row plant spacing, respectively. The gross plot size was 4 m x 3.6 m (18 row x 4 m and 12 row x 4 m, respectively for 20 cm and 30 cm spacing) and net plot size was 3 x 3 m (10 row x 3 m) and 3.2 m x 3 m (16 row x 3 m), respectively, for 30 cm and 20 cm row spacing.

2.3 Raising Seedling

In order to raise the seedlings, appropriate seed bed was established in June 2016. Nursery was raised on 10 m long, 1.5 m wide and 6 cm raised well leveled seed beds. The seeds were drilled in rows 10 cm apart using seed rate of 50 kg ha-1 depending on percentage of seed viability. The seeds were covered with thin layer of soil and dry grass to maintain moisture at all time and to avoid bird damage during germination. The grass was removed when the seedlings start to emerge. The seed bed was watered every day both in the morning and at evening till transplanting. Transplanting was done when seedlings attain 4-5th leaf stages, which is about 20-25 days after emergence.

2.4 Transplanting Seedling and Its Management

Land preparation was done using tractor and human labor. The plots were leveled to permit irrigation and it was irrigated before seedling transplanting. DAP (18% N, 46% P2O5) was applied at transplanting at a rate of 50 kg ha^{-1}. Transplanting of seedling in each plot was done. Gap filling was done at 7-10 day after transplanting. Urea was applied in split form at a rate of 100 kg ha-1. First half was applied after few days on all transplanted plots (just after the seedlings recover from the transplanting shook) and second half was applied at heading initiation. The crop was raised as per the recommended package of practices. Two outer most rows and 50 cm from both ends in each plot was considered as border.

2.5 Data Collection

Days to 50% heading, Days to physiological maturity, Plant height (cm), Panicle length (cm), Number of total tillers, Number of effective tillers, Number of kernels panicle-1,Thousand kernels weight (g), Aboveground dry biomass yield (kg ha-1), Grain yield (kg ha-1), Straw yield (kg ha-1) and Harvest index.

2.6 Data Analysis

Data were analyzed statistically by using analysis of variance (ANOVA) technique with the help of Genstat Version 18th edition [9]. When significant difference existed between treatments, comparisons of means were made using the Least Significant Difference (LSD) test at 5% probability levels.

3. RESULTS AND DISCUSSION

3.1 Crop Phenology and Growth Parameter

3.1.1 Days to 50% heading

Main effect of spacing showed a highly significant ($P < 0.01$) effect while number of seedling per hill showed significant ($P < 0.05$) effect on days to 50% heading. However, the interaction effect of the two factors was not significant. Among the spacing, the highest days to 50% heading (95 days) was obtained from 30 x 20 cm spacing and the lowest days to 50% heading (92 days) was obtained for 20 x 10 cm (Table 1). [10] Reported one day earlier head emergence in plots with 15 cm than with 25 cm row spacing. In addition to row spacing the main effect of number of seedling per hill significantly affect 50% head emergence. Rice growth delayed with the successive decrease in seedling per hill. Generally the higher planting density results in smaller number of productive tillers per plant and in turn hastens heading time. In conformity with the present study, higher planting density has also been reported to quicken early heading in rice plant [10].

3.1.2 Days to physiological maturity

Analysis of variance showed highly significant ($P < 0.01$) effect of spacing on days to physiological maturity while the main effect of number of seedling per hill and the interaction effect did not show significant effect on days to physiological maturity. On the other hand, highly significant difference (P<0.01) was observed between intra row spacing for the same parameters. Physiological maturity was significantly earlier at closer spacing (20 x 10 cm) than wider spacing (30 x 20 cm). However, it was statistically in parity with the time of physiological maturity obtained in response to the spacing of 20 x 15 cm, 20 x 20 cm and 30 x 10 cm (Table 1).

