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EFFECT OF PLANTING DISTANCE ON YIELD AND YIELD COMPONENTS OF FOUR INTRODUCED UPLAND RICE VARIETIES UNDER AEROBIC CONDITIONS

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Abstract

Plant density is one of the important factors that affect yield in rice. To investigate the effect of three plant spacing (15X15, 20X20 and 25X25cm between plant and rows) on grain yield and yield components of four introduced upland rice varieties (N22, Moroberekan, Kinandang Patong and Azucena) and the local variety Anber as check variety. Afactorial experiment using a randomized complete block design with three replications was conducted under aerobic conditions. Results revealed that, spacing effect significantly ($P<0.01$) on plant height, flag leaf area, panicle number and grain number. Plant density of 15×15 cm treatment was the highest grain yield with 4.71 tonnes per hectare ($t.ha^{-1}$), while the25×25 cm treatment had the lowest with 4.09 tonnes per hectare. All studied trait were significantly different due to effect. Interactions between spacing and variety on grain yield were significant ($P=0.004$), where the variety interact differently due to spacing. N22 in 25X25cm spacing treatment was the highest and produced 6.92 t. ha^{-1}, while Moroberekan in the same spacing treatment was the lowest.

Key words : *Oryza sativa*, planting distance, yield component.

Introduction

Rice (*Oryza sativa* L.) is one of the most important crops worldwide, It occupies the second place after wheat in terms of land cultivated and production, and feeds about half of the world's population, It is the main resource for millions of people in Asia (Liu *et al*., 2007). The global rice area harvested in 2016 was 17615.79 tonnes and an annual production of 740961445 tonnes with a yield of 5.11 tonnes/ha (FAO, 2018). About 114 out of 193 countries in the world are growing rice. Countries growing rice in Asia alone produce about 90% of the Global rice production with just about half of the total crop production is accounting for India and China. Rice crop grown weather in irrigated or rain fed lowland environments need standing water in field for at least 5 – 10 cm for all or part the cropping season, but this method require a large amounts of water ranged from 50 to 80 cm (Baloch *et al*., 2002) and in some environments, these levels of water use may reaches to more than 300 cm (Hukkeri and Sharma, 1980). In addition, standing water in flooded rice fields makes it more difficult to use compost and pesticides, and to use special machines in rice fields. The large quantities of water used in rice fields give rise to thinking of rice varieties that can grow in an aerobic soil conditions after water became an important restriction factor for growing summer crops in Iraq, especially rice crop in light of the current water scarcity. It has become necessary to think about new strategies that allow growing rice in aerobic soil conditions. The varieties of aerobic conditions are hybrids that have desired traits of high production of lowland rice varieties and genetic traits that allow plant to tolerate drought (Lafitte, 2002). In addition to upland rice varieties can tolerate aerobic conditions; Plant density affects the competitions between plants on water up take and other growth resources. Thus, it is important to determine the optimum plant density that assure high yield. The plants mainly rely on solar radiation, temperature, soil moisture and fertility for their nutrition up take and optimum growth. The availability of these factors may be limited by plant spacing. Therefore, to obtain maximum yields, the optimum population density of crops is necessary to be determined (De Datta, 201981). Optimum plant density ensures proper growth of plant shoot and root system and ultimately maximum yield production. The optimum spacing rely on divers factors, some of which related to plant such as plant size, characteristics and the duration of growth period, others related to environment such as soil fertility, moisture, available nutrients and solar radiation and some others are associated to farm management such as planting methods, planting time, time and method of irrigation (De Datta *et al.*, 19737). Gorgy (2010) reported the importance of plant density in transplanted rice. Plant spacing was investigated by Mohapatra *et al.* (1989)) who reported that plant productivity in normal soil is netter that of 15X20 or 15X15cm. Patel (1973) found that plant spacing of 20X20cm increased panicle number, grain number per panicle and grain straw yield compared with that of plants growth with plant spacing of 20×15 or 20×10 cm. while Maske *et al.* (1997) confirmed that plant spacing of 15X10 cm were higher in leaf area index, plant height, and grain yield and yield components of plants compared with those of rice plants grown in 15X15 or 15X20 cm plant spacing. Singh *et al.* (1983) studied the effect of two factors (row spacing and nutrient supply) on yield of Narendra 1 rice variety which was grown in three (15, 20 and 25cm) spacing and found that plants grown in 20 cm spacing treatment out-yield those in other spacing treatments. Bari *et al.* (1984) investigated the effect of spacing on grain yield and yield components and found the plants grown in plant density of 20 × 20 cm spacing out-yield those grown in other spacing treatments. Chandrakar and Khan (1981) studied spacing effect on grain yield of tall growing indica rice varieties with three duration (early, medium and late) and determined that the 20 × 10 cm spacing produced the highest grain yield for varieties with medium and late duration. With the limitation of rainfalls in recent years, growing rice varieties under aerobic conditions in the area mainly depending saturated or flooded conditions for rice production can suggest the potential to develop a high productive rice variety suitable for water limited conditions. The aim of this study was to investigate the effect of different plant densities on grain yield and yield components of some aerobic rice varieties to find the optimum plant spacing for these rice varieties under study and to know the performance of these introduced varieties under Iraqi circumstances compared with the Iraqi variety (Anber). With the limitation of rainfalls in recent years, growing rice varieties under aerobic conditions in the area mainly depending saturated or flooded conditions for rice production can suggest the potential to develop a high productive rice variety suitable for water limited conditions.

