Prime Scholars Library

Full Length Research Paper

Available online at
https://primescholarslibrary.org/

Advances in Agriculture, Food Science and Forestry

Vol. 1 (3), pp. 041 - 048, August, 2013

Effect of water deficit at grain repining stage on rice grain quality

B. Kone[2], K. Futakuchi[1] and A. Audebert[3]

[1]Africa Rice Center (AfricaRice); 01 B.P. 2031 Cotonou, Benin.
[2]Université de Cocody-Abidjan, 22 BP 582 Abidjan.
[3]CIRAD, Département cultures annuelles, B.P. 5085, 34032, Montpellier.

Abstract

Rice production is usually reduced by water stress that can evenly occur during rice cycle in West Africa under bimodal rainfall pattern. In order to determine the effects of water stress on rice grain quality, experiments were conducted on upland site (on ferralsol) at the main AfricaRice research center at M'be, 30 km North of Bouaké, Côte d'Ivoire. The rice varieties CG14 (*Oryza glaberrima*), WAB56-104 (*Oryza sativa*), and NERICA1 (cross WAB56-104 x CG14) were sown at 25 × 25 cm spacing during the dry season cropping period of 2000, 2001 and 2002. Irrigation line (Boon irrigation) was used to supply water until flowering stage. Water was then supply manually from the milky stage of each variety to its full ripening stage. Physical (husking yield, milling recovery, and head rice ratio), chemical (amylose and proteins contents) and cooking parameters (cooking time, volume expansion, rice flour gelatinization temperature, consistency and viscosity) of the harvested grains were determined in the laboratory. The results showed a significant difference ($p < 0.05$) between all the parameters in comparison with the checks samples and stressed crop. In general, NERICA 1 showed better physical and cooking quality traits than its parents. Rice samples from plots subject to lower water availability during repining stage showed higher protein content for all varieties studied. Increase in the average protein content of stressed samples were 31, 11.8 and 13.3% times, respectively for NERICA 1, CG14 and WAB56 -104, where (using the protein content of check plots as 100%) NERICA 1 showed higher husking yield, total mean milling recovery and head rice ratio for samples collected on stressed plots than the g*laberrima* and the *sativa* samples recorded on similar plots. Finding showed that cooking properties that meet West African rice consumers' preferences for cooked rice were more improved for NERICA 1 than its parents in comparison with samples collected from stressed plots. It is concluded that moisture stress at ripening stage should be further investigated as potential indirect means of improving rice grain quality.

Keywords: Interspecific, grain quality, water stress, *Oryza glaberrima*, *Oryza sativa.*

INTRODUCTION

Although rice is consumed worldwide, there is no universal rice quality attribute (Veronic et al., 2007). Nevertheless, rice appearance and cooked rice texture are the characters considered as main quality attributes by consumers (Okabe, 1979; Rousset et al., 1999). Thus, measuring and understanding factors that influence appearance and texture properties are a great challenge for industries and breeders in meeting consumer preferences. About 13% of the world's 147 million ha of rice is cultivated as rainfed rice under upland conditions (Crosson, 1995) where moisture stress affects rice growth and reduces grain yield and quality (Carlos et al., 2008) . Water is a major constituent of plant tissue as reagent for chemical reactions and solvent for translocation of metabolites and minerals as well as an essential component for cell enlargement through increasing turgor pressure (Carlos et al., 2008). The occurrence of soil Ilmoisture stress affects many of the physiological processes such as photosynthesis and transpiration resulting in reduced growth and poor grain filling (Samonte et al., 2001). In West Africa, rice annual consumption increase at the rate of 6.5% (WARDA, 2008), whereas, there is increase in water stress occurrence for

Table 1. Physical and chemical properties of the soil at 0 - 15 cm depth.

