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Field Report

Influence of Intra-annual Croping Seasons on Rice Yield in the Sahel

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Abstract. Rice is a staple food in the Sahel countries. However, the crop production does not match population growth and demand. Hence, it is important to enhance rice yield to meet the demand. Achieving greater yields depends on increasing total crop biomass, because there is little scope to further increase the proportion of that biomass allocated to grain. Total crop biomass is determined mainly by crop photosynthesis and respiration losses, both of which are sensitive to environmental factors such as temperature. Rice cultivation in Niger is practiced during two cropping seasons yearly. Climate parameters change radically through the year across cropping seasons. The aim of this study was to assess intra-annual variation impact on rice genotypes productivity. Hence, 35 breeding lines were evaluated during two cropping seasons in an alpha lattice design with three replications. The results showed that the two cropping seasons were significantly different mega-environments. The mega-environments impacted significantly and differently genotypes performances. Some genotypes performed well in wet season while others did in dry season. The ideal genotype across cropping season was the genotype1. Both cropping seasons were ideal for some genotypes. But none of them was for all the genotypes. To increase the yield and production each genotype should be cultivated during the ideal cropping season.

Key words: Rice, cropping season, influence, Sahel, yield

Introduction

Rice is one of mankind's major food staples. Due to the continuing growth of the global population and a decrease of availability of arable land, increasing grain yield is an important goal of scientists and rice breeders particularly[1]. Hence, world rice production must increase by 1% annually to meet the growing demand for food that will result from population growth and economic development[2]. Most of this increase must come from greater yields on existing cropland to avoid environmental degradation, destruction of natural ecosystems, and loss of biodiversity[3]. Achieving greater yields depends on increasing total crop biomass, because there is little scope to further increase the proportion of that biomass allocated to grain. Total crop biomass is determined mainly by crop photosynthesis and respiration losses, both of which are sensitive to environmental factors such as temperature[4]. Despite tremendous improvements in technology and rice yield potential, the production remains highly dependent on climate, because solar radiation, temperature, and precipitation are the main drivers of crop growth.

Temperature is a major environmental factor affecting the rice growth and development worldwide. Low and high temperatures are considered as the major environmental stresses for this crop plants. Both these stresses have devastating effects on metabolism, growth, and development of plants. Rice is sensitive to low and high temperature stresses. The optimal temperature for the rice cultivation is 25–35°C, and temperature below or higher than optimal negatively affects the growth, physiology, and yield of crop[5]. High temperature negatively affects the growth of roots and shoots, hampers pollination, causes poor anther dehiscence, and leads to spikelet sterility.

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Likewise, low temperature delays rice germination and seedling establishment, hampers tiller formation, affects flowering, causes panicle sterility, and finally leads to lower grain yield[6, 7]. According to previous study[4] in the dry season, maximum temperature was not related to grain yield. There was a negative relationship between grain yield and minimum temperature and a positive relationship between grain yield and radiation. Grain yield was related more closely to minimum temperature than radiation. They indicated that increases in night temperature, even small in magnitude, had a negative effect on the yield of irrigated rice in the dry season and that the effect was independent of radiation. In the wet season, grain yield and yield attributes were not related to minimum temperature, maximum temperature, or radiation. Furthermore, the occurrence of storm in the wet season caused crop lodging in some years, which could weaken the relationship between yield and climatic parameters. Day high temperatures have been implicated to cause reductions in rice yield in many rice-growing areas[8–10].

Rice cultivation in Niger is practiced during two cropping seasons per year: wet season (from June to October) and dry season (from December to April). The climate of the country is an arid and semi arid tropical type. Niger is one of the world hottest areas and is characterized by three types of seasons namely: the cold season (from mid-December to mid-February), the dry hot season (from March to May) and the rainy season (from June to September). Thus, climate parameters (Temperatures, day light, radiation, relative humidity) change radically through the year. Therefore, it is important to know the effect of these changes on rice production. Hence, the goal of this study is to assess intra-annual variation impact on rice genotypes productivity.