Table 1 : variety subgroup (IND, *indica*; TEJ, *temperate japonica*; TRJ, *Tropical japonica*), type and country of origin of four introduced varieties under study.

Varieties	Type	Origin	Subgroup
N22	Upland	India	*aus*
Kinandang Patong	Upland	Malaysia	IND
Azucena	Upland	Philippines	TRJ
Moroberekan	Upland	West Africa	TRJ

Materials and Methods

To study the effect of plant density and varieties on the yield and its components in rice, a factorial experiment was carried out at a research station belong to College of Agriculture – University of Baghdad in Al-jadriya, with 33°31' N latitude and 44°36' E longitude and 34 m above sea level (https://www.latlong.net/), based on randomized complete block design with three replications. The results of soil analysis show that the texture of the soil was Silty Loam and pH 7.2. The experiment factors included three plant spacing levels (15×15, 20×20 and 25×25 cm) and five varieties, four of which are introduced upland rice varieties (N22, Moroberekan, Kinandang Patong and Azucena) (table 1) and the fifth one is the local variety (Anber). These four introduced varieties were kindly supplied by International Rice Research Institution (IRRI) - Manila - Philippine, while Amber variety was kindly supplied by rice research centre, Abu Ghraib, Baghdad, Iraq. The land was prepared including two times of ploughing and applying triple super phosphates fertilizer at a rate of 80 kg $P_2O_5.ha^{-1}$ with the secondary plough. All treatments were fertilized with urea fertilizer (46% nitrogen) at a rate of 280 kg $N.ha^{-1}$ and applied in two split doses. The first one applied after a month and the other after two months passed from the transplanting time (NPDRC, 1996). The plot area was $4m^2$. Seeds were sown in nursery on May 15 and on Jun 1. The two weeks old seedlings of the five varieties were manually transplanted at one per hill to main field in the square planting method for the three different spacing. Weed control was done manually through occasional hand picking and all other cares of cultivation were ordinarily carried out during growing season. The following parameters were measured before harvest: plant height, flag leaf area. On October 29, plants were harvested and the following parameters were measured: tiller number per meter, panicle number per meter, grain

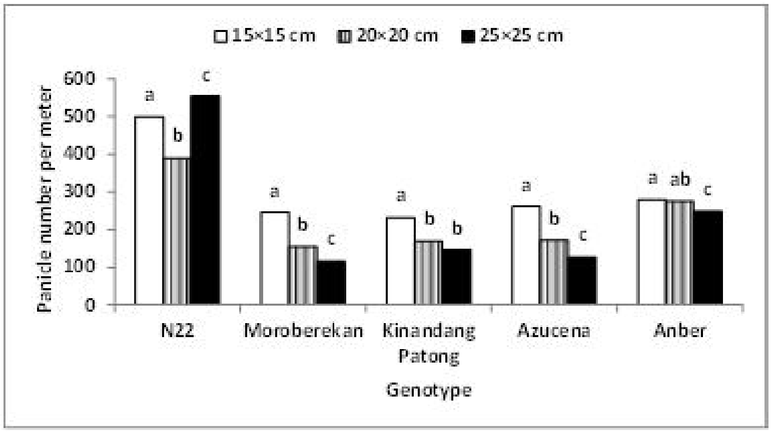

Fig. 1 : Effect of spacing and variety on panicle number per meter. Bars with different letters above are significantly different based on Fisher's protected LSD (P = 0.05) within the variety.