Parameters	Contents
pH water	5.4
Clay (%)	31
Silt (%)	18
Sand (%)	51
Pf 2.0 (%)	29
Pf 4.2 (%)	6
Carbon (%)	0.84
Nitrogen (%)	0.03
Organic matter (%)	1.44
Ca (meq/100 g)	1.2
Mg (meq/100 g)	0.82
K (meq/100 g)	0.21
Na (meq/100)	0.1
Exchange Cation Capacity (meq/100 g)	6.16

rainfed crop as rice (Koné et al., 2008, Koné et al., 2009) essentially induced by notable climate changes (CNRS, 2000) . Therefore, soil moisture stress appears to be a major factor for the gap in producing enough quantity of rice as well as grain quality (Tomlins et al., 2005). However, drought effect on crop is depending on soil nutrient content (Gandah et al., 2003) as well as climate and cultivar (Cooper et al., 1987). Except characterization study of tolerance of the New rice of Africa (NERICA) under mid-season drought (Kone et al., 2008), there is missing knowledge on grain quality on acid soil of West Africa. These cultivars (NERICA) are generated by AfricaRice crossing *sativa* from Asia and *glaberrima* from Africa. The main purpose of this study therefore, was to examine the effect of late season soil moisture stress on the most popular upland NERICA rice variety (NERICA 1) grain quality. Results should provide Knowledge for planning interventions as supplementary irrigation.

MATERIALS AND METHODS

Site description

In the upland field at Africa Rice Center's headquarter at M'bé, Bouaké, Côte d'Ivoire (7°52N, 5° 6 W and 300 m of altitude). The soil was a ferralsol type (Table 1).

Experimentation

NERICA 1 was sown during three years from 2000 - 2002 similarly with WAB 56 -104 and CG14. NERICA 1 is one of the most adopted of the 18 released NERICA in West Africa. Four grains of rice was sown per hill, spaced by 25 × 25 cm and tinned latter (21 days) to two plants per hill. The total area of each plot was 15 m^2. A split plot design was used. The main factor was the irrigation with two levels (well watered and stressed). Variety was the sub-factor with three levels. The check was irrigated at the rate of 30 mm per square meter each three days from seeding to the rice harvest. The second main plot was stressed from milky stage to full ripening. Each irrigated plot was designed as one factor in randomized complete design with three replications. The space between the two blocks was fifteen meters to avoid water migration from well watered plots to stress plots.

An irrigation line (boom irrigation system) was used until the reproductive stage. Since the beginning of the ripening stage (milky stage) of varieties differing by few days, water was supplied manually throughout reproductive stage to ripening. Rice growth patterns registered by national and international research centers in West Africa were followed. Basal fertilizer application was 200 kg/ha of N, PO5, K2O. Sixty days after (60 DAS) seedlings emergence, only nitrogen fertilizer was applied as top-dress at the rate of 40 kg/ha.

Weather data collection

Daily weather parameters (Precipitation, air temperature and moisture) were collected from AfricaRice's weather station located near the trials.

Soil moisture measurement

Soil moisture measurement stated when the last variety reaches its milky stage and last fifteen days. Volumetric moisture content (%) in soil was weekly measured by Time domain reflectometer (Delta-T Devices Ltd, UK) in all the plots throughout the stress period. Due to large variation of measurements within each plot as the result of substantial heterogeneity within soils, 10 measurements were taken per plot and the average values considered. The moisture-meter was calibrated with the experimental soil samples and gravimetric methods to generate a calibration curve that was used for trans-forming the moisture-meter reading to true soil moisture status values (Hamlyn, 2007).

Yield determination

At grain maturity, rice was harvested in 6 m^2 of each micro-plot leaving two lines in the border. Samples of rice grain collected from three plots of same treatment were mixed together. After threshing, the grains were sun-dry, sieved and weighted after the measurement of the moisture content. The grain yield was determined for cor-responding weight of standard moisture of 14%. Grain moisture was monitored by a Kett Riceter (KETT C600).

Milling characteristics

Husking yield (HY), milling yield (MY) and head rice ratio (HRR), the ratio of, respectively, brown rice to paddy, milled rice to brown rice and head rice to milled rice on a weight basis- were determined. For each interspecific line, the 250 g of winnowed paddy was hulled with a Satake testing husker (THU 35H). Brown rice was weighed and HY was determined. The 150 g of brown rice was milled with a milling machine for laboratory use (Yamamoto Test Rice Whitener VP-31 T). After milling, rice bran was removed with 1.7 mm sieve. A cleaned sample of milled rice was weighed and MY was determined. From 20 g of cleaned milled rice, all head rice were taken and weighed. HRR was then calculated. Milled rice grains with a length greater than three-quarters of complete grains were considered as head rice. Colored and damaged grains were also removed from the category of head rice.

Determination of amylose content

The cleaned milled rice was ground and powdered by an Udy Cyclone

.