Material and Methods

Plant materials were composed of 35 breeding lines including 5 checks (Table 1). The experimental Design was an alpha lattice design with three replications. Each replication was made of 7 incomplete blocks of 5 entries. The experiment was conducted through 2 cropping seasons: the wet season and dry season 2015. Each plot consisted of 5 rows of 5 m long. The distance between and within the rows was 20 × 20 cm. Fertilizer application was done as follow: A pre-drilling base application of 200 $kg.ha^{-1}$ of NPK (15-15-15) was made at transplanting stage. A total of 100 $kg.ha^{-1}$ of urea was made at panicle initiation. Weeding was done before fertilizer application. Hand weeding was also done when needed. The harvest was done by eliminating one row from each side of the plot. (4.6 m × 0.60 m). Winnowing and weighing were done at 14% moisture content. Agronomic traits in the Table 2 were collected in all the trials. Statistical analysis was performed using Genstat software version 18th. GGE by plot method was used for genotypes by environment interaction. Each cropping season was considered as an environment

Table 1. Entries list

Variety	Number	Variety	Number
WAB 2101-WAC1-1-TGR5-WAT B6	1	WAB 2056-2-FKR2-5-TGR1-B	19
DKA-M2	2	WAB 2066-6-FKR4-WAC1-TGR1-B-WAT-B11	20
FAROX 508-3-10-F43-1-1	3	WAB 2076-WAC1-TGR1-B	21
IWA 2	4	WAB 2076-WAC2-TGR1-B	22
JARIBU 220	5	WAB 2094-WAC2-TGR2-B	23
TXD 88	6	WAB 2098-WAC3-1-TGR1-4	24
WAB 1436-20N-3-B-FKR2-WAC1	7	WAB 2101-WAC3-1-TGR1-WAT B6	25
WAB 2060-3-FKR1-WAC2-TGR4-B	8	WAB 2101-WAC4-1-TGR1-WAT B6	26
WAB 2060-FKR4-WAC1-TGR5-B	9	WAB 2125-WAC B-1-TGR3-WAT B1	27
WAB 2061-2-FKR1-WAC2-TGR4-B	10	WAB 2125-WAC B-1-TGR3-WAT B8	28
WAB 2081-WAC2-2-TGR2-WAT B3	11	WAB 2134-WAC B-TGR1-B	29
WAB 2094-WAC2-TGR4-B	12	WAB 2153-TGR3-WAT B5	30
WAB 2095-WAC1-TGR1-B	13	NERICA-L19 (Check 1)	31
WAB 2098-WAC2-1-TGR2-WAT B2	14	WITA 4 (Check 2)	32
WAB 2098-WAC3-1-TGR2-WAT B5	15	WITA 12	33
L-22-26-WAC B-TGR4-B	16	NERICA-L49	34
SK-19-38-2	17	GAMBIAKA	35
WAB 2056-1-FKR-4	18		

Table 2. Data collected and collection methods

Agronomic data collection	Method
Seedling/vegetative vigor (21 and 42 days after seeding)	Visual rating (SES)
Date of 50% flowering	Record
Date of maturity (85% of grains on panicle are mature)	Record
Rate of final plant stand at harvest (%) (100% indicates that there are no missing plants/hills)	Visual rating
Lodging incidence (%)	Visual rating (SES)
Phenotypic acceptability at maturity	Visual rating (SES)
Spikelet fertility (%)	Visual rating (SES)
Panicle exsertion	Visual rating (SES)
Plant height at harvest (cm) (soil surface to the tip of the tallest panicle (awn excluded)) (3 randomly selected plants)	Measurment
Grain yield and moisture content (border rows should be excluded; 0.6 m × 4.6 m)	Measurment
Panicle length (for 3 panicles of the plants used for measurement of plant height)	Measurment
Panicle number (the 3 plants used for measurement of plant height)	Measurment
1000-grain weight	Measurment

Results and Discussion

Results

The analysis of variances (Table 3) shows highly significant differences among cropping seasons. Hence, genotypes yields significantly change along the year from season to season.

