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Effect of Plant Spacing on the Growth and Yield of Rainfed Rice (*Oryza Sativa*) in the Bimodal Rain Forest Zone of Cameroon

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Abstract

A study was carried out on plant density at the experimental field of the Institute of Agricultural Research for Development (IRAD) Nkolbisson, Yaoundé to determine the appropriate spacing to improve rainfed rice production in the bimodal rainfall forest zone of Cameroon. The experiment was conducted during the main cropping seasons of 2017 and 2018. The planting spacing used were 15cm x 15cm, 20cm x 20cm, 25cm x 25cm and 30cm x 30cm giving the plant populations of 444444, 250000, 160,000 and 111,111 plants / ha respectively using two varieties (Nerica 3 and Nerica 8). The experiment was laid out in a randomized complete block design with three replications. Significant differences were observed in the growth and yield across the years. Treatments were highly significant concerning the number of days to the appearance of the first flower, the number of days to 50% flowering, and the number of days to 50 % maturity. Plants were taller with more tillers and gave higher yields in 2017 than those of 2018. The spacing significantly affected the plant height, number of tillers, and panicle length for both varieties. The interaction of spacing and variety was significant for the number of tillers per m2 and the number of seeds per panicle, however, it was not for the weight of 1000 grains and the percentage of full bales. The yield components determining yield increase were the number of panicles / m2 and the number of seeds/panicles. Nerica 3 variety gave higher yields compared to the Nerica 8, the closer the spacing, the higher the yield. There were a strong significance and positive correlation between yield, number of panicles, and the number of grain per panicle. The spacing that gives the highest number of panicle per m2 was 15 cm X 15 cm and this spacing gave good yield in the region where the study was carried out.

Keywords: Pant density; Rain-fed rice; Growth parameters; Grain yield.

1. Introduction

Rice (Oryza sp.) is the staple food of more than half of the world's population [1]. It ranks as the second most commonly grown cereal crop in the world after wheat [2]. In Africa, rice has become a very strategic and priority product for food security, and its consumption is growing faster than any other major commodity on the continent due to significant population growth, rapid urbanization, and rapid growth as well as changes in eating habits [3]. In a recent report, the national demand for rice in Cameroon for 2020 stood at 576,949 tones [4]. According to the latest household consumption survey, the average per capita rice consumption in Cameroon in 2018 was estimated at 40.56kg per inhabitant on national average. According to data on imports in 2017, from the National Institute of Statistics, about 728,443 tons of rice was imported, making the country to spend close to CFAF 183.7 billion. In order to reduce rice importation, the Cameroonian government, accompanied by its international partners, set up a strategy for the development of rice growing in Cameroon [5], which began with the introduction of the improved NERICA rice varieties.

The new rice for Africa (NERICA) was developed by WARDA following interspecific crosses between Asian rice *Oryza sativa* and African rice *Oryza glaberrima* perfectly adapted to harsh growing conditions. NERICA rice varieties are able to cope with most of the constraints of rice cultivation, such as improved weed competitiveness, drought tolerance and resistance to pests or diseases or simply higher yield potential [6].

Before 2008, irrigated rice and lowland rice cultivation were common in Cameroon, mainly in the areas of Yagoua, Maga, Lagdo, Menchum Valley, and the plains of Ndop, Mbaw and Mbo. Nowadays, with the introduction of the NERICA varieties, there are numerous localities constituting emerging basins (Nanga Eboko, Ebolowa, Galim, Batouri, Akono,) for the production of rice. However, technical challenges still have to be met for the wider dissemination of rain-fed rice cultivation. Rice is a relatively new crop, exotic and unfamiliar for upland farmers in many parts of Africa. The optimal plant density in plateau rice production and crop management is an example of such challenges [7].

Plant spacing plays an important role in rice growth and yield. The optimal density of plants allows the plant to grow properly with their above-ground and underground parts using more solar radiation and soil nutrients. Narrower spacing hinders cross-cultural operations. In high plant density, the competition between the plants increases for the nutrients, air and light, which generally entails a mutual shade, lodging and thus favors a yield in straw higher than that in grains. This paper aimed to investigate the effects of spacing on agronomic parameters of rice and optimum densities / spacing to high yield of rice production in Cameroon.

2. Material and Methods

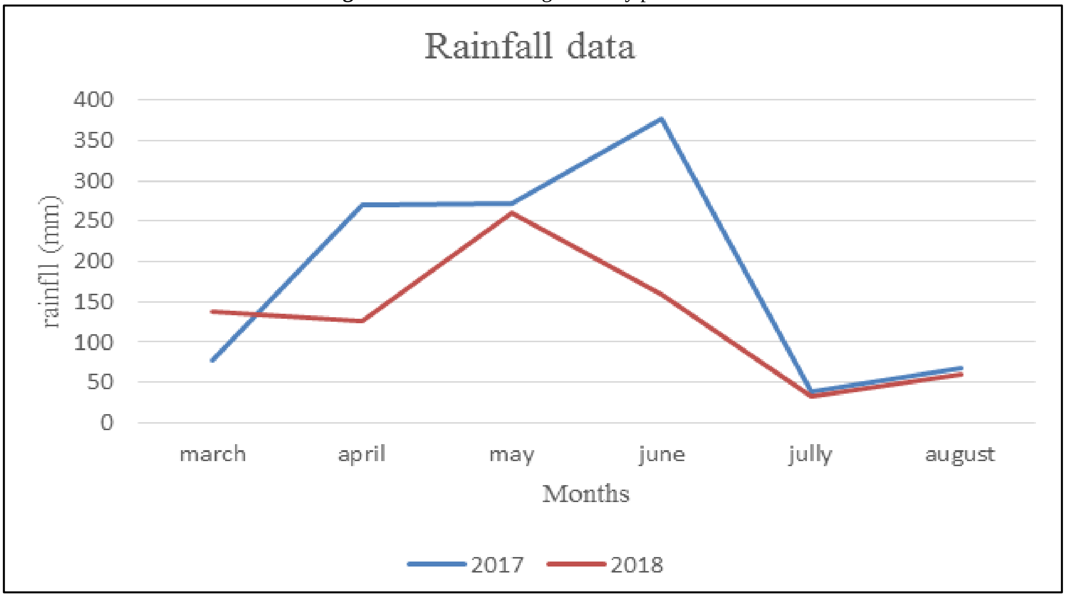
2.1. Materials

2.1.1. Experimental Site

The study was carried out at the IRAD Nkolbisson site, located in the city of Yaounde, Central Region of Cameroon during the main planting seasons of 2017 and 2018. Nkolbisson is located at latitude 3.8712° N and longitude 11.4538° E.

Fig. 1 shows the rainfall data recorded during the two years of experimentation.

Fig-1. Rainfall data during the study period



Source: JICA

2.1.2. Plant Material

The plant material used in our study consisted of two improved varieties (Table 1) of rain-fed rice, the basic seed of NERICA (New Rice for Africa) varieties from Africa Rice namely NERICA3 (N3), NERICA8 (N8). These varieties were adopted during participatory varietal selection conducted for the introduction of NERICA varieties in Cameroon by the Rice Competitiveness Improvement Project in Central Africa.