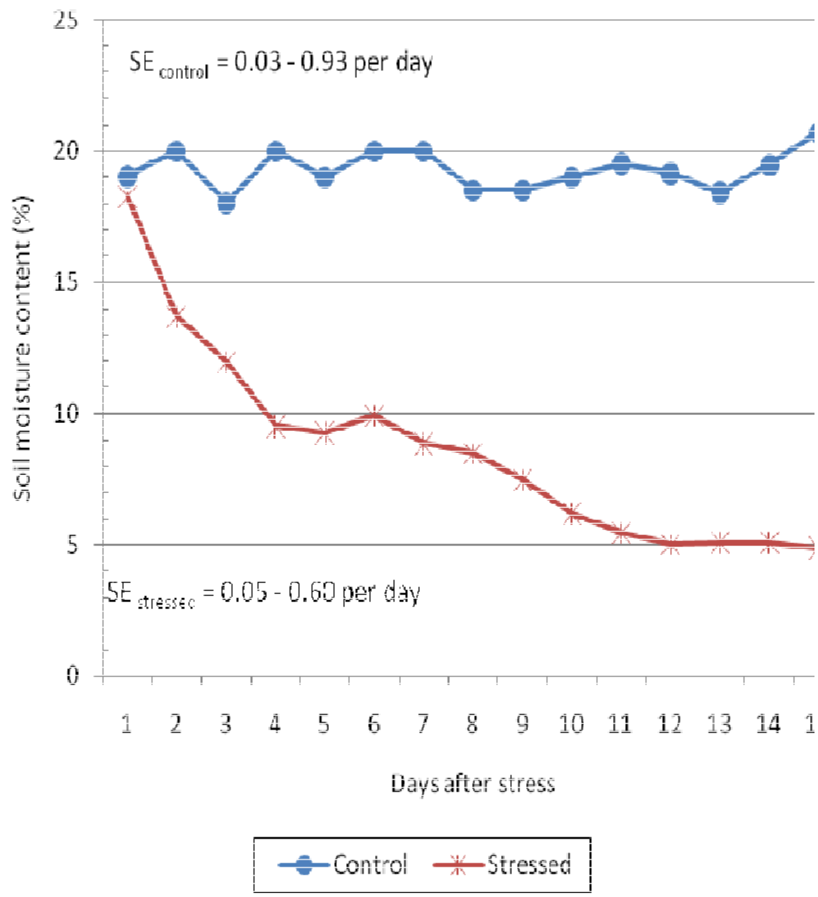

Figure 1. Trend of average daily soil moisture content of the three years of experimentation and their standard error (SE) in stressed and control plots during fifteen days after water stress.

Mill with a 1.0 mm mesh screen. Amylose content was determined by auto-analyzer based on the iodine-colorimetric method (Juliano, 1971).

Determination of protein content

The powdered samples prepared for the determination of amylose contents were used. Total nitrogen content was determined by colorimetric based on Berthelot reaction (Walinga et al., 1989). Protein content was calculated by multiplying total nitrogen content by 5.95, the constant to convert nitrogen content to protein content in rice-and expressed on a dry matter basis of milled rice.

Determination of viscosity characteristics

The interpretation of the viscograph curve was done according to the indication of the AfricaRice Center grain quality laboratory manual. Powdered samples mentioned were passed through a mesh (NO. 40). 50 g of powdered sample of the varieties at 13.3% moisture contents was mixed in 450 ml of distilled water. The following viscosity parameters were determined with a Brabender viscogram by using the rapid method (Watanabe and Futakuchi, 2000): Peak Viscosity (PV), Minimum Viscosity (MIN), Breakdown Viscosity (BD) and Final Viscosity (FV).

Statistical analysis

Analysis of variance (ANOVA) and regression analysis were performed using Statistical Analysis system (SAS 11.0) and Sigma Plot 11.0.