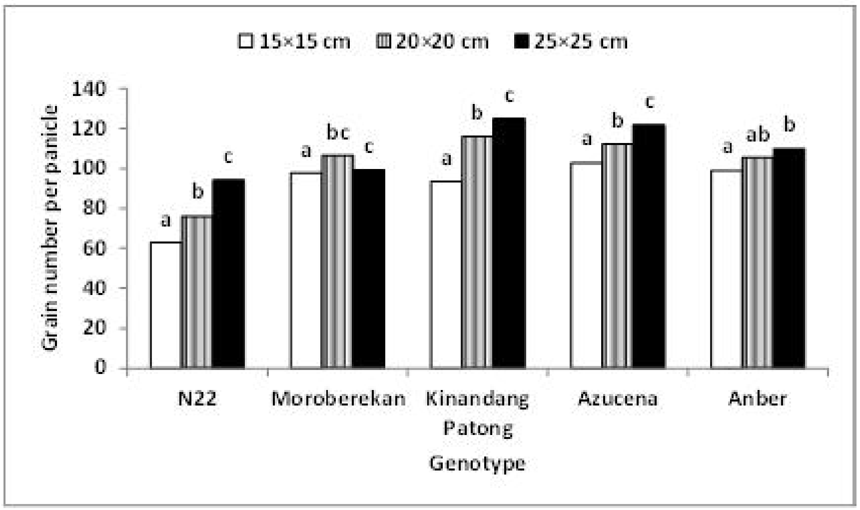

Fig. 2 : Effect of spacing and varieties on grain number per panicle. Bars with different letters above are significantly different based on Fisher's protected LSD (P = 0.05) within the variety.

number per Panicle, 1000grains weight, the percentage of unfilled grain, grain yield, biological yield and harvest index. The percentage of unfilled grain was calculated as follows: Percentage of unfilled grain = number of empty grains / number of grains × 100. The harvest index was calculated as follows: Harvest index = grain yield / biological yield × 100. Data were analysed using Gen Stat software, then the less significant differences at 5% probability level was chosen to test the means of treatments (Steel and Torrie 1982).

Results and Discussion

Plant height

ANOVA output demonstrated in table 2 shows that varieties differ significantly ($P<0.001$) in plant height, where Anber variety was the highest plant account for 130.3 cm while the N22 variety was the lowest at 101.33 cm. plant height was affected significantly ($P<0.001$) by plant spacing, where plants grown in 25 cm plant spacing overgrown those grown in 20 and 15 cm by 10.37% and 25.79%, respectively. These results reveal that plant height was linearly affected by wider plant spacing. This agreed with what Ogbodo *et al*. (2010) reported that plant height was significantly higher when plants were grown at 30 × 30 cm than at 10 × 10 cm and 20 × 20 cm, whereas, Nwokwu (2015) observed no significant differences between plants grown at 40 x 40 cm than at 30 x 30 cm in plant height. There was a significant ($P<0.001$) interaction on plant height. This shows that the plant height of the varieties under study is changing due to plant spacing.