Table 3. ANOVA of variable yield across cropping seasons

Source of variation	d.f.	SS	MS	vr	F pr.
Season	1	7.183	7.183	32.20	< 0.001
Residual	66	14.724	0.223		
Total	67	21.906			

The Fig. 1 shows two mega environments. Thus, each of the cropping seasons constituted a distinct mega environment. The cropping season 1 (wet season) has the longest vector, thus, it discriminates better the genotypes than season2 (dry season). WAB 2101-WAC1-1-TGR5-WAT B6, DKA-M2 and FAROX 508-3-10-F43-1-1 performed well in dry season but had poor performances in wet season. Most of the genotypes gave more yield in environment 2 (dry season) than in environment 1 the best among them are 15 and 18. Genotypes (1) WAB 2095-WAC1-TGR1-B wone in one sector while genotype WAB 2098-WAC3-1-TGR2-WAT B5 (genotype 15), WAB 2153-TGR3-WAT B5 (genotype 30), WAB 2134-WAC B-TGR1-B (genotype 29), and WAB 2094-WAC2-TGR4-B (genotype 12), wone in the other sectors.

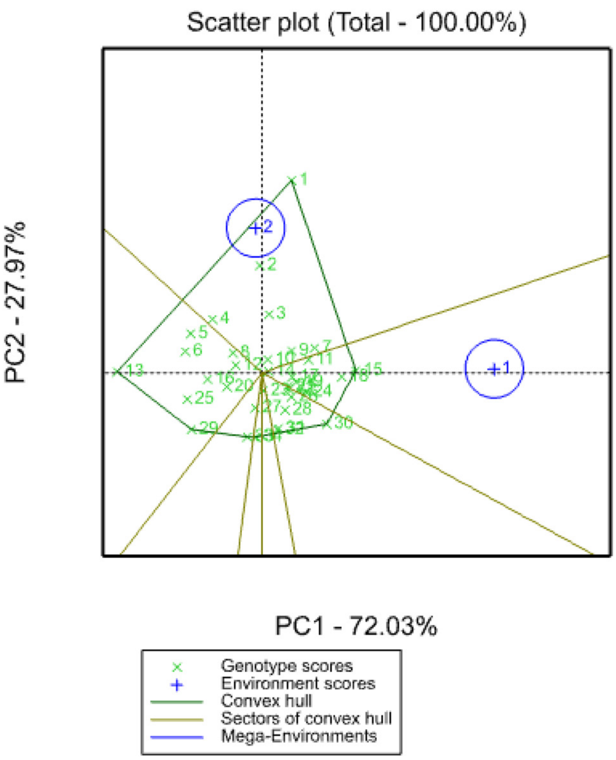

Fig. 1. Genotypes yield comparison plot

The highest average yield across cropping season was observed in with genotypes 1 (WAB 2101-WAC1-1-TGR5-WAT B6) followed by genotypes 15 and 18 (Fig. 2). However, all these genotypes were very sensitive to environment effect. Hence, cropping season have influences on genotypes yield.

The genotypes comparison plot (Fig. 3) showed that the ideal genotype is the genotype 1 (WAB 2101-WAC1-1-TGR5-WAT B6) followed by genotypes 7, 2 and 3.

Environments comparison plot (Fig. 4) showed that both cropping seasons were ideal for some genotypes. But none of them was for all the genotypes.