Table-1. Agronomic characteristics of varieties

Variety	Ecology	Crop cycle (days)	Yield (ton/ha)
NERICA 3	Pluvial	100 - 110	3 – 4
NERICA 8	Pluvial	90 - 100	3 – 4

Source: Institute of Agricultural Research for Development (IRAD)

2.2. Method

2.2.1. Experimental Design and Field Management

The trial was set up in a completely randomized block design with three replications. The different treatments were applied using the following spacing: 15cm x 15cm, 20cm x 20cm, 25cm x 25cm, and 30cm x 30cm

The following operations were carried out:

-Land preparation: The land was cleared and ploughed from the onset of the rains;

- Sowing: seedlings were sown at the rate of 3 to 5 seedlings per stand using the various planting spacing mentioned above;

- Thinning: Plants were thinned to two per planting station three weeks after planting.
- Weeding: weeding was done three times manually before harvest;
- Fertilizer application: NPK (20-10-10) was applied at the rate of 200kg/ha two weeks after planting and urea fertilizer was applied twice at panicle initiation and meiosis at the rate of 50 kg / ha;
- Protection against birds was provided by a net.

2.2.2. Data Collection

The data collected were the number of days to appearance of the first flower, the number of days to 50 % flowering, the number of days to 50 % maturity, plant height, number of tillers, and yield parameters such as the number of tillers per m^2, the number of grains per panicle, the weight of thousand seeds, and the percentage of full bales.

2.2.3. Data Analysis

The data collected were subjected to analysis of variance using SAS software version 9.2 software and the means of parameters were separated by Tukey's tests at the 5% probability level.

3. Results

3.1. Growth Parameters

There was a significant difference in plant growth between the two years. Treatments were highly significant according to the number of days for appearance of the first flower, the number of days for 50 % flowering and the number of days for 50 % maturity, the height of plants, tillers number and the length of panicles (Table 2 and 3).

Table-2. Growth stage characteristics

Source of Variation	Mean square			
	Df	NDFF	ND 50% F	ND50%M
Replication	2	9,5ns	75,87***	1,54ns
Varety	1	32,66**	70,04***	73,5ns
Treatment	3	9,38ns	57,15***	208,94**
Error		4,2	3,44	31,9
G mean		67,25	79,12	107,91
Coef var		3,06	2,34	5,23

***highly significant, **very significant, * significant, Ns non-significant, Df degree of freedom, **NDFF**: Number of days for appearance of the first flower, **ND 50% F:** number of days for 50 % flowering**, ND50%M:** number of days for 50 % maturity G: General, CV: Coefficient of variation

The number of days for appearance of the first flower was not significantly different for the treatments but was very significant for the varieties used. It was 68, 41 for Nerica 3 and 66, 08 for NERICA 8 (Fig. 2).

Regarding the number of days to 50 % flowering, there was highly significant difference for the varieties and treatments. At 77 days NERICA8 reach at 50 % flowering while NERICA 3 reach at 80, 83 days. Treatment 15cm x 15cm reach at 50 % flowering at 76 days and at 30cm x 30cm at 83, 16 days.

As concerns the number of days for 50 % maturity, we noticed a very significant difference between the treatments at 15cm x 15cm the number of days for 50 % maturity was 104,16 days, at 20cm x 20cm it was 103,5 days, at 25cm x 25cm it was 107,66 days, and 30cm x 30cm, 116,33 days (Fig. 3).