Flag leaf area

Results of ANOVA (table 2) show that the effect of varieties on flag leaf area was significant ($P<0.004$), where Kinandang Patong variety recorded the highest flag leaf area almost equal to that of Moroberekan variety but greater than that of Anber, N22 and Azucena by 16.07%, 19.55% and 36.45%, respectively. Comparing

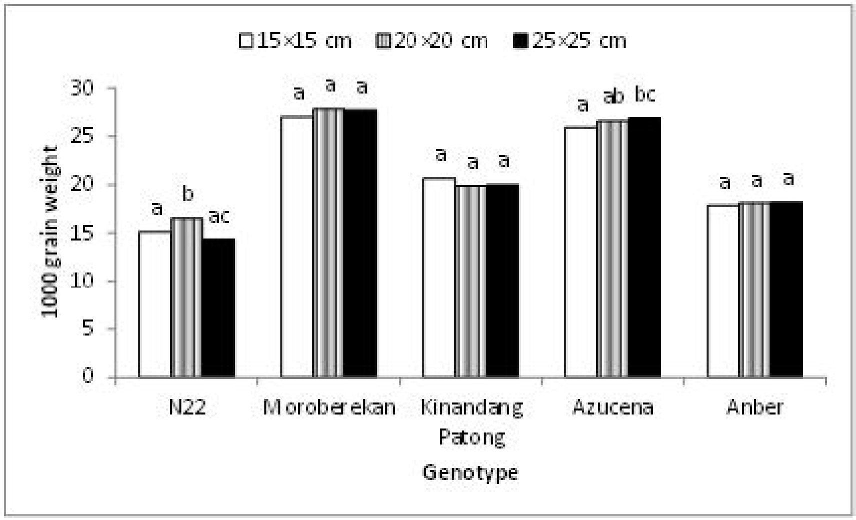

Fig. 3 : Effect of spacing and varieties on 1000 grain weight. Bars with different letters above are significantly different based on Fisher's protected LSD (P = 0.05) within the variety.

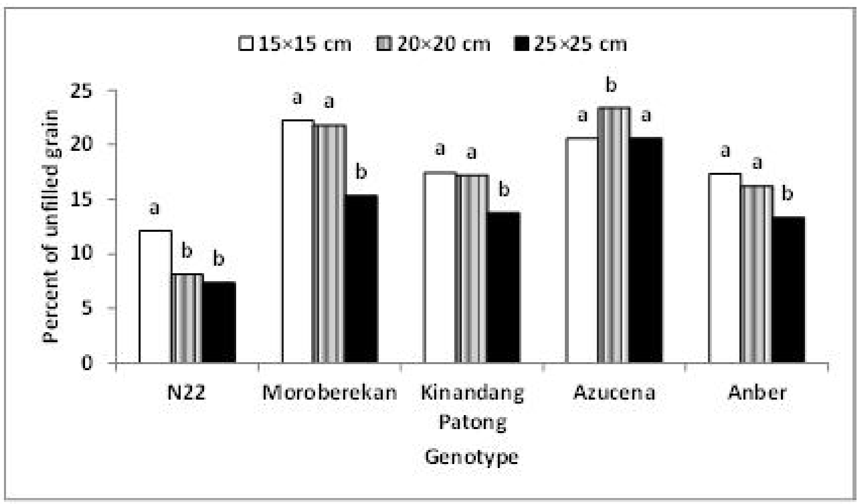

Fig. 4 : Effect of spacing and varieties on the percent of unfilled grain. Bars with different letters above are significantly different based on Fisher's protected LSD (P = 0.05) within the variety.

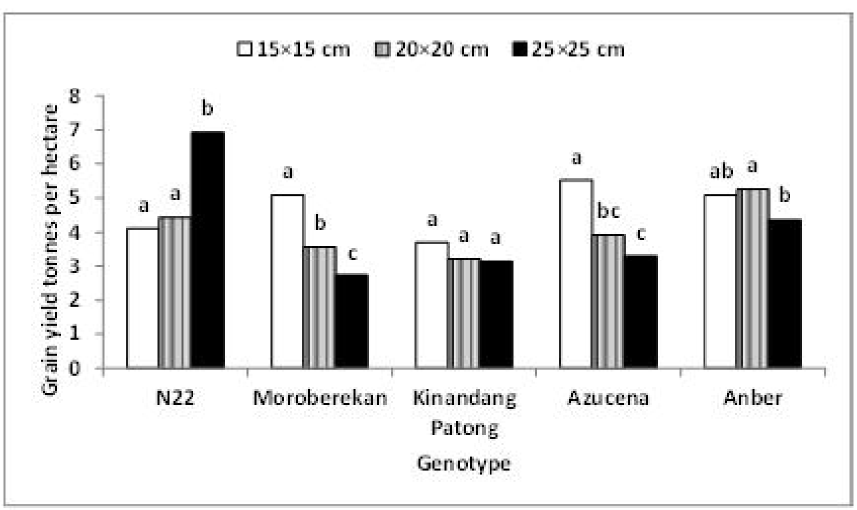

Fig. 5 : Effect of spacing and varieties on grain yield tonnes per hectare. Bars with different letters above are significantly different based on Fisher's protected LSD (P = 0.05) within the variety.