RESULTS AND DISCUSSION

During the drought simulation period, the precipitation during the three years experiments was far much few to cancel the water deficit induced. The average temperatures were higher enough (Figure 2) to allow soil drying during the drought period jugged by the fast decrease of soil moisture content during the stressed period (Figure 1). NERICA 1 showed better yields in both control and drought treatments (Table 2) confirming its ability to produce more than its two parents as discussed by Jones et al. (1997). The low availability of water during this work had less effect on the yields (Table 2). This might be due to its late occurrence during the rice plants life cycles. Similar results were found by Boonjung and Fukai (1996). Husking yield gave an idea of the total amount of edible grains after

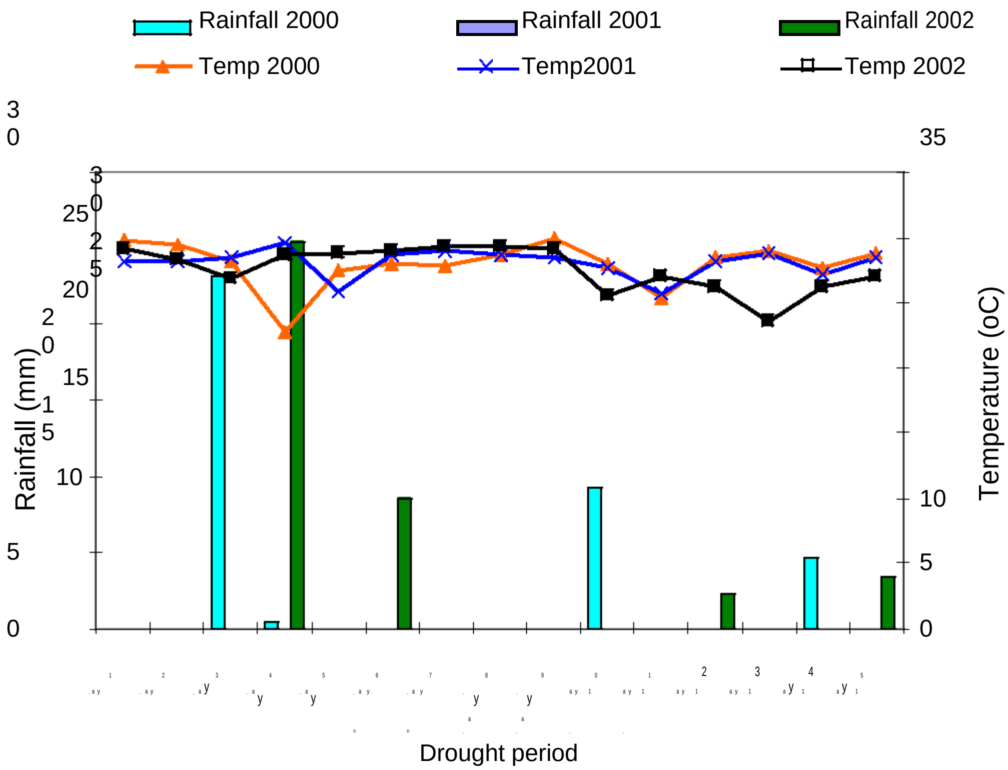

Figure 2. Trend of average daily temperature and precipitation of the three years of experimentation during the drought period.

Table 2. Probability (P) of source of variations) and their significance.

Source	Traits		
	Yield	**Husking yield**	**Total milling yield**
Treatment	0.2490 ns	0.7846 ns	0.0688*
Variety	< 0.0001 ***	0.3996 ns	< 0.0001***
Year	0.9871 ns	0.2645 ns	0.1920 ns
Treatment*Variety	0.1560 ns	0.8884 ns	0.3340 ns
Treatment*Year	0.7419 ns	0.7467 ns	0.9569 ns
Year*Variety	0.7970 ns	0.7046 ns	0.6671 ns

Significance: influence * = 10%; **= 5%; *** = 1%, ns = non significant.

husking. Results showed that this trait was very slightly affected by the occurrence of drought at ripening stage (Table 2). Total milling recovery (TMR) is a measure of milling quality and hence, economic value. A proportion of 50% of head rice or less is undesirable since it means that 50% of the rice is discarded as husk and bran after milling. Although stressed samples had a higher mean value of TMR compared to that of control samples for all the cultivars during the three years trials, these differences were not significant at 5% (Table 3). Base on this fact, HY and TMR could not all be considered as the best indicators of grain quality by using water management as in the present study. The percentage of HRR is one of the most important criteria of selection of rice (milled rice) in West Africa (Sakurai et al., 2006). In this study, the increase of the head rice ratio (HRR) is 8.0 - 13.7% for NERICA 1 with stressed samples (Table 4). Therefore, the occurrence of drought during grain ripening stage could be considered as a useful factor that might help to reduce broken grain in milled rice with high level of head whole. Several factors are generally recognized as probable cause of breakage of rice during milling. Delay in harvesting and threshing (Rhind, 1962) and too rapid drying (Angladette, 1963) enable cracking which always increase the number of broken grains. Autrey et al. (1955) showed that rice breakage was related to milling conditions. From this study it could be concludes that unknown factors such as water manage-ment determine during ripening stage can reduce grain breakage as discussed by Adu-Kwarteng et al. (2003). Study conducted by Sakurai et al. (2006) in urban area in Ghana showed that rice varieties with high proportion of head rice were sold with higher price in the market.