3.1.3 Plant height

The main effects of plant spacing and number of seedling per hill have significant difference on plant height but the interaction effect has non-significant difference on rice height. The results revealed that the height of the rice plant was highly significantly (P<0.01) affected by spacing. From the result it was observed that, the spacing of 20 x 20 cm produced the highest plant height (97.37 cm) and shortest (88.2 cm) was recorded from 30 x 15 cm inter and intra row spacing. Higher competition among the plants in closer spacing may result weaker plants. Use of 20 x 20 cm plant spacing increased plant height by 9.42% compared to 30 x 15 cm spacing (Table 1). Similar results have also been reported by [11,12]. In contrast with this result, [13,14] reported that narrow space of 20 x 10 cm produced the tallest plants.

A number of seedlings per hill had also a significant effect on plant height. Result revealed that the tallest plant (94.01 cm) was obtained from 3 seedlings per hill and the shortest one (90.28 cm) was recorded from 2 seedlings per hill (Table 1). [15] also found that 2 seedlings per hill produced higher plant height than 5 seedlings per hill.

3.1.4 Panicle length

The main effect of plant spacing has a significant difference on panicle length but a number of seedling per hill and the interaction effect has non-significant difference on rice panicle. It was revealed that the panicle length was longest (20.44 cm) at 20 × 20 cm spacing and the shortest (21.94 cm) panicle was found from 20 × 10 cm spacing. Wider spacing produced the longest panicle than closer spacing. In line with this result [16] noticed that wider spacing of 20 x 15 and 30 x 15 cm recorded significantly higher panicles length than the closer spacing 15 x 15 cm. [15] also reported the similar result that wider spacing produced the longest panicle than closer spacing.

Table 1. Days to emergence, Days to physiological maturity, Plant height and panicle length of rice as influenced by the main effects of spacing and number of seedling per hill

Treatments	Days to 50% Heading	Days to physiological maturity	Plant height (cm)	Panicle length (cm)
Inter and intra row spacing				
20 * 10	91.56^{e}	121.7^{d}	94.03^{ab}	20.44^{c}
20 * 15	92.33^{de}	122.0^{cd}	91.38^{bc}	21.01^{abc}
20 * 20	93.00^{cd}	122.8^{bcd}	97.37^{a}	21.78^{a}
30 * 10	93.44^{bc}	123.1^{abc}	88.33^{c}	20.78^{bc}
30 * 15	94.22^{ab}	123.9^{ab}	88.20^{c}	21.15^{abc}
30 * 20	95.00^{a}	124.3^{a}	91.92^{bc}	21.39^{ab}
$LSD_{0.05}$	0.901^{**}	1.385^{**}	3.821**	0.840
Number of seedling per hill				
2 seedling $hill^{-1}$	93.78^{a}	123.33	90.28^{b}	21.17
3 seedling $hill^{-1}$	93.17^{ab}	122.94	94.01^{a}	21.34
4 seedling $hill^{-1}$	92.83^{b}	122.61	91.32^{ab}	20.76
LSD(0.05)	0.637^{**}	NS	2.702**	NS
Mean	93.3	122.96	91.87	21.09
CV%	1.0	1.2	4.3	4.2

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation
Means within a column followed by the same letter are not significantly different at 5% level of significance. NS = non-significant.

3.2 Yield Components

3.2.1 Number of the total tillers

Total tillers per hill were significantly varied among different spacing (Table 4). It was obvious from the table that wider spacing produced higher tillers per hill than closer spacing. Highest total tillers per hill (17.40 and 16.59) were obtained from 30 × 20 cm and 20 x 20 cm spacing respectively and lowest total tillers per hill (12.13) was obtained from 20 x 10 cm spacing. Use of 30 x 20 cm spacing was improved total tiller per hill of transplanted rice by 30.3% over narrow plant spacing (20 x 10 cm). The production of more tillers in widely spaced plants was probably due to absorption of more nutrients and moisture and also to the availability of more sunlight in comparison to densely transplanted plants. Similar results were reported by [17].