Fig-2. Number of days by variety

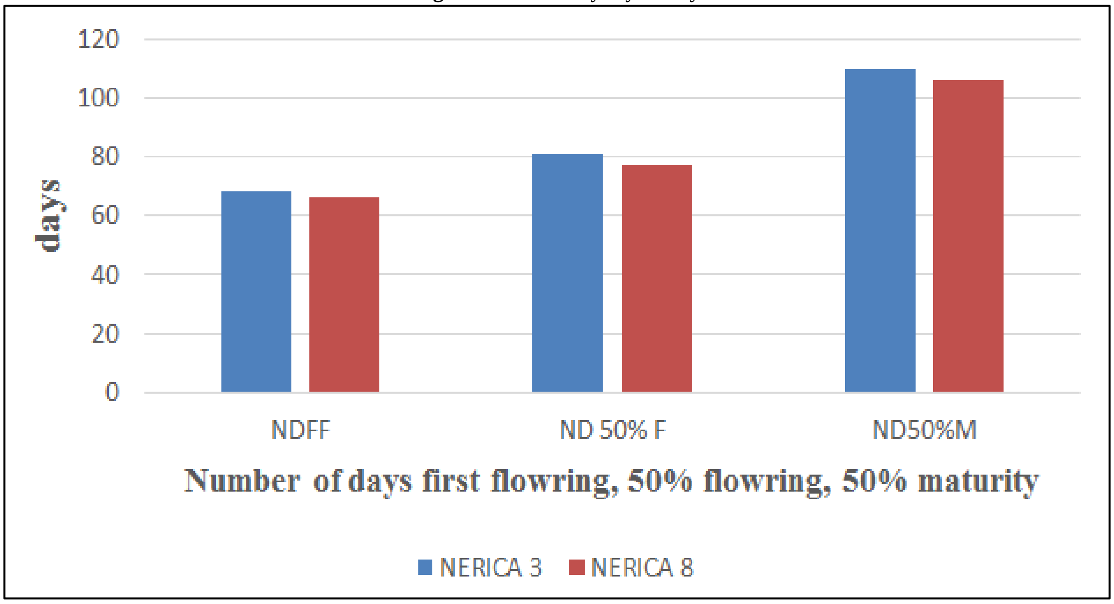


Fig-3. Number of days by treatments

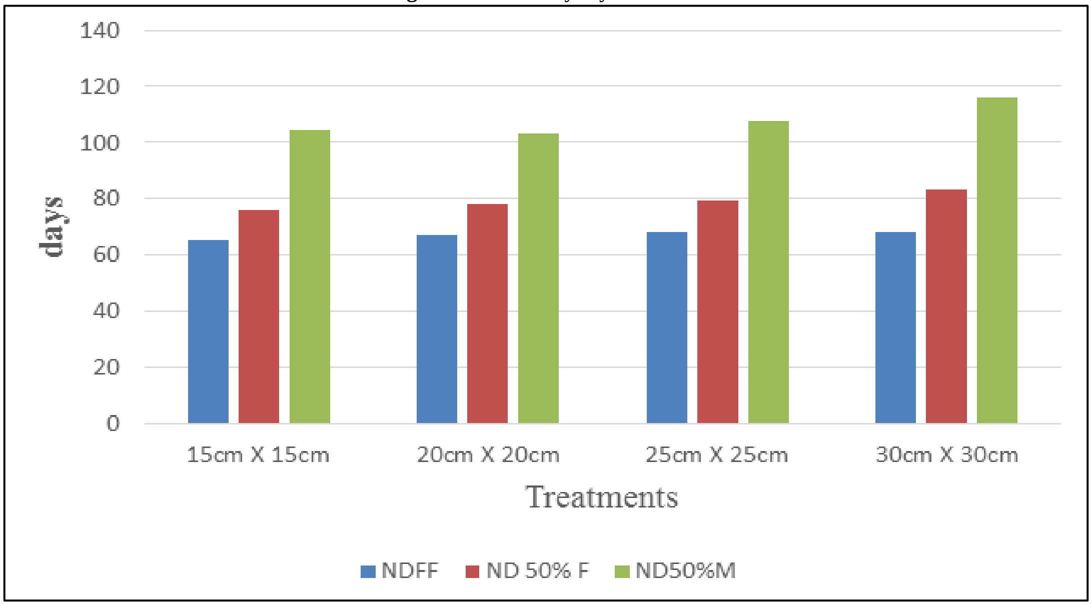


Table-3. Agronomic characteristics

Source of Variation	Mean square			
	Df	HP	TN	LP
Year	1	949,61***	52,22***	58,61***
Replication	2	281,45*	8,89ns	2,31
Varety	1	426,44***	1,89ns	0,48
Treatment	3	398,40	44,59***	9,09**
Error		38,5	1,90	55,20
G mean		106,69	9,21	24,1
Coef var		5,81	2,01	5,7

***highly significant, **very significant, * significant, Ns non-significant, Df degree of freedom, **PH**: Height of Plant, **TN:** Tiller number, **PL:** panicle lengths**,** G: General, CV: Coefficient of variation

3.1.1. Plant Height

Plants experienced high growth period from 6th to 14th week in the two years. In 2017, the plants high were greater than those in 2018 for the two varieties (Fig. 4).

The average height of the plants per variety was not significantly different from week 6 to week 12. However, a significant difference in plant height was observed from week 14 for spacing of 15cmX15cm and 25cmX 25cm, 30cmX30cm and 15cmX15cm, 15cmX15cm and 20cmX20cm for all the varieties. The plant height of Nerica 3 became significantly higher than that of Nerica 8 for all the spacing (Fig. 5).

Regarding the size of the plants compared to the treatments there was no significant difference in the average size of the plant from the 6th to the 8th week between these treatments. We noticed a significant difference in size between these different treatments: 15cmx15cm, 25cmx25cm, 30cmx30cm; treatments such as in 20x20, 25x25, and 30x30 from the 10th week to the 14th week (Fig. 6).

The behavior of average plant size varied according to the year, plant varieties and densities. Here we observed that the plant height of Nerica 3 was significantly higher than that of Nerica 8 (Fig. 7).