.

Table 3. Yield (t/ha) of studied verities during the three year trial.

Variety	2000		2001		2002	
	Control	Stressed	Control	Stressed	Control	Stressed
CG 14	1.2 c	1.1 c	1.3 c	1.0 c	1.5 b	1.0 c
NERICA 1	4.1 a	4.2 a	3.8 a	4.3 a	4.0 a	3.9 a
WAB 56-104	2.5 b	2.1 b	2.6 b	2.3 b	2.5 b	2.3 b
LSD(0.05)	0.7	0.9	0.8	1.1	1.1	0.6
CV (%)	14.7	17	16.8	21	21	13

Table 5. Protein content (%) of studied verities during the three year trial.

Variety	Protein content in check plots samples			Protein content in stressed plot samples		
	2000	2001	2002	2000	2001	2002
CG 14	7.1 a	7.7 a	7.2 a	6.2 c	6.3 c	6.8 c
NERICA 1	7.8 a	8.0 a	7.5 a	10.5 a	10.1 a	10.2 a
WAB 56-104	5.5 b	5.9 b	6.0 b	9.0 b	8.4 b	7.8 b
LSD (0.05)	1.3	0.8	0.8	0.7	0.8	0.8
CV (%)	31.0	19.2	19.5	13.6	15.5	15.6

Therefore, the occurrence of water deficit during grain ripening stage can be considered as a factor that increases grain quality as preferred by local consumer because of low rate of broken grain (Sakurai et al., 2006). Protein and Amylose are factors that mainly influence the eating quality of rice (Adu-Kwarteng et al., 2003, Futakuchi et al., 2008). Negative correlation was found between Amylose content and protein content for stressed samples (Figure 3). These results were similar to those of Koutroubas et al. (2004) on 318 European *sativa* varieties but they were not consistent with the findings of Futakuchi et al. (2008) who found a positive correlation of 0.075 between protein and amylose contents with interspecifics. NERICA 1 is known for its higher protein content than WAB 56 -104 and CG14 in adequate growing conditions (Watanabe et al., 2006). The increase of protein content in NERICA 1 (Table 5) will greatly improve the nutritional status of West African people (Futakuchi et al., 2008) but the protein content should be taken with care since it negatively correlates to rice taste (Ishima et al., 1974). Care should also be taken to decrease the Amylose content (Table 6) since it is well known that less amylose lead to sticky rice after cooking, which West African Rice consumers dislike (Sakurai et al., 2006).

The various parameters of Brabender viscograph results, provide useful information on the texture of cooked rice, although, the test is performed on powdered sample as discussed in the AfricaRice grain quality laboratory manual (1999). Results showed that in general, stressed samples had lower gelatinization temperature and lower peak viscosity (Table 7) . This means that NERICA 1 stressed samples tend to gelatinize quicker than its parents (WARDA, 1999). It is well known that there is a positive correlation between gelatinization temperature and cooking time (Veronic et al., 2007). Therefore, the occurrence of the moisture stressed at the ripening stage could shorten NERICA 1's grain cooking time than that of the two other varieties. Cooking time reduction is very important in terms of energy and time saving that can lead to the reduction of cooked rice price on West Africans' rural markets, where rice is usually sold when cooked. The value of final viscosity (Table 7) indicates that NERICA 1 stressed samples tenderness should be intermediate between those of its two parents. The increase of the peak viscosity time and value of the 'breakdown' observed in stressed samples showed that moisture stress during ripening stage induces higher grain volume expansion upon cooking for all studied varieties (Table 8). In most West African countries, especially in areas with large family size, consumers' first criteria of choice of a given variety is its capacity of expanding after cooking (Sakurai et al., 2006). From this point of view NERICA 1 could meet people demand. From this study, water deficit occurrence at ripening stage could be considered as an important positive factor since it could enable West Africans' rice consumers to afford the type of rice grains they prefer.