The main effect of number of seedling per hill show significant difference on total tiller per hill. The result showed decreasing trend as increasing number of seedling per hill. The highest number of total tillers per hill (15.28 and 15.24) were produced when the crop was transplanted at 3 and 2 seedling per hill respectively and the lowest tiller (13.55) was observed on 4 seedling per hill. Use of 3 seedlings per hill was improved total tiller per hill of transplanted rice by 11.32% over 4 seedlings per hill (Table 2). In contrast [18] reported that two seedlings per hill gave significantly higher number of tillers per hill than three seedlings per hill.

3.2.2 Number of effective tillers

Spacing had significant effect on number of effective tillers per hill (Table 2). The results revealed that wider spacing performed better as compared to lower spacing. The highest number of effective tillers per hill (16.48) were produced when the crop were transplanted at 30 x 20 cm plant spacing. The lowest number of effective tillers per hill (10.94) was observed in narrow spacing (20 cm x 10 cm). In the wider row spacing, the more vigorous plants, with particularly higher tillering ability might have produced more photosynthates than the less vigorous plants with the closer spacing. In addition plants did not get proper nutrition due to nutrient competition in closer plant spacing. Increase in the number of effective tillers per hill with 30 x 20 cm was 36.4% over that of narrow spacing (20 x 10 cm). The result was in conformity with those of [19, 20] reported the highest effective tillers were recorded at medium spacing performed better as compared to lower spacing. [21] reported 30 × 20 cm spacing produced the highest number of effective tillers in transplanted rice. Effective tillers per hill increased linearly with increase in spacing but the increase did not maintain the number of productive tillers per unit area due to reduction in initial plant population per m2 due to variation in plant geometry [12,21,22].

Number of seedlings per hill was important for number of effective tillers per hill as it varied significantly (Table 2). The variation in effective tillers production was found due to variation in different number of seedlings hill–1. Highest (14.49) number of effective tillers per hill was recorded from 2 seedlings per hill and the lowest (12.22) was recorded from 4 seedlings per hill. This result agreed with the result of [23,24] reported that the highest effective tiller per hill was recorded from 2 seedlings per hill and the lowest effective tiller per hill was recorded from 4 seedlings per hill. In contrast with this result [21] reported highest number of effective tillers per hill was recorded from 4 seedlings per hill and the lowest was recorded from 8 seedlings per hill.

3.2.3 Number of grains per panicle

The main effect of plant spacing has significant difference on grain per panicle but number of seedling per hill and interaction effects had non-significant difference on grain per panicle. From the result it was observed that, the spacing of 20 x 20 cm produced the highest grain per panicle (131.4) and the lowest grain per panicle (117.3) was recorded on 20 x10 cm. Uses of 20 x 20 cm inter and intra row spacing produced 10.7% higher over that of 20 x 10 cm plant spacing (Table 2). In addition optimum higher length of panicle contributes to high number of grains per panicle.

3.2.4 Thousand grains weight

Thousand grain weights is an important character which determines the yield per hectare. Analysis of variance indicated that thousand grains weight was significantly affected by spacing. The results showed that with the increase in spacing the 1000 grains weight also increased significantly. The highest thousand grain weight (23.42) was produced when the crop was transplanted at 30 x 20 cm spacing. The lowest thousand grain weight (22.04) was observed in closest spacing (20 x 15 cm) (Table 2). Higher plant population was noted in narrow spacing than other spacing and this higher plant population was accompanied by strong inter and intra-row competition that might have caused reduction in thousand grains weight of rice crop. In line with this result [15,21,25] reported highest thousand grain weight was obtained in wider spacing (30 x 20 cm) than closer spacing (15 x 20 cm). In addition [26] who obtained increased grain weight at wider row spacing in wheat. However, thousand grain weights were not significantly affected among the factors number of seedlings per hill and their interaction with spacing.