Fig-4. Plant height by year

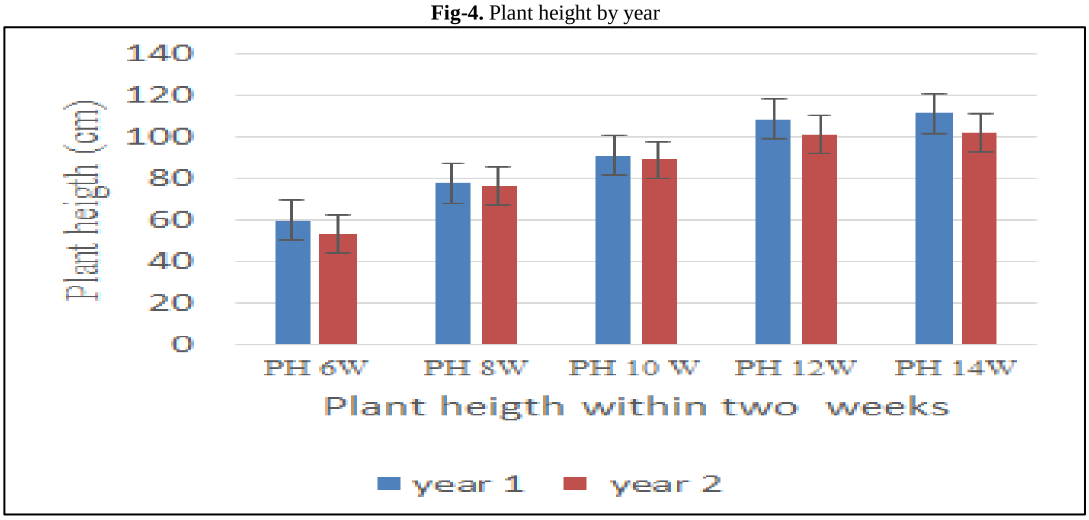


Fig-5. Plant height by variety

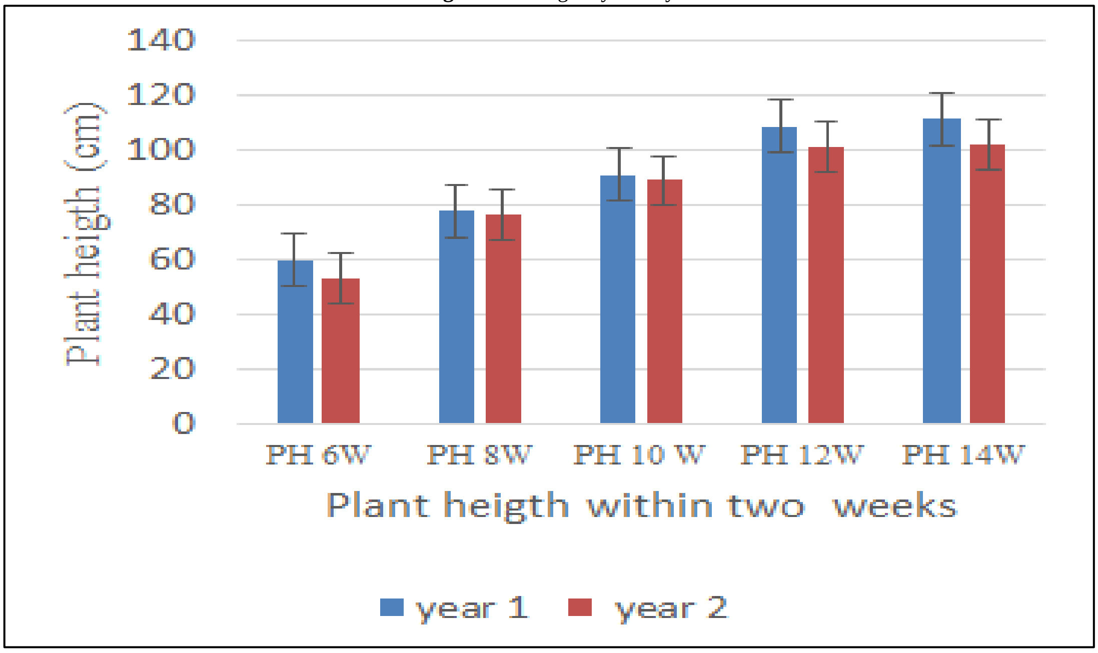


Fig-6. Plant height according to treatments

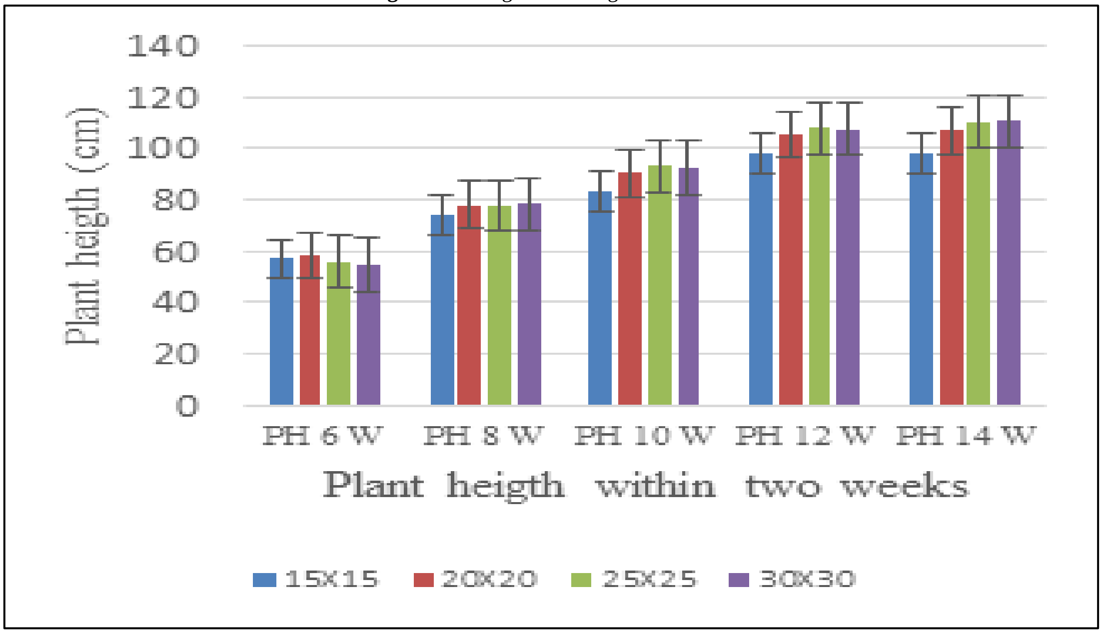
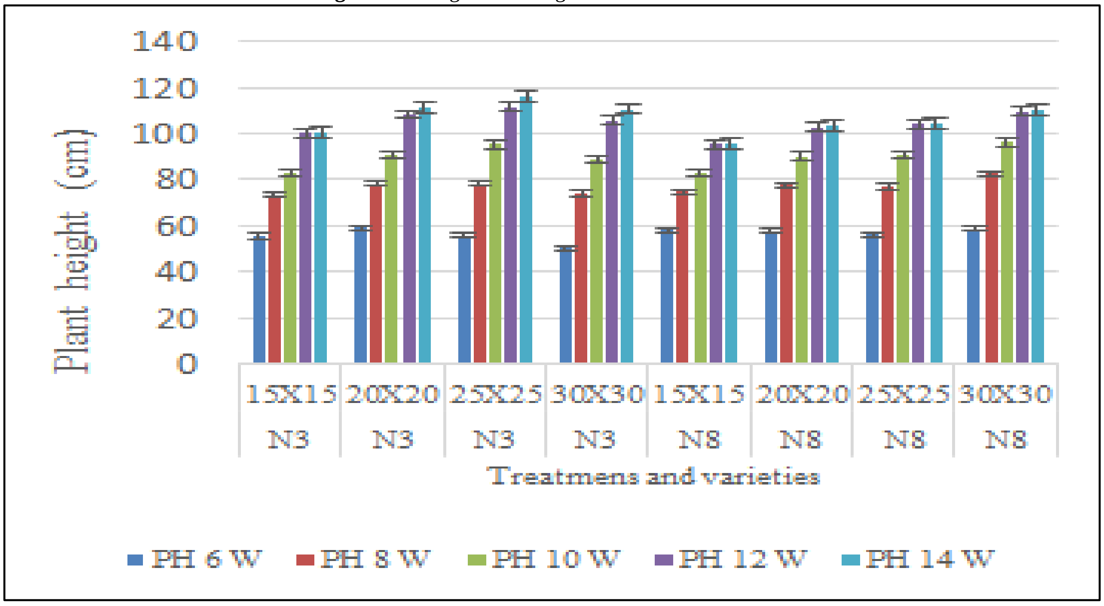


Fig-7. Plant height according to varieties and treatment



3.1.2. Number of Tillers

Very significant differences were observed in the number of tillers between the two years of evaluation (Fig. 8). Six weeks after planting, we had an average of 7.5 tillers in 2017 and 6 in 2018. At the 14th week there were 10.22 tillers in 2017and 8.15 in 2018.

The variation of the number of tillers per variety increased progressively for Nerica 3 and Nerica 8, but this number of tillers was not significantly different from one variety to another. At week 6, the average number of tillers was 7 for both Nerica 3 and Nerica 8 while it was 9 for at the 14 week for both varieties (Fig 9).

The number of tillers varies significantly with the treatment from 6 to 8 weeks but the difference was not significant. There was significant variation at the 8th week for the spacing of 30x30 and 15x15, 25x25 and 15x15, 15x15 and 20x20 treatments. At week 12, significant difference was observed for all treatments excepted for 20x20 and 25x25. At the 14th week, the difference became significant between 30x30 and 20x20, 15x15 and 30x30, 15x15 and 25x25 (Fig.10).

At 6 weeks, there was no significant difference in the number of tillers for all treatments per variety. There was significant difference from the 8th week for both varieties; at 14 weeks, the number of tillers was significantly different for the two varieties at 30x30 and 20x20, 30x30 and 15x15, 25x25 and 15x15 (Fig. 11).