Table 2 : Analysis of variance and average of growth traits, grain yield and yield parameters of five rice varieties grown in three plant densities. Mean = 3

	Spacing	Rice varieties					Mean	*ANOVA output		
		N22	Morobe-rekan	Kinandang Patong	Azucena	Anber		V	S	VXS
Plant height (cm)	15×15 cm	87.67	115.11	105.67	78.33	111.00	**99.56**	**<.001**	**<.001**	**<.001**
	20×20 cm	104.22	106.78	120.89	105.11	130.33	**113.47**			
	25×25 cm	112.11	107.00	117.67	139.89	149.56	**125.24**			
Mean		**101.33**	**109.63**	**114.74**	**107.78**	**130.30**				
Flag leaf area	15×15 cm	32.06	35.09	37.04	29.02	35.59	**33.76**	**0.004**	**<.001**	0.241
	20×20 cm	44.60	44.87	45.12	27.98	37.63	**40.04**			
	25×25 cm	38.42	55.98	55.43	43.83	45.31	**47.80**			
Mean		38.36	45.31	45.86	33.61	39.51				
Tiller number (m^2)	15×15 cm	582.72	291.36	251.85	286.42	325.95	**347.66**	**<.001**	**<.001**	**0.001**
	20×20 cm	422.22	172.22	175.00	183.33	287.51	**248.06**			
	25×25 cm	613.33	120.89	156.44	138.67	248.89	**255.64**			
Mean		**539.42**	**194.82**	**194.43**	**202.81**	**287.45**				
Panicle number (m^2)	15×15 cm	498.77	246.91	232.10	261.73	280.01	**303.90**	**<.001**	**<.001**	**<.001**
	20×20 cm	388.89	155.56	169.44	172.22	275.97	**232.42**			
	25×25 cm	554.67	117.33	147.56	128.00	248.89	**239.29**			
Mean		**480.77**	**173.27**	**183.03**	**187.32**	**268.29**				
Grain number (m^2)	15×15 cm	62.67	97.67	93.33	102.89	98.89	**91.09**	**<.001**	**<.001**	0.275
	20×20 cm	76.22	106.56	116.11	112.00	105.56	**103.29**			
	25×25 cm	94.22	99.44	124.89	121.78	109.78	**110.02**			
Mean		**77.70**	**101.22**	**111.44**	**112.22**	**104.74**				
1000 grain weight	15×15 cm	15.11	27.00	20.67	25.89	17.89	**21.31**	**<.001**	0.543	0.603
	20×20 cm	16.56	27.89	19.89	26.56	18.11	**21.80**			
	25×25 cm	14.33	27.78	20.00	26.89	18.22	**21.44**			
Mean		**15.33**	**27.56**	**20.19**	**26.44**	**18.07**				
Unfilled grain per panicle (%)	15×15 cm	12.11	22.22	17.44	20.56	17.33	**17.93**	**<.001**	**<.001**	0.334
	20×20 cm	8.11	21.78	17.22	23.44	16.22	**17.36**			
	25×25 cm	7.33	15.33	13.78	20.56	13.33	**14.07**			
Mean		**9.19**	**19.78**	**16.15**	**21.52**	**15.63**				
Grain yield $t.ha^{-1}$	15×15 cm	4.11	5.09	3.72	5.52	5.09	**4.71**	**0.003**	0.161	**0.004**
	20×20 cm	4.44	3.58	3.24	3.93	5.26	**4.09**			
	25×25 cm	6.92	2.74	3.15	3.32	4.37	**4.10**			
Mean		**5.16**	**3.81**	**3.37**	**4.26**	**4.90**				
Biological yield $t.\ ha^{-1}$	15×15 cm	15.05	17.31	12.55	14.65	20.62	**16.04**	**<.001**	**<.001**	**0.028**
	20×20 cm	12.05	10.96	10.64	13.11	18.83	**13.12**			
	25×25 cm	14.96	9.53	11.20	9.56	17.15	**12.48**			

Table 2 continued...