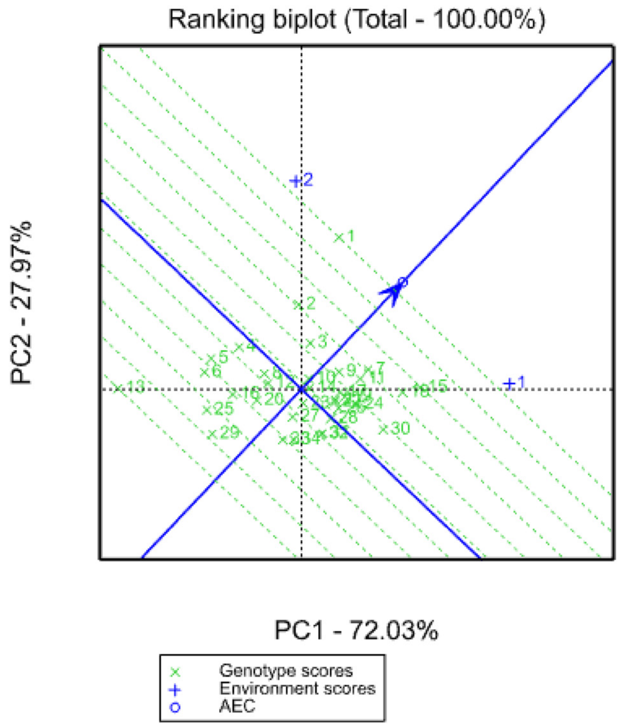

Fig. 2. Genotypes ranking plot

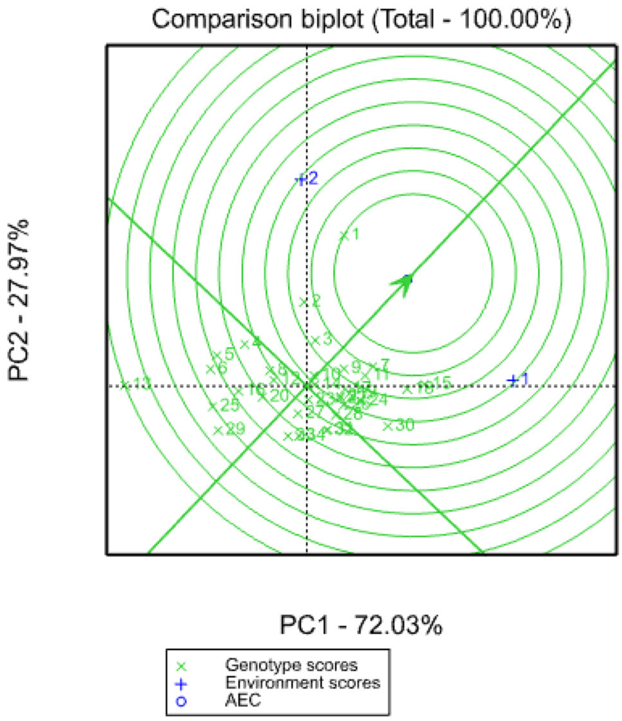

Fig. 3. Scatter plot showing mega environments and sectors

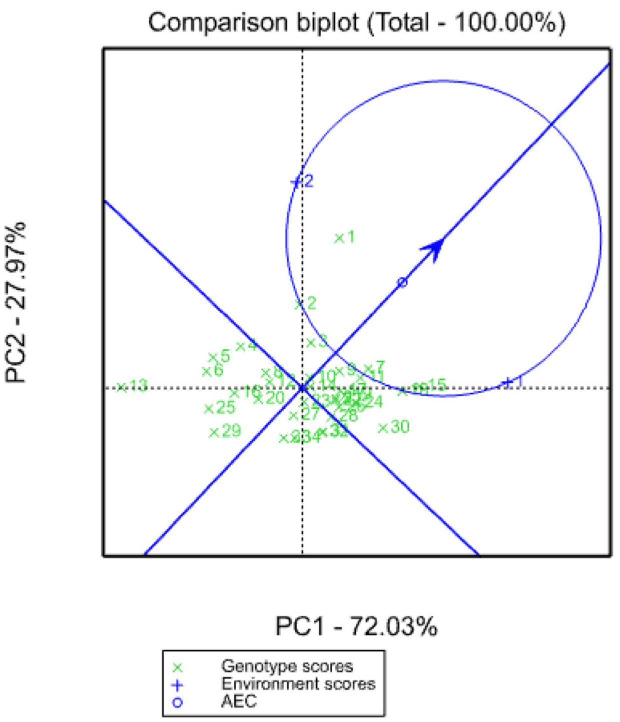

Fig. 4. Environments comparison plot

Discussion

Results showed that there were two different mega-environments. Thus, the intra-year cropping seasons were different. These differences may be due to environments factors, especially climate factors, hence, edaphic ones remains the same. Results also showed that genotypes performed better according to mega-environments.

The temperature appears to be the critical determinant for the rice growth. Rice, being a tropical and sub-tropical plant that requires a fairly high temperature ranging from 20º to 40ºC. Crop is adversely affected by high temperature in the lower elevation of the tropics. This critical temperature differs according to variety, duration of critical temperature, diurnal changes and physiological changes of plant[11]. According to previous study[12], low temperature depresses the rate of germination and prolongs it beyond the desirable span of 6 days while, high temperature of 35ºC or more halted the germination because of high respiration rate. As reported previously[13], temperature has a large influence on germination, especially in the first week of post germination growth it also affects the rate of leaf emergence. A long germination period may imply weaker plantlets and less vigorous rice plants at vegetative stage. Low temperature occurring during booting and/or heading stage induces spikelet sterility[11]. Hence, dry cropping season that generally starts in November during cold period may negatively impact the crop yield unless the variety is not tolerant to this stress. High temperature provides more tiller buds and thereby increases tiller number[14]. Higher maximum and minimum temperature during tillering reduce the yield and depress the yield during panicle initiation[15]. According to previous study[16], tillering rate is inhibited by low temperature, but the period of tillering is prolonged, resulting in more tillers and more panicles than at high temperature. High temperature induced spikelet sterility as stated previously[11]. They additionally, showed that rice is very sensitive to high temperatures