Fig-8. Tiller number per year

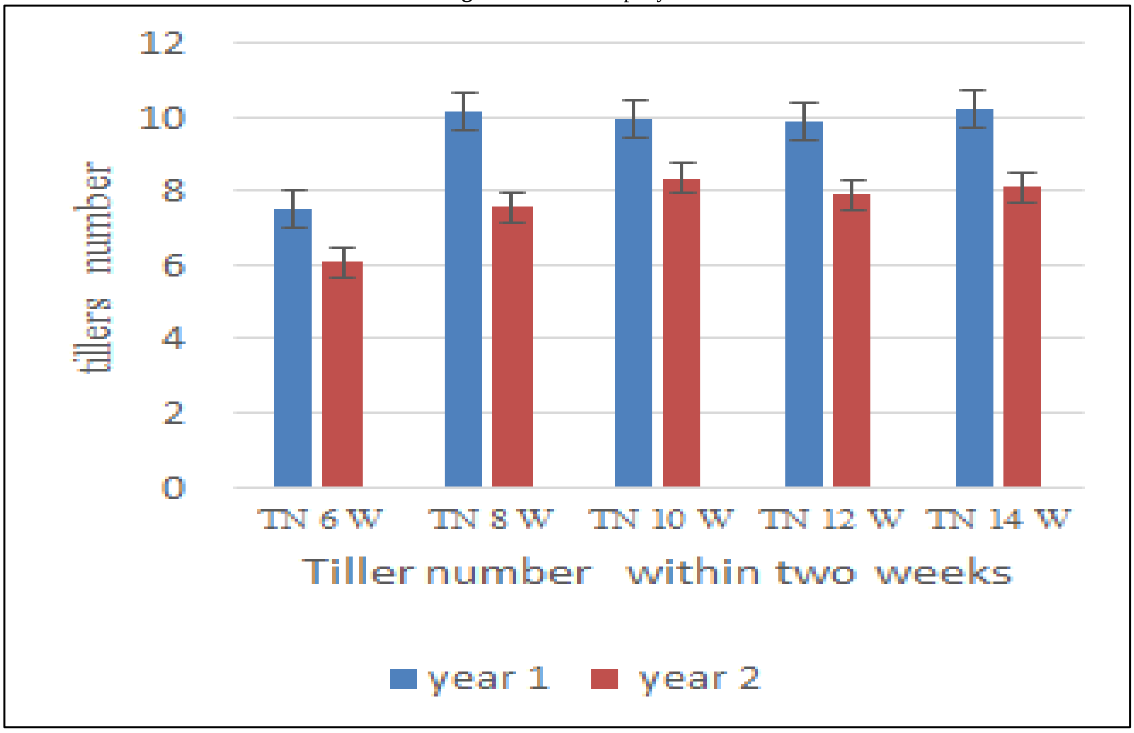


Fig-9. Tiller number by varieties

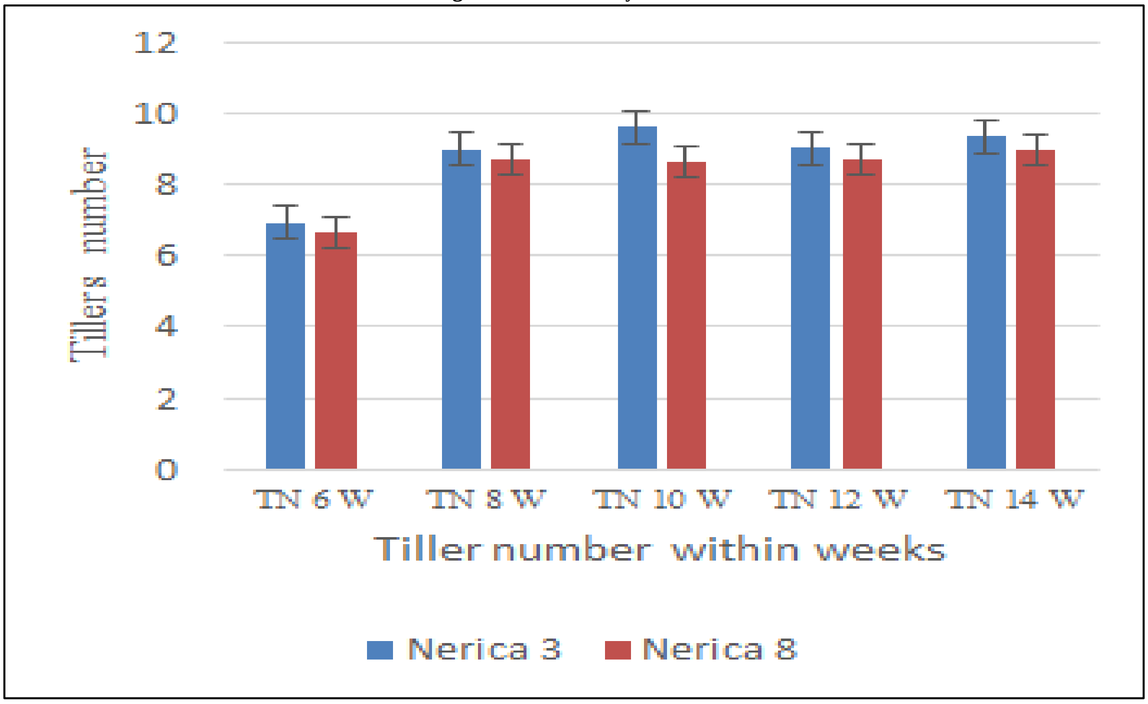
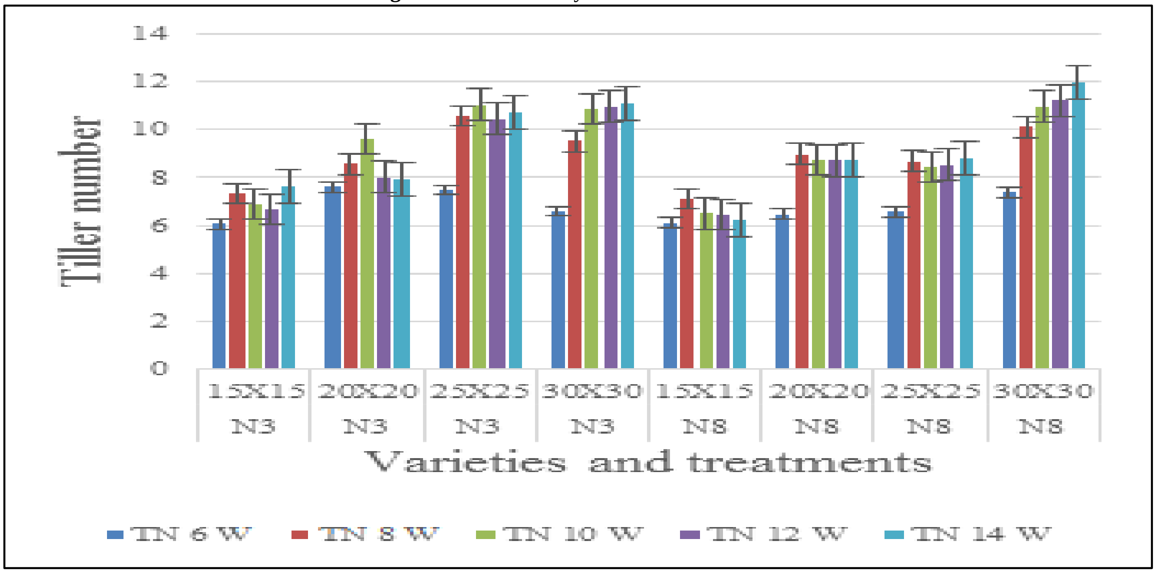