Conclusion

The study clearly showed physico-chemical variation in rice grain when moisture stress occurs during grain maturity stage. There were significant differences among both the stressed and the check samples. Late drought that occurs during ripening stage appears to increase the main characteristics defining rice grain quality including total milling rate, head rice ratio, and protein content. Since the criteria of choice of a given variety depend on each

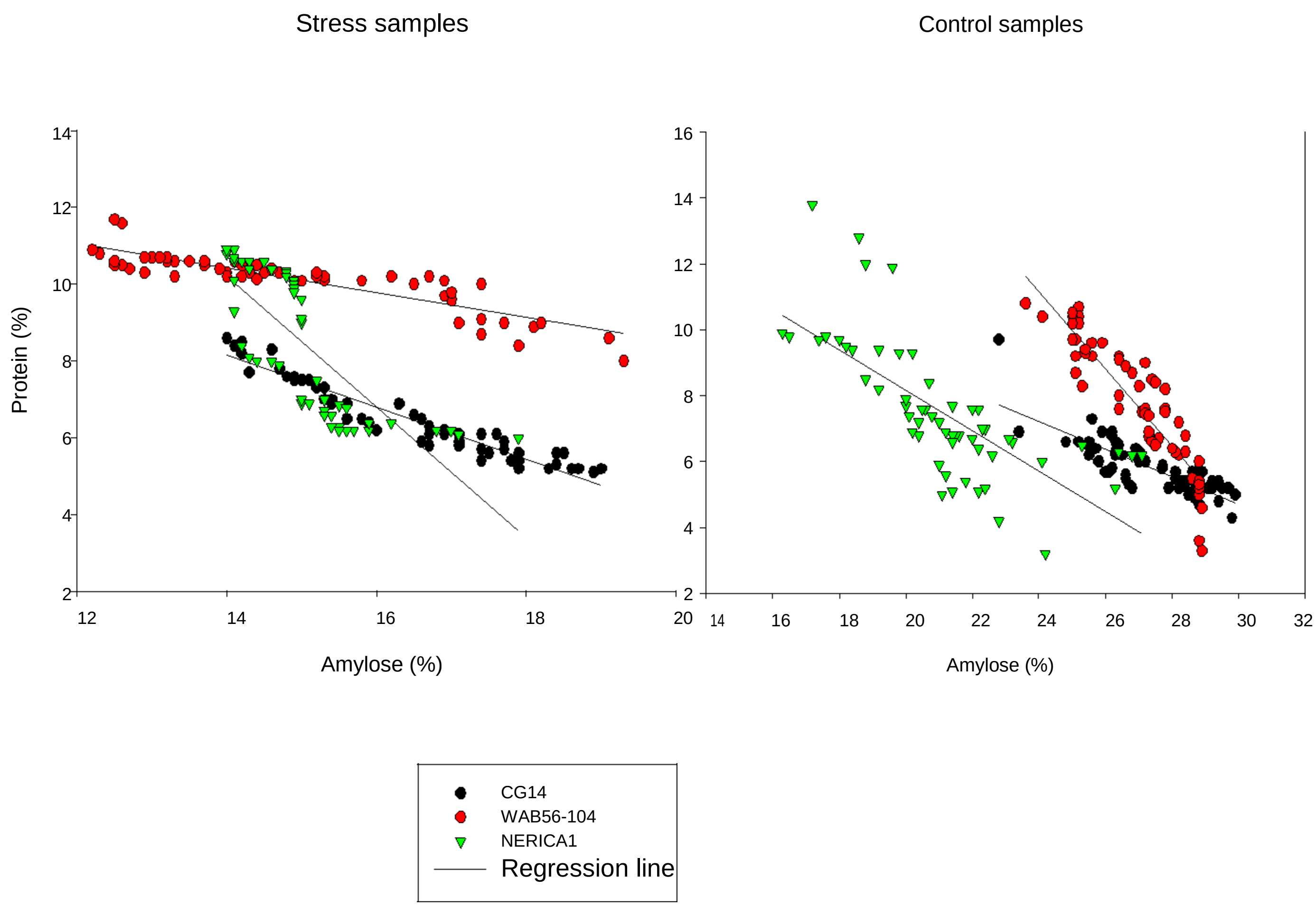

Figure 3. Interaction between amylose and protein content of rice grain.

Table 6. Amylose content (%) of studied verities during the three year trial.