Table 2 continued...

Mean		**14.02**	**12.60**	**11.46**	**12.44**	**18.86**				
Harvest index (%)	15×15 cm	29.04	29.49	29.87	37.67	25.59	**30.33**	**0.007**	0.484	0.132
	20×20 cm	37.40	33.05	31.65	30.58	28.25	**32.19**			
	25×25 cm	46.49	29.03	28.37	35.36	25.96	**33.04**			
Mean		**37.64**	**30.53**	**29.96**	**34.54**	**26.60**				

*V, varieties; S, Spacing; VXS, varieties X Spacing. The factors and interactions in bold are significant.

the means of plant spacing treatments shows that plant spacing affected flag leaf area significantly (P<0.001), where plant spacing of 25×25 cm exceeded 20×20 cm and 15×15 cm by 19.38% and 41.59%, respectively. There is no interaction between factors on flag leaf area.

Tiller number

Data of tiller number presented in table 2 demonstrated that Tiller number per meter was affected significantly by both factors (varieties and plant spacing) with (P<0.001) for both factors. Varieties show different tiller number per meter, where the highest number of tiller per meter was obtained from N22 variety with 539.42 tillers per meter and the lowest was recorded by Kinandang Patong variety with 194.43 tillers per meter. The highest tiller number per meter was obtained from plant spacing of 15×15 cm with 347.66 followed by 25×25 cm with 255.64 and 20×20 cm with 248.06. Number of tiller per meter increased as the spacing between plants decreased despite the effect of competition for water, soil nutrients and light which on plant level may decrease tiller production. Interaction between varieties X spacing was found to be significant (P=0.001) on number of tiller per meter. This means that the varieties under study interact differently due to plant spacing treatments.

Panicle number per meter

Analysis of variance presented in table 2 revealed a significant effect of spacing on number of panicle. Where Azucena, Kinandang Patong and Moroberekan had increased panicle number from 15×15 cm, to 20×20 cm and 25×25 cm plant spacing treatments. Anber, however, had almost the same productive tiller count per meter in all three spacing treatments evaluated (fig. 1), suggesting that Anber had nearly stable panicle number per meter and can be grown in both 20×20 cm and 15×15 cm spacing, unlike Azucena, Kinandang Patong and Moroberekan that need 15×15 cm spacing to produce more panicle number. On the other hand, productive tillers of N22 was affected differently due to spacing, where the highest panicle number per meter was found in plants grown in 25×25 cm followed by 15×15 cm then 20×20 cm spacing treatment. The trend of N22 variety on panicle number is similar to that observed by Mirza et al. [20] that decreased spacing reduced number of productive tillers, therefore reduced number of panicle.N22 variety produced the highest panicle number per meter with 480.77productive tillers, while Moroberekan gave the lowest panicle number per meter with 173.27productive tillers. Similar to tiller number, the interaction between varieties and spacing was found highly significant (P<0.001)for panicle number (Table 2).

Grain number per panicle

Grain number per panicle was affected significantly (p<0.001) due to spacing (table 2). The 25×25cm spacing treatment had 6.52% and 20.78% greater grain number per panicle than 20×20cm and 15×15cm plant spacing treatments, respectively. Almost all varieties were affected almost similarly due to spacing factor (fig. 2). Also, the rice varieties affected significantly (p<0.001) the Grain number per panicle (table 2). The grain number per panicle of Azucena was 44.43%, 10.88% and 7.14% greater than N22, Moroberekan and Anber respectively, indicating that rice variety appears to effect greater than spacing treatment on grain number per panicle. Greater grain number per panicle does not necessarily refer to greater grain yield. These results agree with that reported by Yan *et al*. (2010. There is no significant interaction between varieties and spacing.