Fig-10. Tiller number by treatment

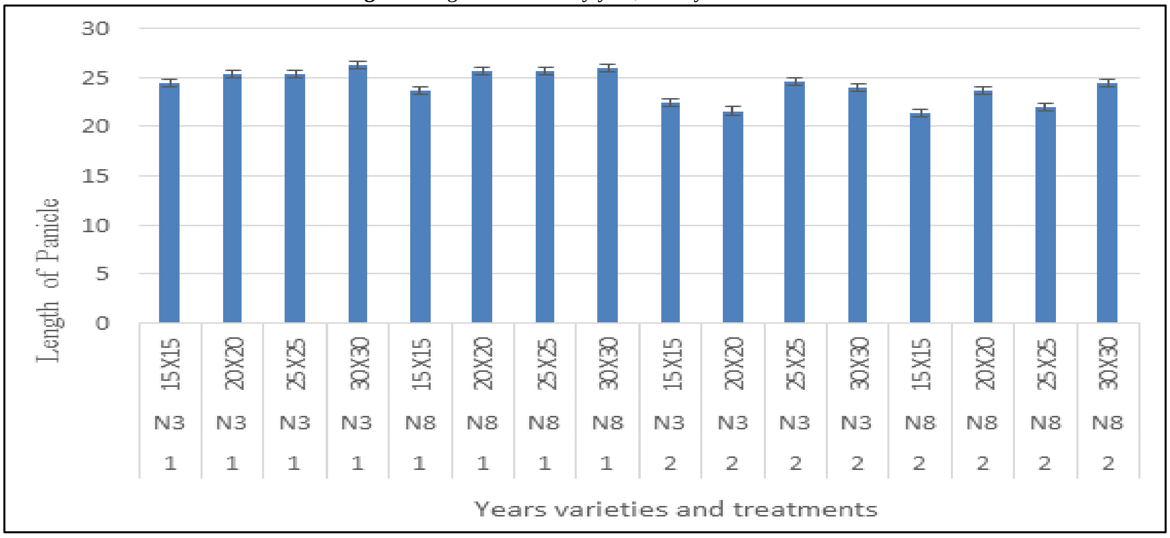
Fig-11. Tiller number by varieties and treatment



3.1.3. Panicle Length

There was a significant difference in panicle lengths over the two years. In 2017, the average panicle length was 25.23 whereas in 2018, it was 23.04. There was no significant difference between the two varieties per year. Regarding treatments, the panicle length was significantly different for the 30x30 and 15x15 spacing for both years and both varieties (Fig 12).

Fig-12. Length of Panicle by year, variety and treatment



3.2. Yield Estimates

Table 4 reveals how certain yield components vary with the treatments and varieties used. There were highly significant and significant differences in the number of tillers per m^2 and the number of seed per panicle.

Table-4. Yield Parameters

Source of variation	Mean square					
	Df	**NT/m2**	**NS/P**	**%GP**	w of 1000 seeds	**Yt/ha**
Years	1	5179,34*	3184,68*	2722,24***	43,49***	49,37***
Replication	2	6362,22**	123,65ns	27,48ns	1,62ns	7,37*
Variety	1	2330,67*	467,33ns	397,08*	0,5ns	11,666*
Treatments	3	27812,9***	3062,67*	44,04ns	2,4ns	5,38ns
Error	29	732,9	400,60	25,40	45,29	2,81
G.mean		176,61	142,19	82,14	28,47	5,84
CV		15,32	14,07	6,13	4,3	28,-_

***highly significant, **very significant, * significant, Ns non-significant, Df degree of freedom, **NT/m²:** number of tillers per m^2, NS/**P:** number of seeds per panicle**, W** of 1000 seeds: Weight of 1000 seeds, **Yt /ha:** yield per hectare, G: General, CV: Coefficient of variation

3.2.1. The Weight of 1000 Grains

There was significant difference in the weight of 1000 seeds between the two years, in the second year the average was 29.46 and in the first year it was 27.52. There was no significant difference between the two varieties and the treatments for the two years (Fig.13)

3.2.2. The Number of Tillers per Square Meter

The number of tillers per m^2 varied from one year to another. We observed a very significant difference in the number of tillers between the two years. In the first year, the average was 188.92 and in the second year it was 163.85. There was also a significant difference between the two varieties for each year of experimentation with an average of 185.44 for 2017 and 167.48 for 2018 year. As regards the treatments, the number of tillers per m^2 was significantly different for the spacing of 25cmx25cm and 15cmx15cm, 15cmx15cm and 20cmx20cm, 30cmx30cm and 15cmx15cm, 20cmx20cm and 25cmx25cm, 30cmx30cm and 20cmx20cm for both varieties during the two years of cultivation (Fig.14).

3.2.3. The Number of Seeds Per Panicle

The number of seeds per panicle varied significantly from one year to another. In the first year the average of this number was 150,067 and in the second year it was 133,979. There was no significant difference between the two varieties for each genotype per year. With regard to treatments, the number of seeds per panicle was significantly different for the 25cmx25cm and 15cmx15cm, 30x30 and 15cmx15cm5, 20cmx20cm and 15cmx15cm spacing for the two growing years and the two varieties (Fig.15).

3.2.4. The Percentage of Full Bales

The percentage of full bales varied with years, treatments and spacing. There was significant difference in the percentage of seed between for the two years, with an average of 89.43 in the first year and 74.54 in the second year. Also, there was a significant difference between Nreica3 and Nerica 8 for each year of cultivation with a respective average of 84.70 and 79.48. There was also no significant difference regarding the treatments, for the two varieties over the two years (Fig. 16).