3.3 Yield Parameters

3.3.1 Aboveground dry biomass yield

Analysis of variance showed the interaction effect of spacing and number of seedling per hill was significant ($P<0.05$) on biomass yield of rice. The highest biomass yield (14348 kg ha-1) was obtained from 20 x 20 cm spacing with 3 seedlings per hill. The lowest biomass yield (7181 kg ha-1) was obtained from 20 x 10 cm spacing with 2 seedlings per hill (Table 3). In line with this finding, [27, 28] reported that the highest grain yield was obtained from plant spacing of 20 x 20 cm along with 3 seedlings per hill. Similarly

Table 2. Number of the total tiller, number of productive tiller, number of kernel per panicle and thousand seed weight of rice as influenced by the main effects of spacing and number of seedling per hill

Treatments	Number of total tiller per hill	Number of productive tiller per hill	Number of kernel per panicle	Thousand seed weight
Spacing				
20 * 10	12.13^{d}	10.94^{d}	117.3^{b}	21.57^{c}
20 * 15	13.62^{c}	12.62^{c}	121.6^{b}	22.04^{bc}
20 * 20	16.59^{a}	15.66^{ab}	131.4^{a}	22.25^{bc}
30 * 10	13.30^{cd}	11.87^{cd}	121.4^{b}	22.18^{bc}
30 * 15	15.11^{b}	14.42^{b}	131.2^{a}	22.46^{b}
30 * 20	17.40^{a}	16.48^{a}	124.4^{ab}	23.42^{a}
$LSD_{0.05}$	1.383	1.402	9.20	0.809**
Number of seedling per hill				
2 seedling hill^{-1}	15.24^{a}	14.49^{a}	125.1	22.50
3 seedling hill^{-1}	15.28^{a}	14.28^{a}	124.9	22.42
4 seedling hill^{-1}	13.55^{b}	12.22^{b}	123.7	22.04
$LSD_{0.05}$	0.978	0.991	NS	NS
Mean	14.69	13.66	124.6	22.32
CV%	9.8	10.7	7.7	3.8

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation
Means within a column followed by the same letter are not significantly different at 5% level of significance.
NS = non-significant

Table 3. Biomass yield of rice as affected by interaction effect of inter and intra row spacing and number of seedling per hill

Plant spacing	Number of seedling per hill		
	2 seedling hill^{-1}	3 seedling hill^{-1}	4 seedling hill^{-1}
20 * 10	7181^{i}	8925^{efgh}	7659^{hi}
20 * 15	8535^{fghi}	9232^{defgh}	8194^{ghi}
20 * 20	9643^{cdefg}	14348^{a}	10762^{bcd}
30 * 10	10192^{bcde}	11284^{b}	8847^{efgh}
30 * 15	8946^{efgh}	10884^{bc}	9307^{cdefg}
30 * 20	9948^{bcdef}	12921^{a}	9210^{defgh}

LSD (0.05) Spacing X Seedling per hill = 1604.8; CV (%) =9.9
LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation
Means within columns and rows followed by the same letter are not significantly different at 5% level of significance

Table 4. Grain yield of rice as affected by interaction effect of inter and intra row spacing and number of seedling per hill

Inter and intra row spacing	Number of seedling per hill		
	Two seedling	Three seedling	Four seedling
20 * 10	2978^{fg}	2993^{fg}	3074^{efg}
20 * 15	2957^{g}	3315^{defg}	3166^{efg}
20 * 20	3505de	5327^{a}	4033^{c}
30 * 10	3209^{defg}	4001^{c}	3382^{defg}
30 * 15	3100^{efg}	4111^{c}	3168^{efg}
30 * 20	3427^{def}	4830^{b}	3653^{cd}

LSD (0.05) Spacing X Seedling per hill = 460.1; CV (%) =7.8
LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation
Means within columns and rows followed by the same letter are not significantly different at 5% level of significance

[21] reported that the interactions of 20 x 20 cm spacing and 4 seedlings per hill give maximum biomass yield. In contrast [29] reported the highest biomass yield was recorded from the interaction of narrow inter and intra row spacing and 5 seedlings per hill. The lowest biomass yield was reported from the interaction of wider inter and intra row spacing (25 x 15 cm) and 2 seedlings per hill.