1000 Grain weight

ANOVA output reported in table 2 revealed that spacing did not have significant effect on the weight of 1000 seeds. Only varieties had a significant (P<0.001) effect. The mean grain weight of Moroberekan was 79.78% greater than that of N22. Morphologically, Moroberekan seeds were thicker and larger, while N22 seeds were relatively thinner and smaller. The mean grain weight of Azucena was 72.47% greater than that of N22. Visually, Azucena seeds have a typical appearance of long rice grain; hence Azucena seeds were relatively larger and longer than N22 seeds. The grain weight of both Kinandang Patong and Anber were the same (fig. 3). Interaction between spacing and varieties on 1000 grain weight was not significant.

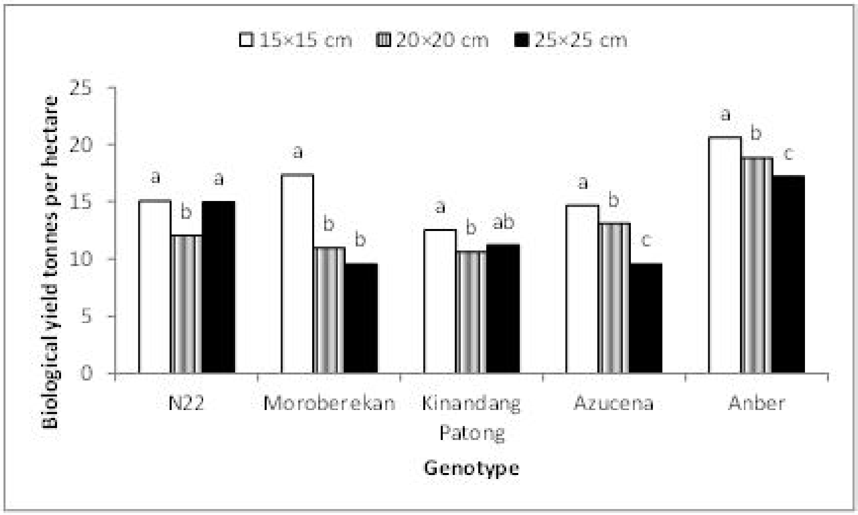

Fig. 6 : Effect of spacing and varieties on biological yield tonnes per hectare. Bars with different letters above are significantly different based on Fisher's protected LSD (P = 0.05) within the variety.

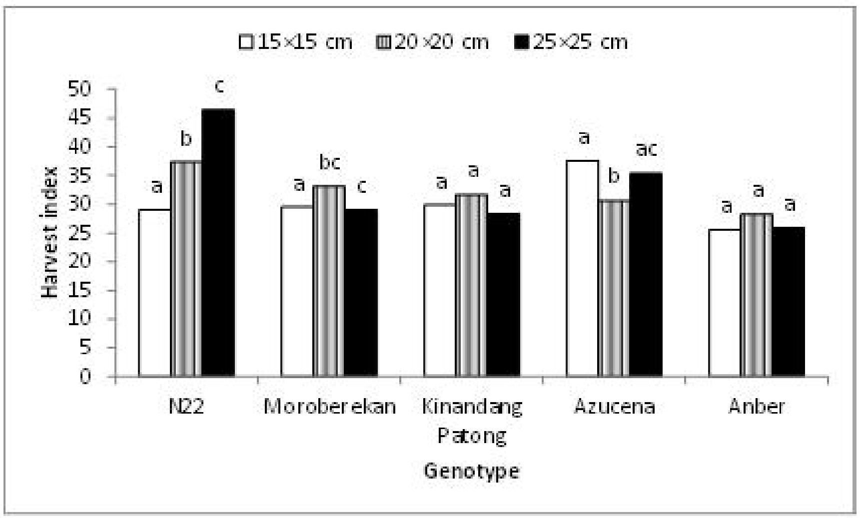

Fig. 7 : Effect of spacing and varieties on harvest index (%). Bars with different letters above are significantly different based on Fisher's protected LSD (P = 0.05) within the variety.