Fig-13. The weight of 1000 seeds

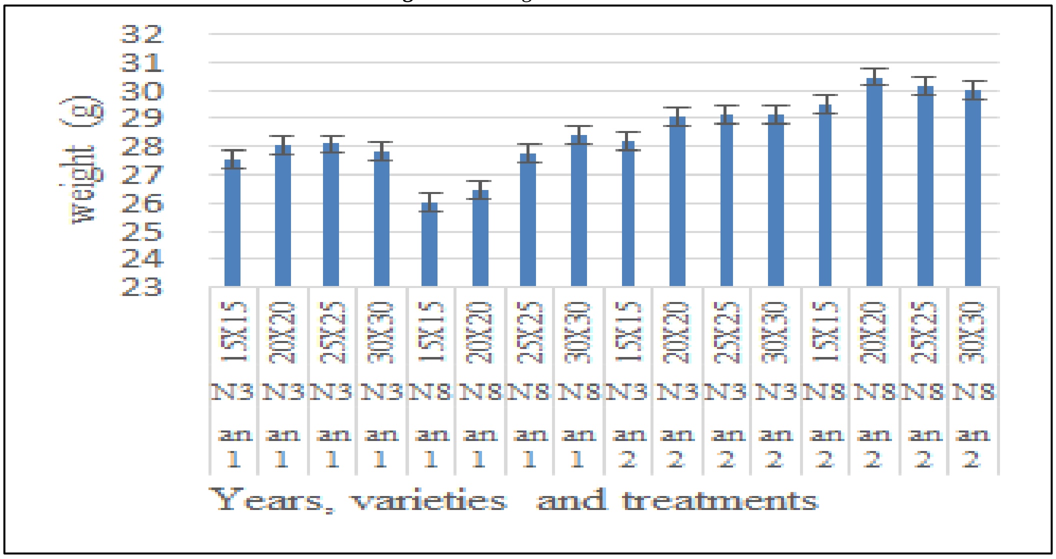


Fig-14. Tiller number per m^2

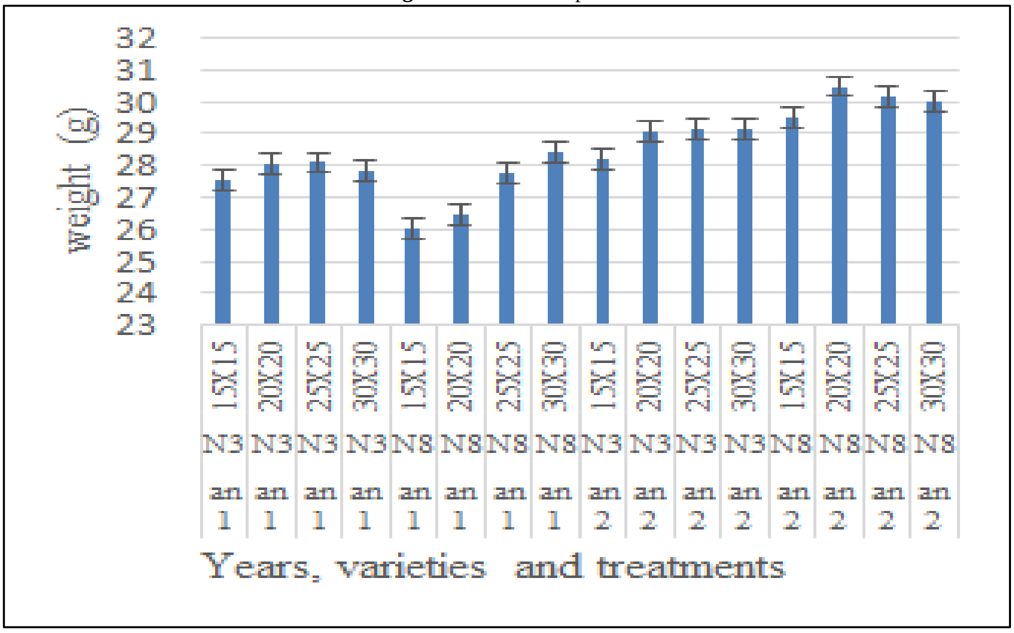


Fig-15. Number of seeds per panicle

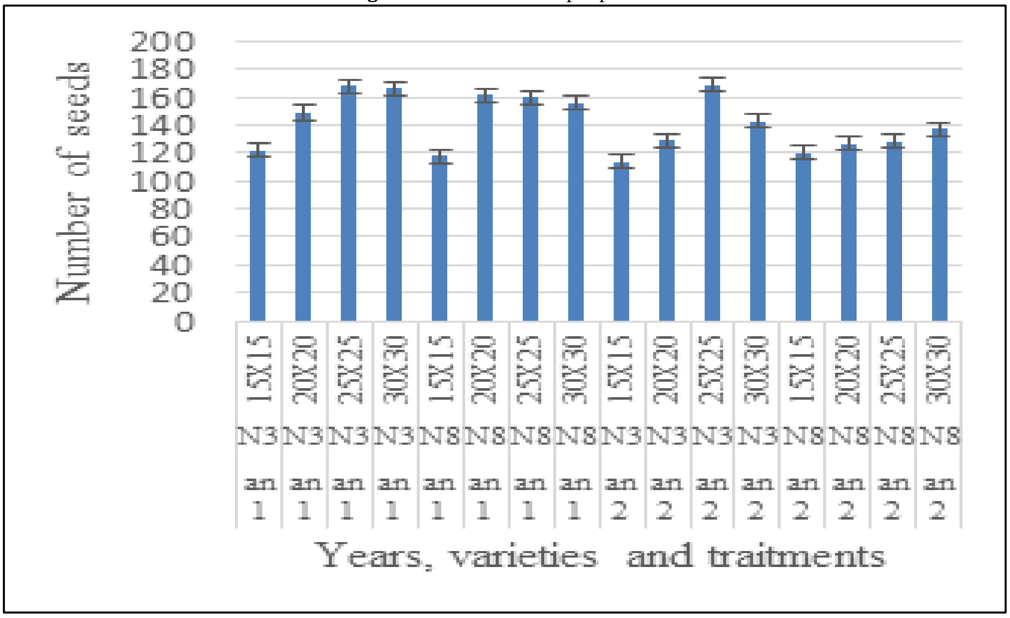
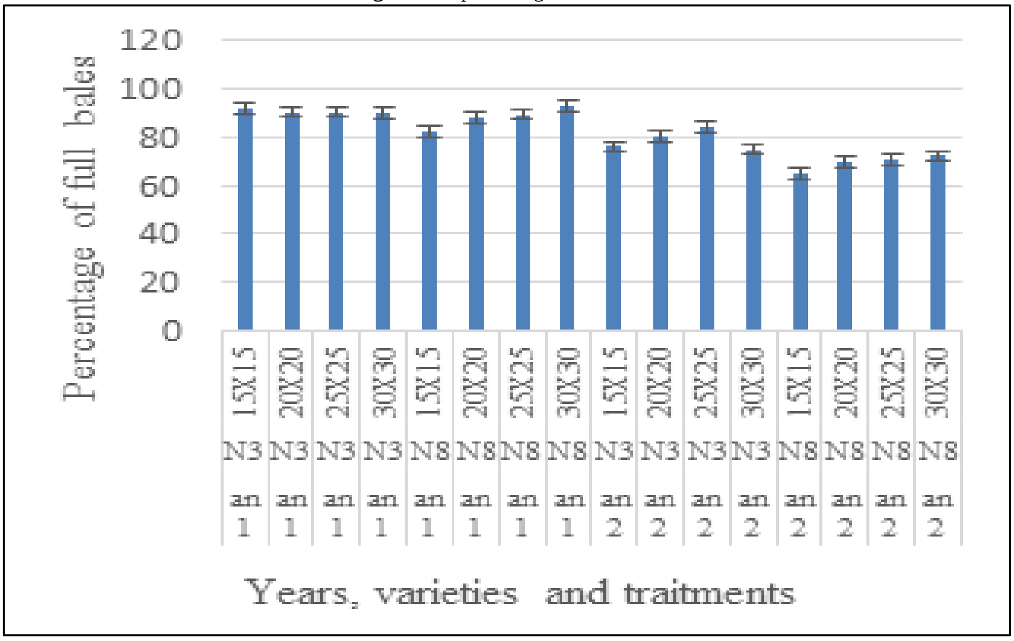