3.3.2 Grain yield

Interaction effect of spacing and number of seedling per hill was highly significant ($P < 0.01$) in determining grain yield per hectare. The highest grain yield (5327 kg ha-1) was obtained from 20 x 20 cm inter and intra row spacing and 3 seedlings per hill the lowest grain yield (2957 kg ha-1) was obtained from 20 x 15 cm inter and intra row spacing and 2 seedlings per hill (Table 4). Use of 20 x 20 cm spacing was improved grain yield of rice by 44.5% over 20 x 15 cm spacing. Higher grain yield might be due to optimum spacing produce a high number of effective tillers per hill was the determinant of final yield. Therefore, the higher the number of tillers, especially fertile tillers, the more will be the yield. In agreement with this result, [27,28,30] reported that the highest grain yield was obtained from plant spacing of 20 x 20 cm along with 3 seedlings per hill. Similarly, [21] reported that the interaction of 20 x 20 cm spacing and 4 seedlings per hill gives maximum grain yield. In contrast [29] reported the highest grain yield was recorded from the interaction of narrow spacing and 5 seedlings per hill. The lowest grain yield was reported from the interaction of wider spacing (25 x 15 cm) and 2 seedlings per hill.

3.3.3 Straw yield

The straw yield was significantly influenced by the successive decrease in inter and intra-row spacing. The highest straw yield (7296 kg ha-1) obtained from 20 x 20 cm plant spacing. The lowest straw yield (4907 kg ha-1 was obtained from 20 x 10 cm spacing. Use of 20 x 20 cm spacing was improved grain yield of rice by 32.74% more than the straw yield obtained from narrow spacing (20 x 10 cm). The lowest Spacing might have influenced vegetative growth in terms of plant height and number of tillers per hill (effective and non-effective tillers) which resulted in increased straw yield (Table 5). [31] also reported a Similar trend of straw yield the higher straw yield was obtained in 20 cm row spacing in rice.

Table 5. Straw yield and Harvest Index of rice as influenced by the main effects of Inter and Intra row spacing and number of seedling per hill

Treatment	Straw yield	Harvest index
Inter and intra row spacing		
20 * 10	4907^{d}	38.56
20 * 15	5508^{cd}	36.62
20 * 20	7296^{a}	37.32
30 * 10	6577^{ab}	35.24
30 * 15	6253^{bc}	35.60
30 * 20	6723^{ab}	37.58
LSD (0.05)	911.7**	NS
Number of seedling per hill		
2 Seedling Per Hill	5878^{b}	35.75
3 Seedling Per Hill	7169^{a}	36.37
4 Seedling Per Hill	5584^{b}	38.34
$LSD_{0.05}$	644.7**	NS
Mean	6210.	36.82
CV%	15.3	11.4

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation
Means within a column followed by the same letter are not significantly different at 5% level of significance.
NS = non-significant

The main effect of a number of seedling per hill significantly ($P<0.01$) affect the straw yield on transplanted rice. Maximum straw yield (7169 kg ha-1) was obtained from hills having 3 seedlings. The lowest straw yield (5584 kg ha-1) was recorded from 4 seedlings per hill. This might be due to the production of high total tiller at 3 seedlings per hill than an effective tiller.

4. CONCLUSION

Results revealed that plant spacing and number of seedlings per hill have considerable role in increasing yield of transplanted rice. The main effect due to plant spacing significantly influenced Number of days to 50% heading, days to 90% physiological maturity, number of total tiller per hill, number of productive tiller per hill, plant height (cm), panicle length (cm), Number of kernel per panicle, thousand seed weight and straw yield. The main effect of number of seedling per hill showed a significant effect on the number of days to 50% emergence, number of total tiller per hill, number of productive tiller per hill, plant height (cm) and straw yield. Grain yield and above ground biomass yield were also affected significantly by the interaction effects of spacing and number of seedling per hill. Optimum plant density and number of seedlings per hill ensures the plant to proper growth and development of rice. Therefore, it can be concluded that spacing 20 x 20 cm with 3 seedlings per hill appears as the best combination to obtain maximum grain yield of NERICA-4 under transplanted system of cultivation.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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