at heading and next most sensitive at about 9 days before heading. One or two hours of high temperature at anthesis has a decisive effect on the incidence of sterility. Consequently, the yield will reduce as a result of poor pollen shedding as well as inadequate pollen growth in temperature above about 34ºC[17]. This phenomenon may occur in Niger rice cultivation during the dry season. Hence, the booting and anthesis stages may coincide with high temperatures of March and April months unless the seeding and transplanting were performed too early to avoid the stress. This may result in reduced yield.

Solar Radiation may differently impact on rice production according to the two cropping seasons. As reported previously[18], sunshine in a week prior to transplanting and the two weeks period coinciding with the grand period of elongation is conducive for better yield. Contrastingly, shading delays tillering and decreases tillering rate. Irrespective of varieties, shading increases the plant height; leaf area index and total chlorophyll content and significantly reduces the tiller number and total dry matter production[19]. Solar radiation and temperature during reproductive stage (before flowering) had the greatest influence on rice yield because they determine the number of spikelets m^{-2} and the most critical sunlight requiring period is around the heading stage[20]. Thus, high rainfall in rainy cropping season may result in the decreased availability of sunlight.

Rainfed pattern discriminates significantly the two environments and may differently impact genotypes yield throughout the year. The rains that only occurred during the wet season facilitate irrigation by providing water free of cost. Furthermore, as reported previously[21], an amount of dissolved substances deriving from the weathering of rocks and soil were included in irrigation water. These substances were higher in wet season than dry season and will contribute to soil fertilization and plant nutrition. During the wet cropping season the relative humidity is also high. This can positively impact rice growth and development, hence, increase productivity. Nevertheless, rains may severely interfere with irrigation water management and cause flooding that can reduce yields.

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