Variety	Amylose content in check plots samples			Amylose content in stressed plot samples		
	2000	2001	2002	2000	2001	2002
CG 14	26.9 a	27.1 a	27.6 a	17.0 a	16.3 a	16.0 a
NERICA 1	27.2 a	26.5 a	26.9 a	14.71 b	14.7 b	15.1 ab
WAB 56-104	20.9 b	21.4 b	21.0 b	14.9 b	15.3 b	14.8 b
LSD (0.05)	0.8	1.5	1.0	0.9	0.8	0.9
CV (%)	6.5	9.4	6.5	9.6	8.5	10.2

Table 7. Gelatinization temperature (0C) and final viscosity (BU*) and Peak viscosity of the flour of the studied verities.

Variety	Gelatinization temperature of stressed plots samples			Final viscosity down of stressed samples		
	2000	2001	2002	2000	2001	2002
CG 14	67.4 a	65.9 a	62.7 b	1511 a	1415 a	1360 a
NERICA 1	66.6 a	66.8	64.2 ba	1010 b	1014 b	1018 b
WAB 56-104	67.3	67.2 a	66.2 a	1001 b	1003 b	1009 b
LSD(0.05)	4.2	3.2	2.3	56.5	24.4	58.4
CV (%)	6.8	5.3	4.0	5.2	2.3	5.6

BU: Brabender unit

.

Table 8. Break down (BU) and peak viscosity (BU) of the flour of the studied verities.

Variety	Break down of stressed plots samples			Peak viscosity down of stressed samples		
	2000	2001	2002	2000	2001	2002
CG 14	171 c	170 c	173 c	701 b	706 b	706 b
NERICA 1	233 b	228 b	234 b	703 b	706 b	696 b
WAB 56-104	399 a	398 a	403 a	770 a	769	768 a
LSD(0.05)	11.9	9.2	11.7	38	31	23.2
CV (%)	4.8	3.7	4.7	5.7	4.7	3.5

BU: Brabender unit.

consumer, it might not be well advised to conclude that the occurrence of water deficit during ripening stage neces-sarily or not enhance rice grain quality. However, the reproducibility of this trial is possible only in the case where weather conditions remain similar throughout consecutive years. The progressive higher carbondioxide concentration due to climate change might be a limiting factor since the biosynthesis of protein and amylose which are the key elements of grains component is significantly influenced by atmospheric conditions especially after heading stage. More investigations should be done on water stress at rice plant reproductive stage to better understand the physiological phenomenon that happened when this constrain occurs.

ACKNOWLEDGMENTS

We thank Ibrahim Teslim and late Ade Sobambo and other technicians in grains laboratory during the study years for data collection

REFERENCES

Adu-Kwarteng E, Ellis WO, Oduro I, Manful JT (2003). Rice grain quality: a comparison of local varieties with new varieties under study in Ghana. Food Control, 14: 507-514.

WARDA (1999). Laboratory Manual for Rice Grain quality Analysis. Bouaké (Côte d'Ivoire), p. 171.

WAARDA (2008). Rice trends in Sub-Saharan Africa 2007. Cotonou, Benin: Africa rice center (WARDA). p. 84.

Angladette A (1963). Rice drying. Principles and techniques. Agr. Eng. Br. F.A.O. (informal work). Bull. p. 23.

Autrey HS, Gricorieff WW, Altschul AM, Hogan JT (1955). Effect of milling conditions on breakage of rice grain. J. Agr. Food Chem. 3: 596-599.

Boonjung H. Fukai S (1996). Effects of soil Water deficit at different growth stages on rice growth and yield under upland conditions. Phenol. Biomass Prod. Yield, 48: 47-55.

Carlos ACC, Orivaldo A, Rogério PS, Gustavo PM (2008). Grain quality of upland rice cultivars in response to cropping systems in the Brazilian tropical savanna. Sci. Agric. (Piracicaba, Braz.), 65(5): 468-473

CNRS (2000). La recherche française sur le climat : le cycle de l'eau-la Mousson d'Afrique de l'Ouest. Lettre nº11 de PIGB-PMRC, CNRS, Paris. En ligne: http://www.cnrs.fr/dossiers/dosclim/rechfran/4them/cyclel'eau/moussonAfOuest.htm. [21 Novembre 2007].