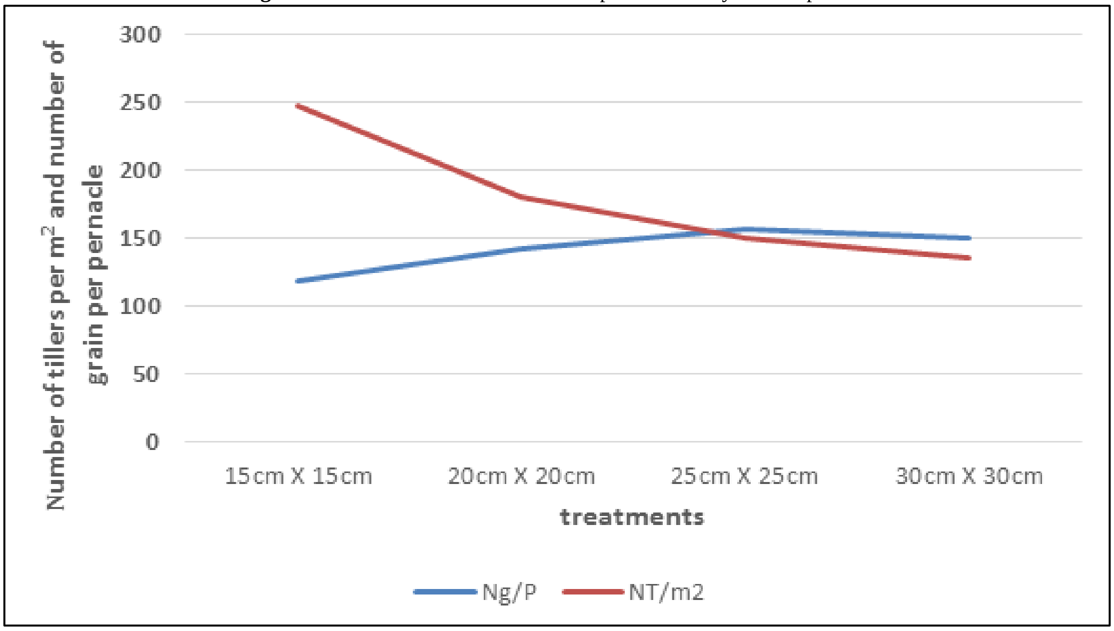
Fig-16. The percentage of full bales



3.3. Influence of Treatments on Yield and Yield Components

A significant difference was observed in the performance of rice genotypes across the years. In 2017, the average yield was 6.48t/ha and 4.76 t/ha in the second year (Fig. 17). The significant difference was observed between the two varieties for each genotype per year with an average of 6.35 for N3 and 5.3 for N8. In contrast, spacing showed no significant difference in the yields for both varieties during the two growing years. The non-significant difference of the weight of 1000 seeds and the percentage of full seeds showed that yield components that determined yield increase were the number of panicles / m^2 and the number of seeds / panicles were highly significant. According to this, the choosing of an appropriate spacing can be based on the number of tillers per m^2 and the number of grain per panicles. The spacing that gave the higher number of panicle per m^2 was 15 cm X 15 cm and this spacing give the good yield in the region where the study was carry out.

Fig-17. Influence of treatment on the two parameters of yield components



3.4. Correlation between Yield Parameters

There is a correlation between the different parameters used to calculate the yield (Table 5). There is a strong significant positive correlation between the yield and the tiller number per m^2 (0, 70***), and the number of grain per panicle (0, 48**).

Table-5. Correlation between yield parameters

Parameters	Number of grains/panicle	% of full grains	TN/m^2	Weight of 1000 grains	Yield
Grains/panicle	1				
% of full grains	0,539**	1			
TN/m2	-0,223	0,16	1		
Weight of 1000 grains	-0,18	-0,448	-0,334	1	
Yield	0,48***	0,663**	0,706***	-0,37	1

4. Discussion

The results obtained in this study show significant differences in all the parameters collected over the years.

Significant differences were observed in the number of days for 50 % flowering, and the number of days for 50 % maturity per treatments. The tightest plants spacing decrease the number of days for 50 % flowering and maturing. These results in accordance to those of Schaafsma and Tamburic-Ilincic [8]. Then we can choose the spacing according to the period of sowing. The results of the current study reveal that high crop density could be applied to reduce the life cycle of the plant during short raining season.

The plants were found to be taller with more tillers in year 1 than in year 2. Similarly, the yields tended to be higher in the 1st year than in 2nd year for the two varieties studied. This observation may be due to the variation in the rainfall between the two years.

The plant height and number of tillers of the plants differed from one treatment to another. 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. This result could be due to the nutrient availability of the soil for the most spaced plants and the competition among them. The variety Nerica 3 was taller and gave more tillers than Nerica 8. This may be due to the varietal ability that N3 processes compared to N8 for these two parameters. Panicle length was significantly affected by spacing. Larger spacing gave long panicles. A previous study reveal that the length of the panicle depends on the plant height [9].

Significant differences were also observed in some of the yield parameters per treatments. The tightest plants spacing gave large number of panicles per meter square than plants with larger spacing for all varieties. This could be explained by the fact that the tightest spacing had a greater number of plants per meter square of land than plants with large spacing despite the fact that the most spaced plants had a greater number of panicles per hills. The large number of panicles per m^2 for plants at the closest spacing was due to the highest number of planting stations per m^2 and not to the number of tillers per plant. These results agree with previous works [10, 11]. Furthermore similar results have also been obtained elsewhere [12, 13].

The results reveal that there was no significant difference for weight of 1000 grains for the two genotypes and across the years. These results match with those of Shunsuke, *et al.* [7].

The number of seeds per panicle varied with spacing. The large spacing produced a large number of seeds per panicle. The plants from the large spacing were tall with long panicles. Similar results were obtained by Shunsuke, *et al.* [7].

The percentage of full seed produced did not show any significant difference in treatment for both varieties during the two years of evaluation. This could be due to a very low proportion of empty seeds for both varieties.

There was a significant difference for the yield for the two varieties. N3 gave more yield per hectare than the N8. This confirmed the choice of Nerica 3 at the time of the introduction of new Nerica rice varieties through participatory varietal selection. Nerica3 was the most chosen by the rice producers therefore it was the most cultivated in the study area and throughout the national territory. N3 had more tillers per hill than N8. It also had more tillers per m^2 than N8 hence the genetic ability of Nerica 3 to give more yield per hectare. The spacing treatments did not show significant difference in yields for the two varieties used in the study. Among the four yield components used in this study, two were significantly different from the spreads, while two were not. There was no significant difference in the weight of 1000 seeds and the percentage of full seeds for both varieties for all spacing, whereas the differences were highly significant for the number of tillers per m^2 and significant for the number of grains per panicle. These results agree with those of Shunsuke, *et al.* [7] who found that the weight of 1000 grains was not significantly different for different spacing. Other authors such as Clerget, *et al.* [14], Hayashi, *et al.* [15] and Nakano, *et al.* [16] did not find similar results on the effect of plant density on the yield components. Previous works revealed no significant differences for all yield components [17, 18].

5. Conclusion

The present study reveal that the yield depended on the number of panicles per m^2 and the number of seeds per panicle. Since the number of seeds per panicle increased with spacing while the number of panicle per m^2 decreased, the yield depends on the number of tillers per m^2. This is justified by the strong correlation between the yield and the number of panicle per m^2. Therefore, the increase in yield per hectare of upland rain-fed rice requires the increase in the number of planting stations per unit in the study area. The spacing that gave the higher number of panicle per m^2 was 15 cm X 15 cm and this spacing gave good yield in the region where the study was carried out.

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