Unfilled grain (%)

The percentage of unfilled grain was significantly ($P<0.001$) affected by varieties (table 2). N22 had 57%, 53%, 43% and 41% lesser percentage of the unfilled grain than Azucena, Moroberekan, Kinandang Patong and Anber, respectively. Putting in mind, four of five studied varieties were introduced varieties, hence varieties with higher percentage of unfilled grain may affected by high temperature of August month through which nearly most varieties were passing through heading stage. The differences between varieties on unfilled grain than in this study were consistent with the result reported by Ying *et al*. (1998). These results also showed that a variety like N22 with small panicle size usually filled well, while Azucena and Moroberekan that belong to the tropical japonica subgroup that with large panicle size filled poorly. As mentioned above, N22 had smaller seeds that were filled well relative to the bigger seeds of Azucena, resulting in much lower percentage of unfilled grains (fig. 4). The effects of spacing on grain filling was significant ($P<0.001$). The greatest unfilled grain was under 15×15 cm spacing treatment followed by 20×20 cm spacing treatment and then 25×25 cm spacing treatment. This result indicates that the percentage of unfilled grain decreased with increased spacing. Spacing and varieties had no significant interaction effect on the percentage of unfilled grain.

Grain yield

The grain yield per hectare was significantly ($P=0.003$) affected by variety (table 2). The Indian variety N22 achieved grain yield 53.12%, 35.43%, 21.13% and 5.31% greater than that of Kinandang Patong, Moroberekan, Azucena and Anber respectively, indicating that rice varieties performed differently on grain yield trait. Similar observation was reported by Kreye *et al.* (2009). Variation in variety performance was also reported by Zhao *et al*. (2010). Results presented in table 2 showed no significant effect of spacing on grain yield, but there is a significant (P=0.004) interaction between varieties and spacing. This means that the varieties interact differently with spacing levels. For Moroberekan and Azucena, grain yield increased significantly from wider to medium and narrower spacing (fig. 5). The same trend was true with Kinandang Patong with no significant effect of spacing on the grain yield. As for Anber variety, the grain yield per meter of plants grown in 20×20 cm spacing treatment out-yield significantly those in 25×25 cm spacing treatment, but not the 15×15 cm spacing treatment. This result is consistent with observations of Singh *et al.* (1983). On the contrary, the grain yield of the Indian variety N22 in25×25 cm spacing treatment was35.84% and 40.61% lower than yield in20×20 cm plant spacing treatment and 15×15 cm plant spacing treatment respectively. The production of grain yield per unit area relies mainly on the individual performance of each plant, number of panicles, number and weight of grain per panicle. Spacing between plants influence all these yield parameters through affording enough space allowing plants to receive necessary light, water and nutrient. In this studies N22 variety grown with wider spacing perform better than that with narrower spacing. This variety performance is consistence with observation reported by Chandrakar and Khan (1981).

Biological yield

Biological yield was affected significantly (P<0.001) due to variety (table 2). Varieties show different biomass accumulation, where the highest biological yield was obtained from Anber variety with 18.86 tonnes per hectare and the lowest was recorded by Kinandang Patong variety with 11.46 tonnes per hectare. Spacing affected biological yield significantly (P<0.001). The highest biological yield was obtained from spacing of 15×15 cm with 16.04 followed by 20×20 cm with 13012 and 25×25 cm with 12.48. Interaction between varieties X spacing was found to be significant (P=0.028) on biological yield. This means that the varieties under study interact differently due to plant spacing treatments (fig. 6).

Harvest index

Varieties differ significantly (0.007) on harvest index, where N22 had the highest (37.64%) harvest index followed by Azucena (34.54%), Moroberekan (30.53%), Kinandang Patong (29.96%) and the lowest was Anber variety (26.6%). This result is consistent with that reported by Zhao *et al*. (2010, who investigated tropic aerobic conditions - bred rice genotypes and found most tested rice genotypes have greater harvest index and produced more grain yield than check varieties. Spacing and interaction between varieties and spacing was found to have no significant effect on harvest index (table 2).

Conclusion

Spacing, varieties and the interaction between spacing and varieties significantly affected growth traits, biological and grain yield. N22 was best in 25×25 cm spacing treatment but Morobe-rekan, Kinandang Patong and Azucena produced more in 15×15 cm spacing treatment, while the local variety Anber can nearly equally produce grain in the three spacing treatments. The interaction between spacing and varieties suggest the necessity for rice variety specific for plant density. Results support the potential of obtaining higher grain yield rice variety with appropriate plant density under aerobic conditions

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