Crosson P (1995). National Resource and environmental Consequences of rice Production. In: IRRI Fragile Lives In fragile Ecosystems. Proceeding of the International Rice Research Conference, 13-17 Feb. 1995., P.O. Box 933, Manila, Philippines, pp. 83-100.

Cooper PJM, Gregory PJ, Keating JDH, Brown SC (1987). Effect of ferti-lizer, variety and location on barley production under rainfed conditions in northern Syria. 2. Soil water dynamics and crop water use. Field crops Res. 16: 67-84.

Futakuchi K, Watanabe H, Jones MP (2008). Relationship of grain Protein Content to Other Grain Quality Traits in Interspecific Oryza sativa L. x Oryza glaberrima Steud. Progenies Agric. J. 3(1): 50-57.

Gandah M, Bouma J, Brown J, Hiernaux P, Van-Duivenbooden N (2003). Strategies to optimize allocation of limited nutrients to sandy soils of the Sahel: a case study from Niger, West Africa. Agric. Ecosyst. Environ. 94: 311-319.

Hamlyn GJ (2007). Monitoring Plant and soil Water status: Established and Novel Methods Revised and their Relevance to studies of Drought Tolerance. J. Exp. Bot. 58(2): 119-130.

Ishima T, Taira H, Mikoshiba K (1974). Effect of nitrogenous fertilizer application and protein content in milled rice on organoleptic quality of cooked rice. Rep. Nat. Food Res. Inst. 29: 9-15.

Jones MP, Mande S, Aluko K (1997). Diversity and potential of Oryza glaberrima Steud in upland rice breeding. Breed Sci. 47: 395-398.

Juliano BO (1971). A simplified assay for milled rice amylose. Cereal Sci. Today, 12: 334-360.

Koné B, Ettien JB, Amadji G, Diatta S (2008). Caractérisation de la tolérance de NERICA à la sécheresse de mi-saison en riziculture pluviale. Afr. Crop. Sci. 6(2): 133-145.

Koné B, Diatta S, Saıdou A, Akintayo I, Cisse B (2009). Réponses des variétés interspécifiques du riz de plateau aux applications de phosphate en zone de foreˆ t au Nigeria. Can. J. Soil Sci. pp. 555-564.

Koutroubas SD, Mazzini B, Ntanos DA (2004). Grain quality variation and relationship with morpho-physiological traits in rice (*Oryza sativa* L.) genetic. Resour. Eur. Field Crops Res. 86: 115-130.

Okabe M (1979). Texture measurement of cooked rice and its relationship to the eating quality. J. Texture Stud. 10: 131-152.

Rhind D (1962). The breakage of rice on milling: review. Trop. Agr. Trin. 39: 19-28.

Rousset S, Pons B, Martin JM (1999). Identifying objective characteristics that product clusters produced by sensory attributes in cooked rice. J. Texture Stud. 30: 50-532.

Sakurai T, Furuya K, Futakuchi K (2006). Effects of industrial amassment on the improvement of efficiency and quality. A case study for rice milers in Ghana. In Market and economic development. Sonobe T and Sawada Y (Eds), Tokyo Keizai Shinpou Sya, Tokyo, pp. 151-179.

Samonte S, Wilson LT, McClung AM, Tarpley L (2001). Seasonal dynamics of non-structural carbohydrate in 15 diverse rice genotypes. Crop Sci. 41: 902-909.

Tomlins KI, Manful JT, Larwer P, Hammond L (2005). Urban consumer preference and sensory evaluation of locally produced and imported rice in West Africa. Food Qual. Preference, 16: 79-89.

Veronic V, Brigitte P, Judith B, Stephan H, Xavier R, Christian M (2007). Cooking behavior of rice in Relation to Kernel Physicochemical Properties. J. Agric. Food Chem. 55: 336-346.

Watanabe H, Futakuchi K (2000). Rapid method of Brabender Viscograph and its application to analysis of large number of samples. Nippon Shpkuhin Kagaku Kogaku Kaishi, 47: 926-931.

Watanabe H, Futakuchi K, Jones MP, Sobambo A (2006). Grain protein content of interspecific progenies developed from the cross of African rice (Oryza glaberrima Steud.) and Asian rice O.*sativa* L.). Plant Prod.

Sci. 9: 287-293.
Walinga I, Van VW, Houba VJG, Van der LJJ (1989). Plant Analysis Procedures (Soil and Plant Analysis, Part 7). Syllabus. Wageningen Agricultural University.